A Review of the Integrated Status and Effectiveness Monitoring Program: 2003 - 2006

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NAVIGATING THE THREE YEAR REVIEW

This document was created to provide a review of the accomplishments of the ISEMP in the Upper Columbia Basin since its inception in 2003. The review is broken into chapters that reflect the various components of the program. Chapter 1 presents an overview of the philosophy behind ISEMP, the challenges in data collection and analysis that exist in the Columbia River basin, and how the ISEMP is designed to meet those challenges. Chapters 2 through 6 provide a review of how the various components of the ISEMP have progressed over the past three years. Chapter 2 describes the overall programmatic coordination of the ISEMP, while Chapters 3 through 5 describe the ISEMP's progress in each of three pilot project subbasins – the John Day (Chapter 3), Wenatchee/Entiat (Chapter 4) and Salmon River (Chapter 5). The information presented is taken from ISEMP documents and contractors' and collaborators' annual reports from 2004 and 2005. Within each pilot project's chapter, we present a summary of the pilot project's progress so far, an outline of the annual budget, provide excerpts from, and links to, annual reports where available, and outline the ISEMP's plans for the next five years. The ISEMP's efforts in the Wenatchee/Entiat subbasin are presented under subchapters that reflect the indicator categories established by the Upper Columbia River Basin Monitoring Strategy (Hillman 2006). The John Day and Salmon River chapters mirror the ISEMP objectives laid out in Chapter 1. Chapter 6 presents the progress made by the ISEMP in data management and the objectives for the future, and Chapter 7 presents results of the data analysis undertaken so far and a discussion of analyses underway and those planned for the future.

ACRONYMS USED IN THIS REVIEW

AFG Analytical Framework Group
AIC Akaike Information Criterion
ARS Aquatic Resource Schema
ATM Archive Template Modules
B2B Bridge-to-Bridge
BLM Bureau of Land Management
BPA Bonneville Power Administration
CCCD Chelan County Conservation District
CJS Cormack-Jolly-Seber
CSEMP Collaborative System-wide Monitoring & Evaluation Project
CV Coefficient of Variation
DEM Digital Elevation Model
EDT Ecosystem Diagnostic & Treatment
EMAP Environmental Monitoring and Assessment Program
ENSO El Niño/Southern Oscillation
EPA U.S. Environmental Protection Agency
ESA Endangered Species Act
ESU Evolutionary Significant Unit
ESR Ecological Sub-Region
FCRPS Federal Columbia River Power System
FRME Federal Research, Monitoring, and Evaluation
GIS Geographic Information System
GRTS Generalized Random Tessellation Stratified Design
HCP Habitat Conservation Plan
HUC Hydrologic Unit Code
ICBEMP Interior Columbia Basin Ecosystem Management Project
IDFG Idaho Department of Fish & Game
ICBTRT Interior Columbia River Basin Technical Recovery Team
IMW Intensively Monitored Watershed
ISEMP Integrated Status and Effectiveness Monitoring Program
ISRP Independent Science Review Panel
JDSP John Day Subbasin Plan
LCP Lemhi Conservation Plan
LiDAR Airborne Light Detection and Ranging
MCRFRO Mid-Columbia River Fishery Resource Office
MPG Major Population Group
NLCD National Land Cover Database
NOAA National Oceanic and Atmospheric Administration
NPT Nez Perce Tribe
NWFSC Northwest Fisheries Science Center
ODEQ Oregon Department of Environmental Quality
ODFW Oregon Department of Fish and Wildlife
OSU Oregon State University
PBI Pacific Biodiversity Institute
PDO Pacific Decadal Oscillation
PIBO PACFISH/INFISH Biological Opinion
PIT Passive Integrated Transponder
PNAMP Pacific Northwest Aquatic Monitoring Program
PNWSHP Pacific Northwest Salmon Habitat Project
PUD Public Utility District
RME Research, Monitoring, and Evaluation
RTT Regional Technical Team
S-BT Shoshone Bannock Tribes
SDM Science Data Management
SFJD South Fork John Day
SFSR South Fork Salmon River
SRFB Salmon Recovery Funding Board
STEM Status Trend Effectiveness Monitoring
TIR Thermal Infrared
TMDL Total Maximum Daily Load
TNC The Nature Conservancy

UCSRB Upper Columbia Salmon Recovery Board
USBR U.S. Bureau of Reclamation
USFWS U.S. Fish and Wildlife Service
USFS U.S. Forest Service
WDOE Washington Department of Ecology
WDFW Washington Department of Fish and Wildlife
YN Yakama Nation

CHAPTER 1: OVERVIEW OF THE INTEGRATED STATUS AND EFFECTIVENESS MONITORING PROGRAM (ISEMP)

Columbia River Basin anadromous salmonids have exhibited precipitous declines over the past 30 years, with several populations now protected under the Endangered Species Act (ESA) (Schaller et al. 1999; McClure et al. 2003). Considerable scientific and political debates have ensued as to the cause of the declines, the mitigation requirements and management responsibilities of government agencies, and the strategies to reverse this trend (Karieva et al. 2000; Marmorek and Peters 2001; Peters and Marmorek 2001; Peters et al. 2001; Ruckelhaus et al. 2002). Much of this debate may have been circumvented if a more comprehensive monitoring strategy had been implemented to reduce uncertainties.

Uncertainty or lack of information, often results in criticisms of recovery planning or paralysis in adopting new strategies, thereby placing the burden of proof on the resource (Peterman 1990; Tear et al. 1995). Data collected from current and historical monitoring programs are generally not adequate or reliable enough for the purposes of ESA assessments and recovery planning (Tear et al. 1995; Campbell et al. 2002; Morris et al. 2002). Monitoring programs for anadromous salmonids in the Columbia River Basin have typically been initiated to evaluate the effects of specific management actions, such as the demographic effects of hatcheries. As such, data are most appropriately viewed at the scale of the subpopulations and populations for which they were derived. However, the ESA requires assessments of species and their habitat at multiple spatial scales – from specific reaches, to subpopulations, populations, and the ESA management unit of Pacific salmon, the Evolutionary Significant Unit (ESU), which is a distinct population or group of populations that is an important component of the evolutionary legacy of the species.

Current monitoring programs for Pacific salmon did not develop as a cohesive design, thus aggregating existing data from a myriad of independent projects creates challenges in addressing these spatially complex questions. These problems arise because information is often not collected in a randomized fashion (Larsen et al. 2004); sampling techniques and protocols are not standardized across programs; and abundance, distribution, population dynamic, and demographic data for species and their habitat is often not available (Tear et al. 1995; Campbell et al. 2002; McClure et al. 2003). As recovery planning has focused more effort on tributary habitat restoration to mitigate for the mortality resulting from the Federal Columbia River Power System (FCRPS) the limitations of historic and current sampling programs have become increasingly apparent.

Between 2000 and 2003, the Pacific Coastal Salmon Recovery fund alone spent over $170 million for salmon habitat restoration projects (Roni 2005). Surprisingly, restoration efforts are rarely coupled with effectiveness monitoring, and those that are often cannot demonstrate a benefit to the target population (Roni et al. 2002; Bernhardt et al. 2005; Roni 2005) or they arrive at an erroneous conclusion by not accounting for other changes, such as fishing pressure (Thompson 2006). Therefore, the lack of rigorous monitoring has led to a lack of consensus as to which restoration actions are most effective (Reeves et al. 1991; Kondolf 1995). Evaluating whole watershed responses to restoration in an experimental fashion has been suggested as a means to overcome these problems (Roni et al. 2002; Bilby et al. 2005; Roni et al. 2005; Reeve et al. 2006).

The Columbia River Basin region lacks a systematic approach to the implementation of population and habitat status and action effectiveness monitoring for the ESA recovery planning for salmon and steelhead. Perhaps more importantly, the region lacks a strategy to design and evaluate these large-scale monitoring approaches. The development of a federal research, monitoring, and evaluation (FRME) program for the Columbia River Basin is now a requirement under the U.S. National Oceanic and Atmospheric Administration Fisheries (NOAA-Fisheries) 2000 and 2004 FCRPS Biological Opinions (NMFS 2000, NOAA 2004), as well as a component of all ESA recovery plans for these species. The tributary FRME is charged with describing the 'health' or the status and trends of fish populations and their habitat to assess the mitigation and management requirements to ensure their long-term survival, identify and prioritize restoration actions to improve habitat features identified as limiting factors, and evaluate whether the implemented restoration actions have achieved their assumed benefits (Jordan 2003).

The Columbia River is the largest river in North America that flows into the Pacific Ocean and drains an area nearly the size of France. This immense spatial extent crosses multiple jurisdictional boundaries, and thus monitoring must rely on a vast network of monitoring infrastructures and personnel, and represents a major investment by the co-manager community. The Integrated Status and Effectiveness Monitoring Program (ISEMP) has been created as a cost effective means of developing protocols and new technologies, novel indicators, sample designs, analytical tools, data management, communication tools and skills, and restoration experiments.

The ISEMP has been initiated in three pilot subbasins, the Wenatchee/Entiat, John Day, and Salmon, and is funded by the Bonneville Power Administration (BPA) Fish and Wildlife Program to support the development of a region-wide FRME. To balance replicating our experimental approaches with the goal of developing monitoring and evaluation tools that apply as broadly as possible across the Pacific Northwest, these subbasins were chosen as representative of a wide range of potential challenges and conditions, e.g., differing fish species composition and life histories, ecoregions, institutional settings, and existing data.

The most straightforward approach to developing a regional-scale monitoring and evaluation program would be to increase standardization among status and trend monitoring programs. However, the diversity of species and their habitat, as well as the overwhelming uncertainty surrounding indicators, metrics, and data interpretation methods, requires the testing of multiple approaches. Thus, we are developing a broad template that may differ in the details among subbasins, but lessons learned from this effort will ultimately lead to the formation of the unified FRME plan for the management of anadromous salmonid populations and habitat across the Columbia River Basin.

The ISEMP has constructed a framework that builds on current status and trend monitoring infrastructures in the pilot subbasins but challenges current programs by testing alternative monitoring approaches. In addition, the ISEMP is:

1) Collecting information over a hierarchy of spatial scales, allowing for a greater flexibility of data aggregation for multi-scale recovery planning assessments, and
2) Designing methods that:
    a) Identify factors limiting fish production in watersheds;
    b) Determine restoration actions to address these problems;

c) Implement actions as a large-scale experiment (e.g. Before After Control Impact, or BACI design), and
d) Implement intensive monitoring and research to evaluate the action's success.

The intent of the ISEMP project is to design monitoring programs that can efficiently collect information to address multiple management objectives over a broad range of scales. This includes:

- Evaluating the status of anadromous salmonids and their habitat;
- Identifying opportunities to restore habitat function and fish performance, and
- Evaluating the benefits of the actions to the fish populations across the Columbia River Basin.

The multi-scale nature of this goal requires the standardization of protocols and sampling designs that are statistically valid and powerful, properties that are currently inconsistent across the multiple monitoring programs in the region. Other aspects of the program will aid in the ability to extrapolate information beyond the study area, such as research to elucidate causal mechanisms, and a classification of watersheds throughout the Columbia River Basin. Obviously, the scale of the problem is immense and the ISEMP does not claim to be the only program working towards this goal. Other programs include the Pacific Northwest Aquatic Monitoring Partnership (PNAMP; http://www.pnamp.org), and the Collaborative Systemwide Monitoring and Evaluation Program (CSMEP; http://www.cbfwa.org/csmep), which are regional scale processes using collaboration among several agencies to tackle some of the large-scale problems associated with monitoring. While there is overlap in participation and approaches in these processes with the ISEMP, the ISEMP is addressing the design of monitoring at a different scale using a different strategy.

A major difference between the ISEMP and other monitoring design efforts is the integration of the ISEMP with current subbasin monitoring programs. We are relying on the current monitoring infrastructure to test and develop monitoring strategies, while acting as a coordinating body and providing support for key elements such as data management and technical analyses. The ISEMP also ensures that monitoring programs can address large-scale management objectives (resulting largely from the ESA) through these local efforts. While the ISEMP maintains a regional focus it also returns the necessary information to aid in management at the smaller spatial scales (individual projects) where manipulations (e.g., habitat restoration actions) actually occur.

We believe coordination and collaboration with the local monitoring practitioners is perhaps one of the most important elements in the development of a monitoring program. Even at the size of the pilot project subbasins, the scale of the study domain is quite large and it is difficult for any single agency to undertake the implementation and testing of a monitoring program in a timely and cost efficient manner. In addition, multi-scale management objectives are almost always likely to cross jurisdictional and political boundaries and therefore require effective coordination. The ISEMP encourages members of the coordination body to address the development of a monitoring program first as researcher. While intimate knowledge of agency management objectives and current programs is also important, a successfully coordinated regional monitoring program depends on the participation of individuals who work easily with others and can find ways to bridge the inevitable gaps between agency mandates to advance the goals of the larger monitoring program. In addition, local representatives of these agencies will conduct the long-term program implementation. Their participation in the development process will ideally lead to some sense of ownership in the final program that will encourage long-term involvement.

The elements of the ISEMP framework that we believe will lead to the development of a standardized and comprehensive monitoring and evaluation program for the Columbia River Basin are:

(1) Programmatic coordination for design, planning, and implementation

Establish contacts, summarize and coordinate current monitoring and evaluation activities and goals, identify gaps in information needed to address multiple goals, develop strategic plans and timelines for implementing monitoring activities and the other program elements.

Although relevant for any restoration or monitoring and evaluation project, the need for effective coordination increases as the spatial scale of interest increases. For example, as the geographic extent of a project's focus increases, so does the number of agencies involved in restoration, monitoring and evaluation (RME) activities. A coordination body comprised of the agencies and non-government organizations is a forum to relate the multiple programmatic goals, expectations, and project details. It also provides a means to collaboratively develop standardized monitoring programs, such as the variables, protocols, and sampling designs to be used. Since many of the most powerful effectiveness monitoring designs rely on staged implementation of restoration actions and sufficient control reaches, failure to adequately coordinate the implementation of restoration activities can undermine effectiveness evaluations (Caughley 1994). Likewise, as the diversity and number of funding sources and resource management agencies increases, so to does the difficulty of determining where and when RME activities have been completed, are occurring, or have been proposed. Thus, communication is paramount to ensuring that proposed RME activities capitalize on past actions and adequately synchronize with ongoing and proposed actions. Finally, given that centralized and accessible databases are only now becoming commonplace, effective communication is required to ensure that all available data are utilized to optimize designs and that new data collection is not duplicative.

Aside from these technical requirements, monitoring and evaluation activities are constrained by funding; thus, the implementation of new RME programs often comes at the expense of existing programs. Therefore, explicit coordination with funding agencies is critical to ensure they understand that new programs must often address the information needs of existing projects in kind with their own. Explicit up-front participation of funding agencies in project coordination may also ease budget transitions and improve efficiency as existing and newly implemented activities are merged.

While each of the ISEMP subbasins have convened or accessed existing coordination processes, the Wenatchee/Entiat ISEMP exemplifies these efforts. The Upper Columbia Regional Technical Team (RTT) was formed several years prior to the initiation of the ISEMP project to review restoration projects and provide scientific input to regional fisheries managers. The group's role has expanded into monitoring coordination by facilitating the ISEMP's initiation into the Wenatchee/Entiat subbasin. The RTT now serves as the technical oversight committee for the ISEMP's Wenatchee/Entiat activities.

An aspect of the RTT that makes it particularly effective is that members serve on a non-representational basis; while often employed by the agencies active in regional fisheries issues, RTT members do not formally represent these agencies within RTT deliberations. The existence of this group upon initiation of the ISEMP, and its ability to work productively and easily across institutional boundaries, has allowed for rapid and enduring coordination in the Wenatchee/Entiat subbasin. For example, over a dozen tribal, state, federal, county, and private contractors are currently implementing components of the ISEMP in the Wenatchee/Entiat subbasin. Coordination among these entities occurs at all levels, ranging from the programmatic scale (e.g., three agencies contributed funding for a passive integrated transponder (PIT) tagging study beginning in 2006) to the field level (e.g., United States Forest Service (USFS), Yakama Nation (YN), United States Fish and Wildlife Service (USFWS), Washington Department of Ecology (WDOE), and two private contractors conduct snorkel and habitat surveys within a few days of each other at approximately 100 sample sites per year). The Chelan County Conservation District (CCCD) facilitates landowner access permission, affording these agencies unprecedented access to sites on private land.

The ISEMP is helping to link restoration activities and monitoring by developing an implementation strategy for the suite of projects to be implemented under the Entiat Subbasin Recovery Plan and Intensively Monitored Watershed (IMW) study by coordinating public demand, funding, design engineering and construction implementation, and monitoring activities. In addition to preparing this strategy, an effort founded on careful partnership building, the ISEMP contributes funding for coordination at the landowner and restoration implementation levels, as well as for research and monitoring activities, to ensure that the implementation strategy will be carried out.

A similar implementation strategy produced by the ISEMP currently guides monitoring in the Wenatchee subbasin. Within this strategy, programs and schedules are described so that completed, active, and proposed monitoring activities capitalize on past actions. For example, the ISEMP's performance evaluations of smolt trapping activities have added to an existing time-series of data rather than creating new time-series data unrelated to other efforts. Similarly, the strategy ensures that all proposed activities are adequately synchronized with ongoing actions and all other proposed actions, and provides the framework to manage the timing and performance of a dozen separate contracts for integrated monitoring in the Wenatchee subbasin. The ISEMP supports this strategy document through the development and maintenance of an on-line "decision-tracking tool" that serves much as a lab notebook would for an individual researcher. However, this tool tracks all minor and major adjustments in methods for dozens of research activities monitoring as many as 67 ecological indicators, and is accessible to the participating researchers in the Wenatchee/Entiat subbasin.

Standardizing protocols is another way the ISEMP coordination has helped ensure that all available data are optimally utilized. For example, the ISEMP developed interim protocols for the capture, handling, and tagging of wild salmonids in the Upper Columbia River Basin for projects that use PIT tags. The ISEMP collaborative process enabled information sharing among local field staff and outside experts. The initial success of this effort is reflected by the use of these protocols by all five state, and federal and tribal agencies engaged in this work in the

Wenatchee/Entiat subbasin, and by the adoption of these protocols in other, nearby non-ISEMP subbasins. Other products include subbasin-scale monitoring strategies, a habitat field-survey manual, data entry templates, and a data management system. In short, this collaborative process provides a forum for an exchange of information that otherwise may not occur.

The ISEMP also has a website that houses documents, collaborator contact information, images, and database tools available to both the ISEMP participants and other interested parties. This website is open to the public and is updated quarterly to reflect the progress of current projects and distribute data to interested parties.

(2) Ecological indicators and variables: development and testing

Determine variables and develop indicators that best capture relevant mechanisms useful for management and recovery planning.

The decisions as to which variables or indicators (i.e. surrogates of variables) need to be collected when designing a monitoring program should be based on management objectives and ecological principles (Spellerberg 1991). A common approach to designing a monitoring program is to borrow from designs previously implemented, and collect all variables and indicators potentially relevant to the resource in question. However, developing monitoring programs may incorrectly assume the variables from other programs are transferable to their focus organisms and study domain, and several variables or indicators collected may therefore be uninformative. This is not a problem if additional metrics can be added to the monitoring program at minimal cost (e.g., the main cost may be transportation to the field sites); however, the collection of non-informative variables and indicators could certainly preclude the collection of informative ones, or generate a false sense of security that the necessary data is being collected. Therefore, time should be spent evaluating variable and indicator relevance and importance to avoid the collection of non-informative metrics. This requires analyses of the ability of collected information to explain the observed variability in response variables. Thought should also be given as to whether the program requires novel variables or indicators to adequately address management objectives. Directed research can elucidate whether alternative variables and indicators can represent important and relevant ecological processes.

The ISEMP is both adopting metrics from other monitoring programs and conducting research to establish a set of variables and indicators most relevant to multiple management objectives addressed by the FRME. For example, a system-wide fish and habitat status and trend-monitoring program developed for the Oregon Plan for Salmon and Watersheds Monitoring Program has been successfully implemented in Oregon's coastal watersheds. The Oregon Department of Fish and Wildlife (ODFW) have also adopted this program for implementation in the John Day subbasin. Although many of the measured habitat variables have been demonstrated to correlate with fish performance variables (Nicholas 1997), it is uncertain that these represent the most important set of variables to collect in a very different ecoregion and species composition such as in the John Day subbasin. A review of the literature was also used to determine a set of 67 variables or indicators characterizing habitat and fish performance to be monitored in the Wenatchee/Entiat subbasin (Hillman 2006). As in the John Day, the approach is to collect a plethora of information and retrospectively evaluate the amount of variation this can explain in fish performance metrics. While this approach may seem over-zealous, it minimizes the risk that important information is not collected. The ISEMP anticipates that the synthesis of pilot project information will alter the list of variables and indicators prior to implementation of the overall FRME program.

The ISEMP project has also been applying ecological principles to develop relevant indicators and conducting research to test if these relationships are realized. For example, macroinvertebrate assessments in monitoring programs throughout the Columbia River basin use benthic species composition to create indicators of water quality. These indices, however, do not provide information on the quantity or quality of food available for drift feeding salmonids, which may be the most important factor regulating salmonid growth, and ultimately survival and productivity (Wilzbach and Cummins 1986; Filbert and Hawkins 1995). Total invertebrate drifting abundance has been suggested as a more appropriate metric of food availability for salmonids (Billy and Usseglio-Polatera 2002; Billy et al. 2002; Esteban and Marchetti 2004) and thus may be a more direct method of estimating potential fish production than counts or indices of benthic invertebrates.

In the ISMEP invertebrate productivity monitoring study, we are comparing estimates of terrestrial and aquatic drift and benthic invertebrate biomass to estimates of juvenile anadromous and resident redband trout (O*ncorhynchus mykiss gairdneri*) growth and density across multiple reaches and watersheds differing in temperature and habitat characteristics. From this study, we expect to determine the most relevant invertebrate metric (e.g. total invertebrate biomass) to fish performance.

(3) Sampling protocols: development, refinement and testing

Determine the accuracy and precision of information collected from different protocols.

Monitoring programs throughout the Pacific Northwest use a variety of protocols to describe the same general metric. Protocols often differ enough that data collected under different protocols are not comparable, preventing an aggregation of data to address larger scale management questions, such as those related to the ESA. For example, instream large woody debris (LWD) is extremely important in the formation of pools or structure for fish and is therefore generally measured in many habitat monitoring programs (Maser and Sedell 1994; Ralph et al. 1994). A reach estimate of LWD can be measured as either: (1) the number of pieces of wood greater than 0.15 m diameter at breast height and greater than 3 m in length found within or touching the bankful width of the stream channel (Wiley et al. 2005); or (2) 0.1 m in diameter as measured one-third of the way up from the base, greater than 1 m long, and found with at least 1 m of the wood within the bankful width (PIBO 2004). These protocols would lead to different estimations of LWD for the same reach.

Protocols not only vary in how they define the variable collected, but also in their precision, accuracy, dependability, and cost. Protocols often differ in precision or their ability to provide consistent information by different observers across the same reach (Roper and Scarneechia 1995; Poole et al. 1997). This inconsistency may depend on the complexity of the method or the intensity of training of inexperienced crews (Wang et al. 1996), the within site heterogeneity of the environment (e.g. pebble counts to describe a reach; Roper et al. 2002), or the technology available. The accuracy or the ability of a protocol to collect information to describe the "true" value is also dependent on these factors. The accuracy of a given protocol can be difficult to establish because a benchmark or proven alternative method to describe the "true" value may not be available. In addition, the dependability of a protocol is important to consider before implementation. For example, malfunctioning mechanical or electrical instruments may result in a loss of data that perhaps could have been prevented by a more dependable method even though it may be more labor intensive or less precise and accurate. Dependability is more likely to be a problem with new technology that has not been thoroughly tested by monitoring practitioners. Finally, the cost and feasibility of protocol implementation should be considered. Funds are always limiting and trade-offs will have to be made between these factors when choosing the appropriate protocols.

Given these inherent problems, it is important to develop a quantitative understanding of the strengths, weaknesses and relatedness of different protocols and their resulting metrics. Quality assessments and control on the accuracy and precision of a protocol should be a standard component of monitoring programs that include the evaluation of variance associated with observers, sites, and time (Roper et al. 2002; Larsen et al. 2004). Side-by-side comparison of the accuracy, precision, and cost of implementation of multiple protocols establishes the basis for deciding the most reasonable protocol to adopt or whether to create “crosswalks” to convert values collected from one protocol to values collected from another. As well as assessing protocol quality and efficiency, the ISEMP is working towards standardizing protocols, or the creation of crosswalks between protocols to allow for assessments that cross program boundaries.

(4) Sampling design: development and testing

Use information on accuracy and precision of different indicators and potential strata to develop and test alternative sampling designs.

Monitoring programs for salmon and steelhead have been implemented in the Columbia River Basin for several decades. A common approach, which has occurred in the pilot project basins since the late 1950s (Beamesderfer et al. 1997), is to count redds at index sites to estimate adult escapement. The problem with this approach is that this design does not lend itself to a statistically valid representation of the status of populations or the aggregation to the ESU due to the lack of randomization employed in the selection of sites. A challenge for the region is to develop statistically sound sampling schemes to allow for the assessment of both status and trends of resources that lends itself to multiple assessments.

The ability to extrapolate a collection of samples to provide an accurate assessment at the appropriate scale is dependent on the sampling design, which in turn is dependent on the accuracy and precision of the sample protocols. The sampling design describes where, when, and how much to sample. The design is not only dependent on the protocols used to collect the information but on how the information will be used. For example, to describe the status of a resource distributed broadly across a landscape, samples need to be collected across this area in a randomized design to prevent the introduction of biases through deliberate site selection, and to be able to infer the condition of entire networks of interest from sample locations (Larsen et al. 2004). This sample design may require some stratification strategies to ensure greater representation of important differences.

Estimation of resource trends can be detected more quickly through a sampling design with planned revisits to sites (Urquhart and Kincaid 1999; Roper et al. 2003). Split panel (rotating and fixed) sampling designs are used to balance both status and trend monitoring (Urquhart and Kincaid 1999; Stevens 2002). A rotating panel represents a collection of sites that are added at each sampling interval, but that will be revisited over a long period (e.g. three to five times the sampling interval), while a fixed panel is a collection of sites that will be resampled every sampling interval. In this design, status detection dependent on spatial variance is captured by the increased spatial coverage of the "new" rotating sites, while trend detection dependent on temporal variance is best captured by the repeat visit fixed sites. Effectiveness monitoring will require yet a different design that balances the need of contrast between treated and untreated areas; thus, sites will have to be selected to provide contrast spatially but visited through time to evaluate trends.

For status monitoring, the EPA's Environmental Monitoring and Assessment Program (EMAP) has developed a spatially-balanced, site-selection process for sampling aquatic systems (U.S. EPA 2000). This design is becoming more popular for monitoring programs in the Columbia River Basin and underlies the major monitoring programs in the ISEMP pilot projects. The site-selection process is based on 1:100,000 hydrography for the U.S. and can select a set of sampling locations that are simultaneously random draws and spatially dispersed (Stevens and Olsen 2004). These two features are very useful for natural resource monitoring in that statistical inference from random samples is straightforward and robust, but is difficult in practice due to the potential for clumped sampling locations. Therefore, the added spatial balance condition on the sample location process results in a set of sampling points that are more dispersed than random, yet not hyper-dispersed or uniform. The approach has the added benefit that it is scale independent, and groups of sampling locations are interpenetrating such that a lower density set is a subset of all higher density sets. Therefore, the EMAP site-selection approach can be used to develop sampling designs at varying spatial extents, an important consideration when trying to meet multiple monitoring objectives. The dynamics of the resource should guide when to sample and at what frequency. For example, annual adult carcass surveys obviously must be conducted during the spawning season, while screw traps used to capture juveniles should be deployed during migration periods. However, the time of year that some variables should be sampled is not as apparent. For example, seasonal changes in stream characteristics (e.g. vegetation or stream discharge) may influence the estimates of several habitat variables (Archer et al. 2004). The frequency of sampling should also consider the relevant temporal variability associated with the resource. Riparian vegetation may not exhibit much year-to-year change and therefore only require sampling perhaps every 5 years. Conversely, some variables change fairly rapidly (e.g. temperature) and must be sampled at a much higher frequency to capture their dynamics. Where possible, assessing temporal fluctuations should be considered in the development of a monitoring program. However, logistical constraints often override the need to collect sampling events at preferred frequencies and times, such as limitations in field crew availability or weather.

The sources of variability arriving from the protocols used (observer and measurement error) and the natural spatial and temporal variation (environmental heterogeneity) needs to be analyzed to estimate the power of the sampling program under different sample sizes. Power analyses can be used to evaluate the efficiency of alternative sampling designs (Urquhart and Kincaid 1999). This requires some estimate of these components of variation inherent to the study area and protocols used, which is problematic in that this information is not available prior to the implementation of monitoring. Therefore, initial designs are often based on results from similar programs, and as information becomes available the designs are altered; thus, the determination of a monitoring design will be an iterative and continual process. Arriving at better year-to-year estimates of variability, for example, cannot be solved simply by adding more sampling sites, and will only improve with more years of monitoring (Larsen et al. 2004). Once the components of variability are estimated, this information can be used determine the number of samples required to address a given monitoring objective (Larsen et al. 2001, 2004; Roper et al. 2002, 2003).

The ISEMP is coordinating and aiding in the design of the collection of information across multiple scales to identify patterns, and describe the status and trends of fish and their habitat. In some cases, complete censuses are conducted so statistically valid sampling designs are not a consideration. For several other types of information, however, sample designs are crucial and are thus being tested. In the John Day subbasin, status and trend monitoring for juvenile and adult steelhead and Chinook populations and their habitat are conducted by ODFW based on a monitoring program that has been implemented in Oregon's coastal watersheds (Wiley et al. 2005). Where a census is not feasible, sample locations are chosen through the EMAP spatially-balanced site-selection process, and are collected over a split rotating panel design. A sampling program similar in design and effort to the John Day subbasin project is being implemented in the Wenatchee subbasin (Ward 2005). However, the Wenatchee subbasin is about 1/8 the size of the John Day subbasin, therefore the density of sample sites is effectively much higher. We will compare the influence of an increased density of sample sites on the precision of summary metrics. Analysis of variance structures will be evaluated as information becomes available to describe the power of the different sampling designs. In addition, subsampling routines of the data will be used to evaluate whether current designs are too intensive and thus wasteful for addressing relevant management objectives.

The ISEMP is proposing to initiate and test an entirely different habitat and population status and trend project in the South Fork Salmon River (SFSR) watershed in Idaho. This monitoring program will test a different set of protocols and sample designs in a "common garden" with existing programs to determine whether a single sampling design can return the information needed for multiple species/life histories, and whether relationships can be constructed to enable programs to employ alternative sampling methods without losing the time series of information that has been generated by existing infrastructure/sampling designs. This program also highlights the idea that the elements discussed thus far will not be evaluated in isolation but rather as an integrated approach to designing a monitoring program.

(5) Effectiveness monitoring: design and implementation

Determine the effectiveness of restoration actions through an experimental management framework, such as the IMW studies.

Ecosystem experiments are arguably the most direct method available for predicting a population or environmental response to management (Carpenter et al. 1995). Ecosystem-scale experiments have contributed greatly to our understanding of ecological processes within watersheds (Likens et al. 1970; Wright et al. 1993; Hartman et al. 1996), and results from many of these studies have led to changes in management strategies (Likens et al. 1978; Wright et al. 1993; Hartman et al. 1996). However, generalization beyond a single system requires knowledge of mechanistic interactions or multiple ecosystem studies (Carpenter et al. 1995).

Since ecosystem experiments have led to great insights into the mechanisms regulating populations and are conducted at the appropriate scale to assess management implications to populations, IMW studies to evaluate population level responses to large-scale restoration efforts have been initiated throughout the region (Bilby et al. 2004, 2005; PNAMP 2005). Experimental designs and statistical analyses for these types of large-scale experiments are well documented (Carpenter 1990; Stewart-Oaten and Bence 2001; Roni et al. 2005). The goal is to develop a network of IMWs to assess limiting factors, develop actions aimed at restoring ecosystem processes, and evaluate the effectiveness of different actions or a suite of actions on fish populations across a range of watershed types. The ISEMP has proposed, or is involved in, IMWs in each of the pilot projects to evaluate large-scale restoration actions in an experimental framework approach.

(6) Identification of causal mechanisms and limiting factors

Establish causal relationships between ecological processes that control fish population dynamics. Synthesize causal relationship to assess limiting factors.

Increasing our understanding of the mechanistic relationships between fish and their habitat across a hierarchy of scales will improve our ability to apply this information across a range of management problems of different spatial and temporal extents (Faush et al. 2002). Therefore, directed research to reveal these important causal relationships and the appropriate variables to characterize these relationships is crucial. Further, a synthesis of the interaction of these mechanisms is not only important in determining factors regulating focal fish populations, but also in prescribing and prioritizing restoration actions. This synthesis can be referred to as a limiting factors analysis.

The ISEMP has developed and coordinated research directed at identifying causal relationships. For example, the invertebrate study will evaluate the relative importance of temperature and invertebrate biomass influence on growth and production of juvenile resident and anadromous redband trout. Other examples of directed studies currently coordinated within the ISEMP include:

- Influence of land use factors on sedimentation;
- Effects of land use and landscape patterns on temperature;
- Impact of riparian and physical stream characteristics on temperature; and
- Limitations of temperature on juvenile redband trout distribution, abundance and growth.

Several other studies have been identified and proposed. We also anticipate that if restoration actions result in large improvements in habitat and fish production, the IMW studies will reveal important cause and effect relationships.

A general framework to assess limiting factors will help prioritize and develop restoration programs as hypotheses to test, and should be integrated into IMWs or other restoration studies (Roper et al. 1997). The ISEMP is exploring analytical tools to aid in this comprehensive assessment based on information collected through the monitoring programs. However, a comprehensive evaluation of all potential limiting factors requires multi-dimensional datasets collected over long time periods that are costly and beyond the scope of most monitoring programs. Often the resources, especially those listed under the ESA, do not have the luxury of time for this type of comprehensive analysis.

The experience of researchers and managers may provide a reduced set of likely limiting factors that can be used to narrow the scope of limiting factor assessment and therefore the amount of information required for evaluation. For example, temperature is thought to be a major limiting factor for much of the John Day subbasin (Bouwes 2004). The Heat Source model uses physical processes to define a heat budget for a reach (Boyd and Kasper 2002) and is currently employed in the Total Maximum Daily Load (TMDL) process in the John Day subbasin (Bouwes 2006). The ISEMP is developing algorithms to process airborne light detection and ranging (LiDAR) information that can be used as direct inputs (such as topographical and vegetation data) into the Heat Source model. Impacts of different scenarios on stream temperature, such as increasing the riparian canopy through a riparian fencing project, or increased discharge by purchasing instream water rights, can be estimated with the Heat Source model. Results may be coupled with a bioenergetics model to evaluate temperature dependent growth rates (Railsback and Rose 1999) and can be used to identify habitat factors limiting growth, and presumably survival, which could be addressed through restoration.

Other more complex models have been developed previously for the identification of limiting factors that may also aid in the assessment of limiting factors. For example, the Ecosystem Diagnostic and Treatment (EDT) model has been applied to the John Day, Wenatchee, Entiat and several other subbasins across the Pacific Northwest (http://www.mobrand.com/edt/). The EDT model is complex and spatially explicit, and relates several habitat variables to survival over several life stages. A similar modeling approach is being applied by the ISEMP in the Lemhi IMW in Idaho. Both status monitoring information and the IMWs will provide excellent opportunities to test predictions of these types of models to evaluate their potential for broad-scale use.

(7) Evaluation tools: development and testing

Develop monitoring data analysis and modeling tools.

A danger of intensive monitoring efforts is the potential to be overwhelmed by the huge volume of information to be managed and analyzed (Vos et al. 2000). The analysis of information is where monitoring is translated to monitoring design refinement and management recommendations. The discussion of limiting factors analyses highlights this point. Advances in analytical techniques are constantly occurring. Staying current with these advancements while also implementing monitoring, designing restoration projects, and managing fish populations is challenging to say the least. The ISEMP's primary objective is to aid in the design of efficient and comprehensive monitoring programs to address multiple management objects, but it relies on current monitoring infrastructure for the implementation of monitoring. The ISEMP is also aiding in the development and application of tools to evaluate the diverse, extensive, and hierarchical nature of data collected as part of the pilot projects. Several books and articles discuss analytical techniques for the evaluation of monitoring information (e.g. Jongman et al. 1995; Burnham and Anderson 1998; Scheiner and Gurevitch 2001; McCune and Grace 2002; Quinn and Keough 2003). Analyses will range from simple data reduction, summary, and graphical representation to more complex and innovative multivariate approaches.

Analytical needs include the assessment of the utility of the different variables and indicators, which is related to the identification of potential causal mechanisms. Regression and multiple regression approaches will be common tools to evaluate whether predictor variables can explain the variation observed in the response variables, and can at least generate hypotheses about these relationships.

The precision and accuracy of different protocols, and the efficiency of sampling designs will have to be evaluated. Random effects analysis of variance models are the appropriate statistical tool to partition the spatial and temporal environmental heterogeneity, observation and measurement error (Littell et al.1996; Kaufmann et al. 1999) and will be used to compare protocols and assess and refine sampling designs (Roper et al. 2002; Archer et al. 2004). Power analyses and sample size calculations will also be used to complement these evaluations (Urquhart and Kincaid 1999; Roper et al. 2002).

The development of limiting factor analyses and the ability to address management questions are also analytical requirements of the ISEMP. Reference and managed systems can be compared using ANOVA and ANCOVA approaches (Kershner et al. 2004), and Partial Mantel tests can be used to identify a potentially important set of environmental relationships at multiple spatial scales from a large set of variables while accounting for spatial autocorrelations (King et al. 2005). Hierarchical models and structural equation modeling show promise in testing hypotheses about multiple factors regulating fish performance metrics using spatially explicit data (Shipley 2002; McCune and Grace 2002; Wagner et al. 2006).

As part of the Lemhi IMW, the ISEMP has developed an analytical framework to help prioritize and evaluate the impacts of habitat restoration actions. A modified watershed model for anadromous salmonids (Sharma et al. 2005) is being employed to characterize the relationships between land use and habitat actions on life-stage specific survival rates in the context of overall life-cycle survival. Construction of the life-cycle model was based on ecological concepts relevant to management and later corroborated by empirical information (albeit in another system; Sharma et al. 2005). For parameterization, model variables will have to be monitored, with greater effort expended on sensitive parameters. Thus, the model acts as framework to guide monitoring. By acting as a limiting factor analyses, the model will be used to prioritize habitat actions as well as describe the expected benefits habitat improvements will have on the productivity of Chinook and steelhead populations to be tested in the IMW. The model will then put into context the impact(s) of habitat restoration actions on the freshwater stock recruitment relationship, and whether that influence is of sufficient magnitude to offset mortality resulting from mainstem passage in the Snake and Columbia rivers or poor ocean conditions. Thus, the model is not only an explicit description statement of hypotheses to test in the IMW, but provides a conceptual framework and aids in the design of monitoring and restoration.

The ISEMP is also developing classification tools to apply lessons learned from small-scale efforts to broader scale problems. The ISEMP has classified the watersheds of the Columbia River Basin based on their potential to support anadromous salmonids, represented by a multidimensional numerical score for each watershed (6^{th} field hydrologic unit code, or HUC) based on reducing multiple spatial data layers. Generating the watershed scale descriptors requires the compilation of existing spatial data layers to generate consistent and complete coverages of biophysical conditions. This process takes complex continuous data, including multiple data layers that contain significant spatial correlation, and generates a single score for each watershed. For example, multiple soil or bedrock types could be present within each watershed; thus, to score soils or geology, a dominant or most relevant type will be identified and given a numerical score. Alternatively, elevation, precipitation and air temperature within each watershed are continuous variables and are highly correlated, but each contains sufficiently unique information that one could not act as a proxy for all. Once scored, watersheds are grouped into "like"clusters. The clustering approach most appropriate for these data is a dichotomous ordination and classification procedure that relies on differential characteristics prevalent on one side of a dichotomy. Similar approaches are applied in community ecology analysis (community structure) and phylogenetics. Statistical support for the clusters and branching structure is evaluated by discriminant analysis, cross validation and bootstrapping. There is no preconceived notion of the scale of these clusters, but similar processes have generated groupings of 6th field HUCs that approximate the 4th to 5th field scale, but that are linked by shared conditions, not just the hierarchy of stream networks (Hessburg et al. 2000; Omernik 1995).

The clustering process generates hypotheses regarding the similarity of watersheds with respect to their physical and biological processes. The primary hypothesis or assumption to be tested with these analyses is that of representativeness. First, the pilot project subbasins will be assessed for being representative samples of broad regions of the interior Columbia River Basin. Second, within each of the pilot project subbasins, individual streams are being considered as replicates and potential reference or control sites. The classification/ordination process will allow an assessment of the validity of these assumptions. This will aid in the selection of potential IMWs as well as increase the general applicability of IMW study results to other watersheds.

(8) Data management tools: development and testing

Develop databases, data communication templates, data and information output tools, and populate databases with current and historic monitoring data.

Developing a regional monitoring and evaluation program must overcome significant data organization and management challenges in order to meet program objectives. Regional projects produce an enormous volume of data from a plethora of collaborates, sites, and years. For example, in 2004, the ISEMP data collection in the Wenatchee subbasin produced nearly 250,000 unique data records. This sheer volume of data results in issues of storage capacity, retrieval, and distribution. Data collected by disparate collaborators is often stored in inconsistent formats and typically do not follow consistent rules of quality assurance, making automated processing nearly impossible. Additionally, it is crucial that only designated individuals perform data entry and updating and that data only be analyzed or used after it has been approved for release. Once field data has been collected and processed, it may be necessary to derive metrics from raw data. These calculations should be performed consistently across years, subbasins, sites, and collaborators. Historically, metadata about who, when, and how data were collected have not been stored directly with data and is often lost or misplaced. Furthermore, monitoring data is utilized in a multitude of functions, including the elements described thus far. Each type of analysis requires a distinct subset of variables, indicators, or metrics and may require data to be organized in distinct formats. As other regional programs have demonstrated, regional data analyses are best supported by the power and flexibility of the relational database architecture. However, data providers are often overwhelmed with requests for data submissions to multiple centralized regional databases, and as a result, each centralized database suffers from a lack of "buy-in" from affiliated data providers.

The ISEMP data management strategy is based on the integration of both localized and centralized data management efforts in order to facilitate data transfer to regional databases. A powerful central database maintained by NOAA-Fisheries provides the storage capacity, metadata tracking, and data processing functionality to meet the needs of the regional monitoring and evaluation program. Unlike most centralized database programs, the ISEMP also provides data management tools and guidance to encourage best data management practices within local agencies. Data management tools and guidance help ensure that newly collected data and historic data are structured in a format consistent with regional databases, that metadata is directly linked to raw data, and that a minimum level of data quality is assured at the time of data entry. To date, local agencies have expressed an overwhelming interest in the ISEMP tools and guidance because these tools assist agencies in meeting both their analysis and reporting objectives. In return, the ISEMP receives data in a consistent format, increasing the efficiency of loading data to the central database.

The ISEMP strategy of integrating all these elements is an efficient approach to the development of a comprehensive monitoring design in addition to building on current monitoring infrastructures. We believe these elements should not be viewed in isolation but rather as an integrated process, and that integrating status and effectiveness monitoring is the most efficient use of resources to best address these requirements. Status monitoring provides crucial information to evaluate the required population production improvements, assess limiting factors, and identify restoration opportunities. It is also useful in the generation of hypotheses about causal relationships between fish, habitat, and landscape variables, and may also establish pre-action information for some watersheds, or act as control watersheds for IMW studies as in the Wenatchee/Entiat subbasin pilot project. Conversely, IMWs provide an excellent opportunity to test some of these hypotheses, and can also serve as the status monitoring for a watershed. For example, the ISEMP is proposing monitoring in the Lemhi IMW that is far more comprehensive and intensive than status monitoring programs can afford to be. However, the design is such that the same status monitoring information collected in the South Fork of the Salmon could be derived in the Lemhi, thus rolling up this information in ESA status evaluations for this ESU. Further, IMWs can be test beds for indicators, protocols, and sampling designs.

The ISEMP is emphasizing the IMW as a major component of this program. Effectiveness monitoring is rarely conducted, especially at a scale large enough to detect a population response. In fact, documenting the benefits of tributary restoration actions at the population level is a requirement of the FCRPS Biological Opinions and other ESA consultations guiding the recovery of anadromous salmonids in the Columbia River Basin. Demonstrating the effects of a restoration action depends on the fulfillment of at least three criteria:

(1) The implemented action actually changes physical or biological processes because the action addresses and alters the impaired, limiting factors,

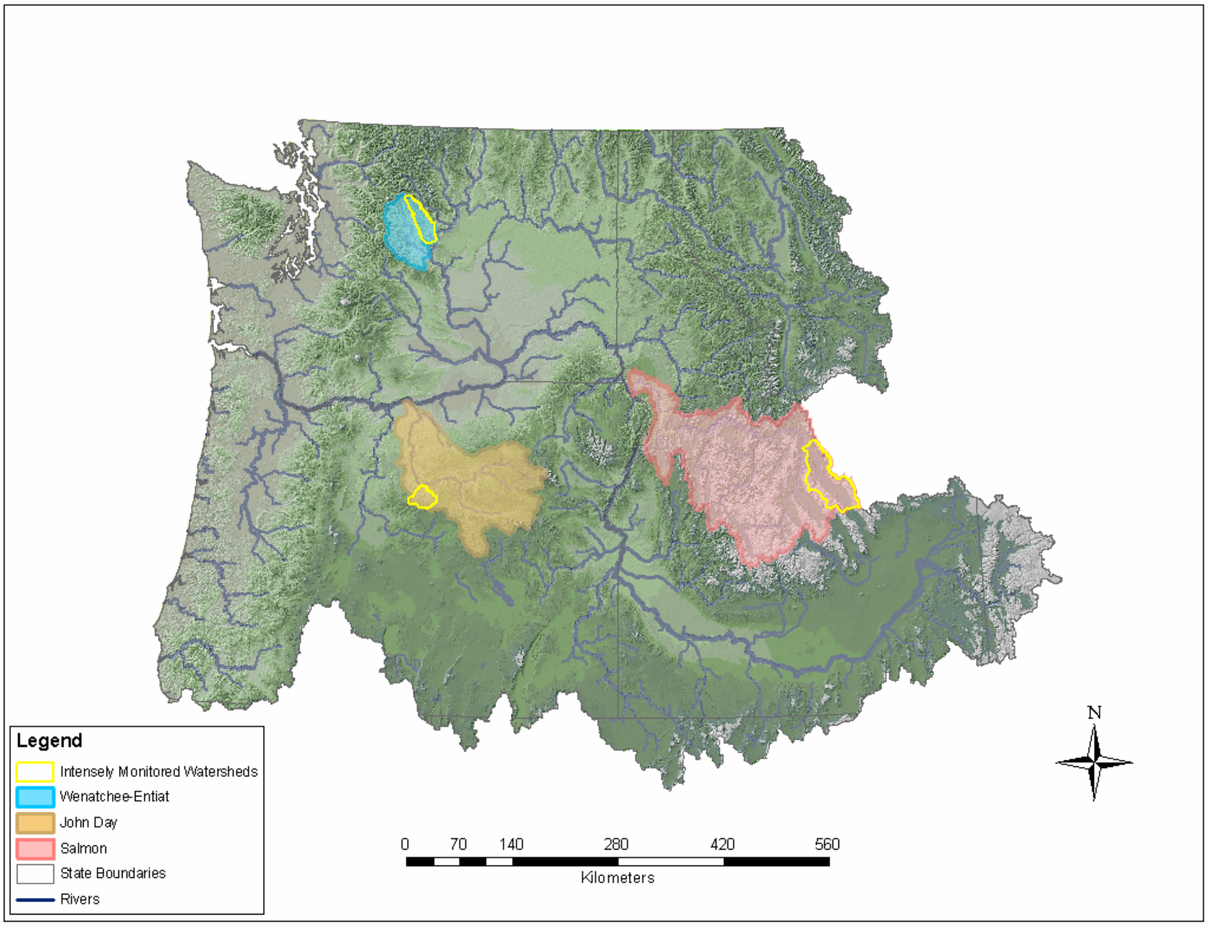
(2) The action’s impact is restricted to the expected area/period of influence so that representative reference or control locales can be identified, and

(3) Monitoring indicators that quantify the effects are collected at both the treatment and reference locations.

These components represent a mixture of project implementation and monitoring. Therefore, a piece-wise approach to the development and implementation of effectiveness monitoring cannot be successful; a programmatic shift must occur to identify, plan, design, install and monitor within a single project. Specifically, a monitoring and evaluation project needs to develop an infrastructure to support the elements of a monitoring program such that simultaneous implementation, monitoring and evaluation can occur in a single adaptive experimental framework.

We believe this experimental approach is necessary to properly study the efficacy of effectiveness monitoring. The current model for the implementation of aquatic restoration projects in the Columbia River Basin may be beneficial for fish but the previous models of effectiveness monitoring will never demonstrate the project's effects; only by coupling the implementation, action design and planning, and monitoring results with a low level of noise and uncertainty, as the ISEMP is testing, will biological benefits be quantified. Further information on the ISEMP program can be found at http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/?CFID=7456048&CFTOKEN=41787654&jsessionid=6430753414d6e677d323.

CHAPTER 2: THE ISEMP IN THE PACIFIC NORTHWEST



ISEMP Coordination and Design

The overarching goal of ISEMP is to act as a major research and development structure to aid in the development of regionally supported status and effectiveness monitoring and evaluation methods. These methods should directly meet the Columbia River Basin's data and information needs with regards to the management of anadromous salmonid populations and habitat. In its most basic state, the ISEMP is a development process: the development of monitoring protocols, monitoring indicators, monitoring data collection schema, and monitoring data management and analysis.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

National Oceanic and Atmospheric Administration –Northwest Fisheries Science Center

Time Line

The ISEMP began in 2003 with limited contracts for coordination of project design and development in the Wenatchee River basin. Project progress in 2004 and 2005 has focused on the development of standardized status monitoring designs and protocols, effectiveness monitoring designs and conceptual gap analyses for IMWs, inventory and compilation of existing agency data and coordination efforts, and the development of data management tools for agency and subbasin scale projects. Funding is currently being sought for the years 2007-2009. Many of the projects being implemented in the pilot subbasins have durations of 10 to 20 years.

Budget

Fiscal Year	Budget
2003	$79,230
2004	$676,482
2005	$1,273,240
2006	$2,310,000

Links to Annual Reports

- Research, Monitoring & Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion.
  - http://www.salmonrecovery.gov/reports_and_papers/research/docs/rme_plan_09-2003.pdf
- Bonneville Power Administration FY 2003 Provincial Project Review.
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/jordan_rmen.doc
- Bonneville Power Administration FY 2003 Provincial Project Review, Revised
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/35019_revised_n.doc
- Fiscal year 2007-2009 Fish and Wildlife Program Project Solicitation.
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2003017000n.doc

- Integrated Status & Effectiveness Monitoring Program Draft Annual Report, Performance Period: October 1, 2004 – September 30, 2005
    - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2003_017_000_nwfsc_fy05.doc

What's been accomplished so far

The ISEMP has focused on generating data, information, analyses and guidance to inform the design and implementation of status and effectiveness monitoring. In all cases, the underlying principal has been to reduce, or at least quantify, the uncertainty associated with each of these facets of a monitoring program. In the last 3 years ISEMP has:

- Initiated pilot monitoring programs in three Columbia River subbasins;
- Developed and tested tools for analyzing monitoring data (see Chapter 7);
- Developed and tested tools to evaluate monitoring programs and approaches (see Chapter 7);
- Developed and tested databases, data communication templates, data and information output tools (see Chapter 6), and
- Populated databases with current and historic monitoring data (see Chapter 6).

In the same period, the ISEMP has also worked closely with the CSMEP, which has been actively involved in metadata surveys and the evaluation of strengths and weaknesses of available information. These evaluations contributed substantially to the design of the Salmon River Pilot Project in Idaho. The design tasks assigned to the CSMEP Status and Trends and Habitat subgroups provided a draft monitoring design for the Lemhi River and South Fork Salmon River, providing a basis for further refinement within the Salmon Pilot Project study design. At a larger scale, the CSMEP workgroup and technical review teams within pilot project subbasins share overlapping membership. Thus, the implementation of pilot projects can efficiently and effectively act as a test-bed for the evaluation of CSMEP design components.

In addition to collaborating with the CSMEP, the ISEMP has served as a vehicle for testing some of the ideas discussed by the PNAMP. As the regional forum where the technical and policy components of large-scale monitoring programs are discussed, designed, and evaluated, the PNAMP provides and coordinates discussions of data management and communication standardization. In particular, the PNAMP has coordinated protocol compilations and tests, tasks in which the ISEMP has participated. The ISEMP has also demonstrated some database products developed to meet project and collaborator needs as examples to help move the regional discussion forward.

Initiation of pilot projects in three Columbia River subbasins

The initiation of integrated status and effectiveness monitoring in the pilot subbasins has taken very different forms in each basin. Each subbasin is beginning the process of coordinated monitoring from a very different place – either based on current/historic monitoring programs and investment, or from a political/philosophical basis on which to build a cooperative program focusing on data collection and management. As the overall project coordinator, the Northwest Fisheries Science Center (NWFSC) and the principal investigator have invested resources to varying degrees and in varying manners in the Wenatchee, John Day and Salmon basins. Also, due to varying degrees of existing coordination and agency contract involvement prior to the

RME program design, each basin has piloted different subtasks of the pilot project according to the immediate strengths and needs of the basin. As a coordinating entity, the NWFSC and sponsoring principal investigator have facilitated communication between subbasin Technical Oversight Committees and coordinators that has resulted in the sharing of piloted information. For example, the development of the John Day Protocol Manager for data management was developed based on protocols that are currently being field tested within the Wenatchee basin. Similarly, the structure of the Status and Trend Monitoring Oracle database designed by NWFSC for the Wenatchee basin has been shared with the John Day subbasin coordinators to facilitate data collection and storage within the John Day subbasin.

Wenatchee and Entiat River subbasins. To initiate the pilot ISEMP in the Wenatchee River basin in 2003, NWFSC and the principal investigator primarily lead discussions and design sessions with an existing coordination entity, the Upper Columbia Salmon Recovery Board's RTT. Beginning in 2004, NWFSC and the principal investigator joined on-going restoration project planning discussions by the Entiat Watershed Planning Unit and offered the capacity to expand existing monitoring work to some as project effectiveness monitoring at the subbasin scale.

John Day River Basin. No parallel organization to the Wenatchee RTT currently exists in the John Day River Basin so project initiation has focused primarily on generating on-the-ground support for the idea of an integrated status and effectiveness monitoring program, and staffing the coordinator position to keep the development effort moving forward. The NWFSC and the project principal investigator have developed a collaborative forum (Analytical Framework Group, or AFG) in 2004, as well as several large on-going monitoring data-collection efforts in the John Day River Basin to investigate the opportunities for program development. We currently support the development of smaller, spatially explicit groups in the basin because of the localized interest of most agencies. For example, work groups have been developed for the South Fork John Day (SFJD)(Oregon State University (OSU), Ochoco National Forest, Confederated Tribes of the Warm Springs and NOAA-Fisheries), and the Middle Fork (Confederated Tribes of the Warm Springs, Malheur National Forest, The Nature Conservancy (TNC) and Grant County Soil and Water Conservation District). The ISEMP is working with these groups to provide data, monitoring program design and advice, and infrastructure that may not currently be available to the small-scale efforts.

Salmon River Basin. In the Salmon River Basin, project initiation has focused on two major issues – which part of the geographically large and diverse basin should be included in the pilot work, and how to balance status and effectiveness components if they were not co-located. To date, progress on these issues has resulted from regular meetings and discussions with staff from Idaho Fish and Game (IDFG), USFS, Nez Perce (NPT) and Shoshone Bannock Tribes (S-BT) and Idaho Department of Environmental Quality. The major co-managers for these basins (NPT, IDFG, S-BT) agreed to the choice of Quantitative Consultants, Inc., as coordinator for this work. To date, Quantitative Consultants has outlined the potential design consideration for the Lemhi and South Fork Rivers, and began coordination in earnest in fiscal year 2006.

Design of subbasin-specific monitoring programs

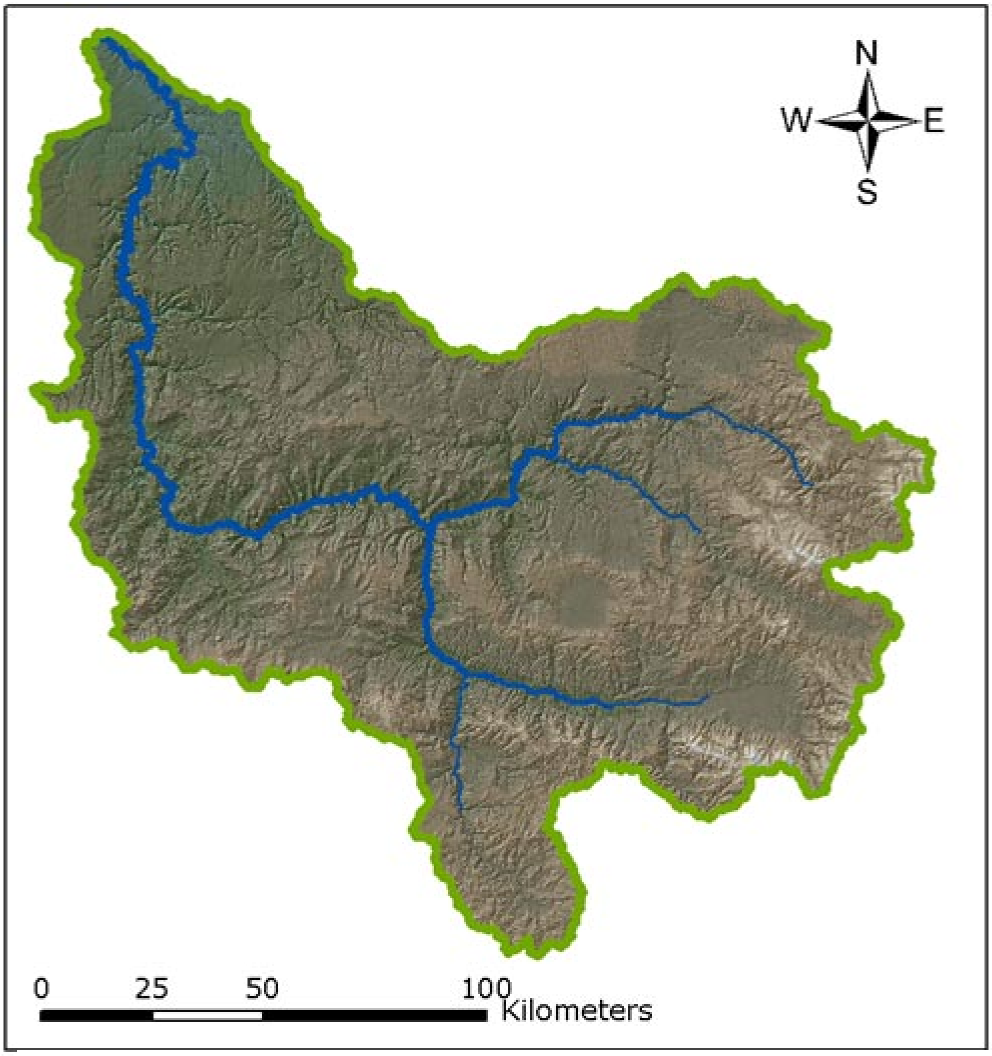
The overall goal of the ISEMP is to develop integrated status/trends and effectiveness monitoring programs, watershed scale effectiveness monitoring, and the rules that guide the design, implementation and evaluation of these programs. However, achieving such a large-scale integrated program will not follow a simple set of steps since the project will be so dependent upon the particular setting that each subbasin presents. In addition, coordinating the diversity of participants necessary to implement a project of this scale will naturally introduce a new set of constraints and variables due to each participating program's personalities.

Target subbasin monitoring programs have been developed along independent time and scope trajectories. For example, extensive coordination of field support by basin coordinators has been necessary in the Wenatchee basin, while in the John Day subbasin far more of the coordination effort has been focused on developing common objectives, plans, methods and approaches across the myriad current and historic monitoring data generators. As a result, each subbasin has presented unique opportunities and challenges with correspondingly differing levels and types of progress and products. These inherent differences in the level of ongoing monitoring activity, coordination and support forces this project to "pilot" a wide range of activities under the common goal of overseeing design of monitoring programs.

What's ahead

Coordinate sampling, data collection, analysis, and reporting	2007 - 2015
Administer project funds and subcontracts	2007 - 2015
Analyze project data to adaptively manage the project	2007 - 2015
Determine adequacy of sampling, metrics, indicators, and data management: annually update designs, models and management tools.	2007 - 2015
Update program design documents annually	2007 - 2015

CHAPTER 3: THE JOHN DAY SUBBASIN, OR



The 20,000 km^2 John Day subbasin crosses multiple jurisdictional boundaries and has more than 150 people from over 30 agencies and institutions connected with fisheries monitoring, restoration, or management in the basin. With six of the 12 threatened steelhead populations of the mid-Columbia ESU residing within the John Day, and a wealth of experience and knowledge to draw and build upon, the John Day subbasin was a natural choice for a RME pilot project and applying the ISEMP.

Funding Agency
Bonneville Power Administration

Contractors
Eco Logical Research, Inc.
National Oceanic and Atmospheric Administration-Northwest Fisheries Science Center
University of Washington
Watershed Sciences

Time Line

Coordination with the many agencies working in the John Day subbasin began in 2003 and has continued through 2006. IMW project design and implementation are underway, and data collection and analysis in projects that ISEMP is coordinating or collaborating on are ongoing.

Figure 1. A crew attempts to “snerd” (a combination of snorkeling and herding) fish into a net in the John Day subbasin, OR, as part of monitoring efforts under the ISEMP.

Budget

Contractor	Scope of Work	FY06 Budget
Eco Logical Research, Inc.	Develop an IMW and RME plan for the John Day subbasin; coordinate and promote sharing of information, data, and equipment; facilitate regularly scheduled meetings with the AFG and other interested parties; produce regular status reports and annual report; manage and administer projects.	$70,000
Eco Logical Research, Inc.	Develop a macroinvertebrate protocol.	$40,000
	Project total through fiscal year 2006:	$110,000

Links to Annual Reports

- Analytical Framework and Study Plan Outline
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2004afg.doc
- First Quarter of 2005 Progress Report on the John Day RME pilot project
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Eco Logical_bpa_1st_quarte2004_2005.doc
- Integrated Status and Effectiveness Monitoring John Day Pilot Program 2005 Draft Annual Report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/john_day_pilot_project11806.doc
- Proposal for the Bridge Creek Intensively Monitored Restoration Project
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/bridgeproposal010606.doc
- Proposal to study the effects of push-up dams on Redband/Steelhead Trout (Oncorhynchus mykiss) production in the mid-Columbia basin.
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/osu-rwo_push-up_dams2hiramsfjd.doc

What's been accomplished so far

Collaboration

The AFG, made up of approximately 30 people representing several agencies, was formed in 2003 to identify information needs and coordinate the development of research and monitoring projects. State, tribal, and local agencies represented in the AFG are implementing current status and trend fish and habitat monitoring programs. Activities include annual steelhead spawner surveys (ODFW), water quality (USFS, Bureau of Land Management (BLM), TNC, Oregon Department of Environmental Quality (ODEQ), OSU, Confederated Tribe of Warm Springs and Monument Soil and Water Conservation District), and stream habitat surveys (EMAP and EPA). Personnel from the USFS formed a Middle Fork John Day workgroup in 2005, and the AFG and the Habitat, Fish, and Geographic Information Systems (GIS) AFG subgroups continued to meet through 2006. Although there is not presently a large-scale forum in which monitoring personnel in the John Day subbasin can coordinate on-the-ground activities, the ISEMP is working to involve individuals that will ensure all active groups are represented in the planning and design of RME efforts, much like the AFG but with more local in participation. In addition to the AFG, the John Day ISEMP coordinators have met with approximately 100 local RME-related personnel, exposing them to the ISEMP's objectives, gathering existing project information and data, and assessing monitoring needs within the basin.

Identifying information gaps

Collaboration among agencies within the AFG and a review of the John Day Subbasin Plan (JDSP, 2005) identified information gaps within current monitoring actions. This led to the ISEMP and collaborators initiating or planning studies to gather information on population structure and distribution information for:

- Salmon and steelhead population structure and distribution (ODFW).
- Hatchery/wild fish interactions (ODFW).
- Juvenile movement patterns (OSU).
- Fish passage monitoring (OSU/ISEMP).
- Water quality monitoring (sampling proposed by ISEMP).
- Invertebrate monitoring (ISEMP).
- Predation and food web interactions (proposed by ISEMP).
- Understanding spatial and temporal variability of collected samples (ODFW, OSU, ISEMP).
- Compliance monitoring (proposed by ISEMP).
- Implementation monitoring and project inventory (ISEMP).
- Effectiveness monitoring (IMWs as proposed by ISEMP).

Indicators and metric development and testing

In order to establish causal relationships between ecological processes controlling fish production, and develop metrics and indices to capture these mechanisms, the ISEMP in the John Day subbasin is involved in several studies.

Macroinvertebrate indicators

The ISEMP, in collaboration with OSU's Department of Fisheries & Wildlife, NOAA-Fisheries and Eco Logical Research/Utah State University (USU), is currently evaluating macroinvertebrate indicators that could potentially predict fish growth when coupled with temperature metrics. Juvenile salmonids depend on aquatic and terrestrial macroinvertebrate drift as their primary food resource (Elliott 1973), and numerous studies suggest that macroinvertebrate abundance may explain variation in salmonid growth and survival in freshwater rearing environments (Cada et al. 1987; Filbert and Hawkins 1995; Nislow et al. 1998). While macroinvertebrate sampling is common among habitat monitoring programs throughout the Columbia River Basin, the metrics obtained from this sampling have been developed to describe water quality rather than food availability. The goal of the macroinvertebrate study in the John Day subbasin is to determine whether a metric of invertebrate food abundance could serve as a surrogate to secondary production, providing a means to estimate production potential of juvenile rearing habitat. Chapter 7 presents the results of macroinvertebrate indicator analyses carried out to date.

Relative bed stability as a metric for substrate quality

Elevated water temperature and excess deposition of fine sediments are thought to be major causes of biological impairment in the John Day subbasin, especially restricting the spatial and temporal patterns of key salmonid species. Many of the streams and rivers in the basin are listed as water quality limited for temperature and sediment on the State-Federal 303(d) list of impaired waters. The ISEMP is testing whether the metric "relative bed stability" provides information on substrate quality for salmonids, and whether this indicator accurately reflects different land use patterns. Working collaboratively with the OSU Department of Fisheries & Wildlife and the EPA, the ISEMP is evaluating the occurrence and potential impacts of excess fine sediments throughout the John Day subbasin using a combination of field sampling and GIS-based modeling tools. Work commenced in November 2004 and is being conducted at the U.S. EPA Western Ecology Division Laboratory in Corvallis, Oregon.

The project is building upon data collected between 2000 and 2003 as part of the U.S. EPA's EMAP–Western Pilot project that sampled 72 probabilistically selected sites on wadeable perennial streams, with an additional 21 sites sampled during the summer of 2005. The modeling component of the study has initially focused on surface (rill and interrill) soil erosion. It applies a set of GIS-based erosion and sediment delivery modeling tools in combination with analysis of remote sensing imagery to characterize land cover changes, with the aim of generating spatially explicit estimates of sediment delivery to streams associated with anthropogenic land cover change.

Field-Based Assessment. An index of relative bed stability, log *RBS*, and an index of excess fine sediments, I_{fs} was computed from the EMAP field sampling data. Large negative values of log *RBS* indicate frequent bed mobility that may be the result of excess fine sediments. Many other metrics of channel habitat condition, including channel morphology and complexity, were computed and examined as potential indicators of channel response to anthropogenic disturbance. Metrics of riparian vegetation structure and indices of anthropogenic riparian disturbance were also computed from the field data.

Preliminary results from the analysis of stream channel substrate in relation to watershed and riparian anthropogenic disturbance showed only weak associations between log *RBS* and other in-channel response metrics, with watershed disturbance based on land cover/land use information derived from the National Land Cover Database (NLCD), which in part motivated the sediment modeling and land cover characterization efforts. A stronger [negative] association was found between log *RBS* and riparian disturbance derived from the field survey data. A subsequent analysis using more detailed disturbance measures from a separate study on a subset of 27 sites in the John Day subbasin revealed a strong negative relationship between log *RBS* and the frequency of upstream road/stream crossings (number/km). The analysis also revealed that, as expected, geology is a key control on stream channel sensitivity to disturbance—streams underlain by relatively erodible sedimentary rocks or unconsolidated deposits appear to be much more likely to exhibit low *RBS* values or high levels of excess fine sediments than those underlain by resistant rock such as basalt.

Since the field data came from a probability sample, it is impossible to estimate the proportion of the stream channel network that has particular habitat characteristics; so cumulative distribution functions for selected metrics have been developed. However, the paucity of relatively undisturbed reference sites among those sampled in the basin makes determination of excess fine sediments (e.g., cut-off values for 'impaired' vs. 'unimpaired' values of log *RBS*) difficult. To address this issue, a re-analysis using an expanded set of reference sites from the surrounding region is currently underway in the John Day subbasin.

As part of this study, an additional 21 hand picked sites were sampled in the John Day subbasin in 2005. These included nine sites (plus three previously sampled EMAP sites) sampled as part of a multi-agency protocol comparison study sponsored by the PNAMP, four additional sites in the Bridge Creek watershed (to get an increased sample of incised channels), and eight additional sites in the SFJD watershed. The SFJD sites were located up- and downstream from a series of landslides and debris flows that entered the SFJD River during an intense July 2004 thunderstorm. This allowed assessment of the channel response to this pulse input of sediments one year after the storm.

The ISEMP is also collaborating with the OSU Department of Fisheries & Wildlife and the EPA to build an erosion and sediment delivery model for the John Day subbasin. Work began in November 2004. Among many challenges met, researchers updated and modified the NLCD land cover for the John Day subbasin to accurately reflect current land cover, developed a "disturbance index" for cover types from mature forest to bare soil, and developed a topographic filter to correct the misclassification of certain types of land cover. Roads, which can have a significant impact on potential surface erosion, were also incorporated into the NLCD land cover.

Current efforts are focusing on:

(1) Finalizing and testing the sediment delivery model code;
(2) Coming up with defensible parameter values for the modified NLCD land cover classes, and
(3) Developing a "potential" (i.e., "undisturbed") land cover layer based on existing land cover, topographic characteristics, and "potential natural vegetation" derived from level 4 ecoregion information.

Once model development and testing is complete, the model will be run using both existing and potential land cover to estimate the spatially distributed changes in sediment erosion and delivery to stream channels associated with anthropogenic land cover changes. These changes in sediment erosion and delivery will then be related to log *RBS* and other field-based indicators of channel habitat condition that might be expected to respond to changes in sediment supply. The results of this analysis will then be combined with a GIS-based analysis of topographic controls (e.g., slope and valley floor width) and geologic controls (e.g., resistant vs. erodible rocks) to develop a map of stream channels at greatest risk of adverse impacts from excess fine sediments.

Subsequent efforts will assess the spatial distribution and relative contribution of mass wasting processes (primarily shallow landslides and debris flows) to the sediment budget of streams in the John Day subbasin. It is expected that sediment assessments will be completed in 2007. Other examples of indicator and variable testing underway in the John Day subbasin include temperature as an index of salmonid carrying capacity (OSU), and stable isotopes as an indicator to describe food web structure (ISEMP).

Protocol development, refinement, and testing

The ISEMP is working towards standardization of protocols or the creation of crosswalks between protocols to allow for assessments that cross program boundaries in the John Day subbasin (Table 1). Many of these studies have just been completed or are still in progress. The ISEMP will analyze this information and provide recommendations to monitoring programs based on results. In addition, several of these studies will be repeated to see if these sources of variability are similar between years (e.g. calibration of fish and macroinvertebrate sampling techniques).

Table 1. Protocols currently being tested in the John Day subbasin coordinated through the ISEMP project.

Evaluation	Protocol	Location	Description
Satellite remote sensing	LandSAT 5 IKONOS	Upper Salmon Basin	Compare less expensive, greater temporal coverage of LandSAT 5 (30 m pixel) scenes to higher resolution Ikonos (1-4 m pixel) scenes for information content.
Comparison of habitat survey protocols	Protocols practiced by 10 different agencies, LiDAR, Intensive engineering survey.	John Day subbasin	Compare variability across 3 crews for each of 10 protocols across 12 sites in the John Day drainage stratified by geomorphic reach types; 1) step-pool, 2) pool-riffle, and 3) plane bed. Estimates of multiple habitat metrics were compared to LiDAR and an intensive engineering survey conducted to establish 'truth.'
Precision and accuracy of juvenile salmonid sampling protocols	Snorkel counts, Snorkel-herding, Electro-herding.	South Fork John Day River	Block nets placed at top and bottom of reach. Snorkel counts were first conducted, then a diver was used to herd the fish into a bag seine ("snorkel-herding"). Several passes are made until no more trout are captured. Captured fish were tagged and released. Reach was resampled by chasing fish into bag seines with an electroshocker at low settings ("electro-herding"). Population size (and 0.95 CI) was estimated using a Peterson Estimate from recaptured fish.
Stress to juvenile salmonid related to sampling protocols	Electroshocking, Snorkel counts, Snorkel-herding, Electro-herding.	South Fork John Day River	Compare sampling protocol (description in cell above) impacts to fish as measured by burn marks, broken backs, recovery time (postural orientation), the ability of fish to hold in current, heat shock protein induction, and the percent of captured fish that became moribund.
Bias of snorkel	Snorkel survey.	South Fork	Video camera was used to observe

surveys		John Day River	juvenile fish behavior for 0.5 hrs before diver entered the water. Response to diver was recorded with camera.
Juvenile salmonid lipid content evaluation	Distell Fat Meter, Soxhlet fat, extraction.	South Fork John Day River	The Distell Fat meter can measure lipid content of live fish in the field. The meter was compared to the accurate Soxhlet Fat extraction method.
Juvenile salmonid temperature induction of heat shock proteins	ELISA assay Western Blot technique	South Fork John Day River/ Oregon State University	Heat shock proteins can be used to detect thermal stress in fish. Temperature induction of heat shock protein 70 was evaluated in the laboratory for redband trout (O. mykiss) using the standard ELISA (Enzyme Linked Immunosorbent Assay) assay (lethal) and the Western Blot technique (nonlethal).

- In an effort to describe the precision and accuracy of the best protocols for collecting habitat information, several of the most widely used stream survey protocols within the Columbia River Basin were used to survey a common set of 12 sites in 2005. Led by the USFS PIBO program, in collaboration with the PNAMP and the John Day ISEMP, at least three crews from each program collected habitat and physical information at each site to ensure sufficient data to evaluate crew variability. To establish a benchmark or "truth", a more precise and accurate total station survey was conducted. Estimates of physical stream metrics were also made using LiDAR remote sensing, a promising technology for high resolution mapping of topography and vegetation at vertical accuracies of less than 15 cm. LiDAR sends a continuous series of laser pulses across the track of the survey aircraft and measures the travel distance and amplitude of the reflected signal. The instrument has a high pulse frequency (50-100 KHz) resulting in a high density of returns from the ground and effective penetration of vegetation. The data are processed to produce detailed topographic maps that include bare-earth and vegetation features. A high-resolution true color digital camera is integrated with the LiDAR system and together these sensors allow precise characterization of channel morphology and riparian vegetation height and structure. However, LiDAR has not been evaluated against ground surveys, and thus the ability of this tool to measure these habitat metrics is unclear.

- The ISEMP is also comparing remote sensing data derived from the LANDSAT 5 Thematic Mapper sensor against data from the IKONOS high-resolution multispectral imager. While IKONOS information has higher resolution its temporal coverage is limited, and it is much more expensive than LANDSAT 5 images. The objective of this analysis is to determine what information is lost by using coarser resolution, yet less expensive, LANDSAT 5 data, and whether the coarser resolution is adequate to describe changes in landscape and landuse pattern evaluations used in the pilot projects.

Temperature modeling

As part of its protocol development, the ISEMP has been collaborating with Watershed Sciences in the collection and analysis of airborne Thermal Infrared Imagery (TIR). Airborne

TIR surveys provide a complete picture of current thermal conditions including sources of heating, temperature accumulation, cold-water refuges, and spatially explicit thermal gradients. The imagery and derived data allow analysis of how morphology, vegetation, and human activities influence in-stream temperatures along the stream gradient. Airborne TIR images were collected on both the upper Middle Fork and SFJD Rivers in August 2003. A GIS database was produced for both basins that included geo-referenced high-resolution TIR images and color video images, longitudinal temperature profiles, and a report illustrating and analyzing temperature patterns (i.e. tributary influences, source heating areas, and thermal refuges). On the upper Middle Fork, the data allowed a comparison of current conditions to temperature patterns measured in the mid-90s that illustrated how changes in watershed management (stream fencing, water buy backs and allocations, etc.) may have influenced spatial temperature patterns and local habitat quality over the past 8 years. On the SFJD, the data provide a map of current thermal conditions and have been utilized by the Juvenile Salmon and Steelhead Production Group for on-ground site selections with respect to thermal habitat.

In August 2004, airborne TIR images were collected on the SFJD (including the mainstem, Murderer's Creek, and Black Canyon Creek), upper North Fork, and mainstem John Day Rivers (from the headwaters to the mouth). This imagery allowed comparison of spatial temperature patterns under two very different temperature and flow regimes (2003, 2004). These data provide a valuable calibration source for ODEQ's Heat Source Model, which will be utilized in the basin-wide temperature TMDL effort. The TIR image acquisition in the upper North Fork extended previous acquisitions to include the upper North Fork John Day River, Granite Creek, and Trail Creek. Results from a preliminary analysis are presented in Chapter 7.

Habitat monitoring

The ISEMP contracted with Watershed Sciences to collect and process LiDAR data taken on the SFJD River in March 2005. The data acquisition covered an approximately 500-m wide corridor along the South Fork (~24 miles), Murderer's Creek (~13 miles), and Black Canyon Creek (~4 miles). The acquisition area covered roughly the same extent as ground crews analyzing fish populations and movement in the South Fork subbasin. The raw data were processed to produce a 1-m digital elevation model, and a "1st return" vegetation model. Data products were completed in July 2005 and delivered to the U.S. Bureau of Reclamation (USBR), OSU, and ODEQ. High-resolution true color digital photos are being ortho-rectified.

On-going analysis of the South Fork dataset includes:

1) Mapping of historic wetlands based on channel complexity/paleo-channels;
2) Calculation of channel morphology characteristics including stream gradient, valley segment width, and bankfull width;
3) Calculation of aspect and slope of near channel uplands (i.e. 300 m from stream centerline);
4) Mapping of habitat types, and
5) Integrating the TIR imagery with the LiDAR data to understand links between observed thermal response and landscape and channel characteristics.

In September 2005, LiDAR data were collected on lower Bridge Creek (from the mouth upstream to the town of Mitchell) to provide detailed channel morphology data to support the study of bank incision and sediment transport that will be studied in an IMW, and on 12 experimental monitoring sites distributed across the John Day subbasin. The LiDAR data and associated digital photography will provide a baseline engineering dataset for planning and tracking stream restoration efforts and an assessment of on-the-ground physical habitat monitoring on the 12 experimental sites. The raw LiDAR data are currently being processed to produce standard data products (i.e. 1-m digital elevation model (DEM) and vegetation model) with completion scheduled for December 2006. Future analysis will focus on generating stream channel metrics, including valley segment widths, bankfull widths, wetted widths, stream gradient, and riparian height and structure. Chapter 7 presents a more detailed discussion of the results to date.

Sampling design development and testing

The ISEMP has developed a watershed classification system that identifies groups of watersheds based on similar characteristics (e.g. precipitation, geology type, air temperature, elevation, etc.). Spatially continuous GIS data is classified into discrete classes using MCLUST software. This regionally continuous classification of watersheds will be used to determine if the selected IMWs adequately represent the landscape diversity. In addition, this classification scheme may provide a way to stratify monitoring sites for analyses, and a means to extrapolate the results beyond the boundaries of the study. These reaches can then be used to make comparison across habitat types.

Effectiveness monitoring design and implementation

Restoration actions have been implemented in the John Day on an opportunistic basis, pending funding, land jurisdiction, presumed needs, and personnel. Restoration is often applied to degraded habitat under the assumption that it will have a benefit to fish. However, this assumption is often not based on a limiting factors analysis and is rarely followed up with monitoring to evaluate restoration effectiveness. Many people working on RME projects in the John Day agree that effectiveness monitoring is sorely lacking. The ISEMP is developing IMW studies to design and test the impacts of restoration as outlined in the Tributary Federal RME program. In addition to testing restoration effectiveness, the comprehensive approach of IMWs will also address the above steps and therefore inform whether this plan to develop a basin-wide RME program needs modifications. The AFG identified a set of potential IMWs in 2005, including Bridge Creek and the SFJD River.

Bridge Creek IMW

Bridge Creek, which drains directly into the lower John Day River, was identified as a priority watershed for restoration because its salmonid production and abundance potential is high (JDSP 2005). The plan also identifies habitat quantity, temperature, sediment load, habitat diversity and flow as limiting factors in Bridge Creek (JDSP 2005). Channel incision results in the lowering of floodplain water tables, the loss of off-channel habitat and riparian forest and a general simplification of stream habitat (Figures 2 and 3)(Elmore et al. 1994).

The ISEMP has proposed a large-scale restoration project to reverse the problems of channel incision in Bridge Creek and has been working cooperatively with OSU since 2005 to conduct fish monitoring. This includes monitoring in potential control and treatment reaches within Bridge Creek, and in potential control reaches within the sub-watersheds of Bridge, Bear and Gable Creeks. In addition, the ISEMP plans to use tributaries to the SFJD River (Murderers, Black Canyon, and Deer Creeks) as control watersheds. The USBR-funded research, implemented by OSU, will also fill the monitoring needs for the Bridge Creek IMW study. Sampling occurred in these areas in the winter of 2005-2006 and the summer of 2006.

Figure 2. A typical incised reach of Bridge Creek at high flow during spring runoff. Incision depth in this reach is 1.5-2 m and the suspended sediment load is high.

Figure 3. An aggraded reach upstream of a 1.5 m high beaver dam on Bridge Creek, Oregon. The pond has almost completely backfilled with sediment and willows, cattails and other riparian vegetation have colonized the new surface. Willows have recently replaced sagebrush on the adjacent terrace where water tables have risen to within 0.5 m of the surface. The dam is just beyond the patch of open water in the upper left of photograph.

Winter Fish Monitoring. All pond and control sites were sampled in a 1-week period during early December 2005 when *O. mykiss* were dipnetted or seined during night snorkels. Captured fish were anesthetized, examined for a caudal mark, and if no mark was present, given a small caudal clip to denote day of capture. Each site was sampled on three consecutive nights, with fish being marked on each of the first two nights. Monitoring of *O. mykiss* movement in nearby drainages with PIT tags and detection antennas suggested that little movement occurred during the sampling period. Abundance estimates for each site were generated (Figure 4).

Summer Fish Monitoring. OSU and NOAA personnel began PIT tagging juvenile steelhead in the Bridge Creek basin during mid-June 2006 (Table 2). Tagging sites were distributed throughout the basin in locations of current and historic beaver pond complexes. Sites were chosen both to maintain data collection at sites sampled during 2005, and also to acquire pre-project data in new treatment and control sites. Tagging was split between potential treatment and control sites.

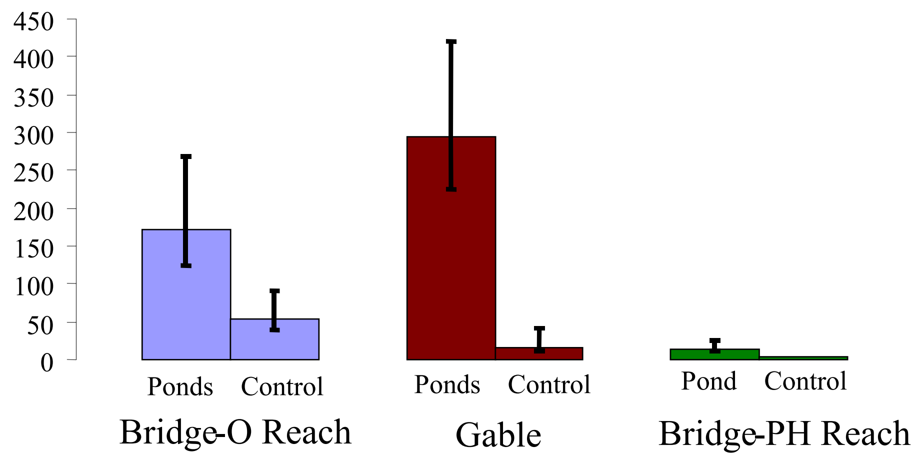


Figure 4. Estimated number of juvenile steelhead observed in beaver ponds and control (non-impounded reaches) in the winter of 2005 in Bridge and Gable Creeks, John Day subbasin, Oregon.

Table 2. Location and numbers of juvenile steelhead PIT tagged in the Bridge Creek IMW in the John Day subbasin, Oregon, during mid-June 2006.

Location	Number tagged
Gable Creek (near to/downstream of beaver ponds)	62
Upper Bridge Creek (near Mitchell)	95
Bear Creek (in-basin control)	89

Concurrent with PIT tagging, mark-recapture population estimates were generated at each of these sites to provide baseline "pre-project" density estimates of juvenile steelhead. These locations will be re-sampled twice a year to estimate seasonal survival and growth rates of individually marked fish in each reach. All unmarked juvenile steelhead will be PIT tagged during these subsequent sampling events.

During late June 2006, juvenile steelheads were PIT tagged at "sentinel" sites in the nearby SFJD basin. Sentinel sites consist of three stratified, randomly selected stream reaches in Black Canyon Creek, three reaches in Murderers Creek, and one reach in Deer Creek, which are all tributaries of the South Fork. This is the third consecutive year of tagging in these locations. These sites, especially those in Murderers Creek, will be used both as "references" and as external controls for trends observed pre- and post-manipulation in Bridge Creek. Initial observations for 2006 found lower densities of juvenile steelhead in Murderers Creek than during the previous 2 years of sampling.

High discharge precluded effective sampling in lower Bridge Creek (downstream of the confluence with Bear Creek) during June 2006 so this area was sampled again in early July when five juvenile steelhead and 16 smallmouth bass were PIT tagged. A temporary PIT tag detection antenna was installed upstream of the tagging location, near the mouth of Bear Creek. All of the juvenile steelhead tagged in lower Bridge Creek were detected at the antenna. Upstream movement of these juvenile steelhead occurred between July 22 and August 7, coincident with the typical period of peak annual stream temperature. Smallmouth bass were also observed to migrate upstream, but at lower rates than juvenile steelhead. This PIT tag detection site will be maintained through the fall to determine timing and magnitude of downstream migration by juvenile steelhead in Bridge and Bear creeks.

The South Fork of the John Day River IMW Study

The ISEMP is working collaboratively with the USBR (the funding agency) and OSU (contracted to conduct the majority of the research) to develop the SFJD as an IMW study. The goal of this study is to examine the influence of push-up dams on the production of redband steelhead trout and to evaluate whether or not Lay Flat Stanchion Dams will alleviate the putative problems caused by push-up dams. The OSU conducted extensive habitat and fish surveys in 2004-2006 in the SFJD and its tributaries that are accessible by redband steelhead trout to form the baseline or pre-treatment information for this study. All push-up dams on the lower SFJD have now been replaced and OSU is evaluating whether this has had an impact on life-history strategies, movement, and habitat use.

Identification of causal mechanisms and limiting factors

The ISEMP is working with the John Day subbasin planning participants that have implemented the EDT model to assess limiting factors and prioritize restoration efforts. Results from the EDT model have been summarized for each watershed in 2005 (Table 3 and Table 4). Some shortcomings of the application of this general model to the John Day have been identified, and recommendations to produce more basin-specific models have been made (JDSP 2005).

Table 3. Qualitative list of priority HUCs and habitat attributes affecting Chinook populations in the John Day River, OR (based on EDT runs submitted on 11/02/04).

POPULATION	PRIORITY 5th HUCs	SIGNIFICANT HABITAT ATTRIBUTES		
		PRIMARY	SECONDARY	TERTIARY
Granite Creek	Granite Cr.	diversity	sediment quantity	stability flow

	NF JDR Big Cr.	quantity	diversity temperature	
	NF JDR Potamus Cr.	diversity quantity	temperature	
Middle Fork	Camp Cr.	temperature quantity	diversity sediment	stability flow
	Big Cr.	diversity temperature quantity	Stability food flow sediment	
	Upper MF JDR	diversity sediment quantity	Stability flow temperature	
North Fork	NF Big Cr.	diversity temperature quantity	Stability flow	
	NF JDR Potamus Cr.	diversity temperature quantity	Stability food flow sediment	
	Upper NF JDR	quantity	diversity temperature sediment	
Upper John Day	Canyon Cr.	diversity	Quantity	stability flow temperature
	Strawberry Cr.	quantity	diversity temperature	stability flow

Table 4. Qualitative list of priority HUCs and habitat attributes affecting steelhead populations in the John Day River, OR (based on EDT runs submitted on 11/02/04).

POPULATION	PRIORITY 5th HUCs	SIGNIFICANT HABITAT ATTRIBUTES		
		PRIMARY	SECONDARY	TERTIARY
	Laycock Cr.	quantity	Diversity	stability diversity flow sediment temperature
Lower John Day	Rock Cr.	obstructions sediment quantity	Stability diversity flow sediment	
	Mountain Cr.	stability diversity temperature	Flow pathogens	

		sediment quantity		
	Bridge Cr.	obstructions sediment quantity	Diversity temperature	stability flow
North Fork	NF JDR Big Cr.	temperature quantity	Stability diversity	
	NF JDA Potamus Cr.	diversity temperature quantity	Flow sediment	
	Cottonwood Cr.	sediment temperature quantity	Flow diversity	
	Desolation Cr.	sediment quantity		
	Upper Camas Cr.	sediment quantity	Stability flow temperature	
Middle Fork	Camp Cr.	sediment quantity	Stability flow temperature	
	Big Cr.	diversity temperature quantity	Stability food flow sediment	
	Long Cr.	quantity	Flow diversity sediment temperature	
South Fork	Lower SF JDR	sediment temperature quantity	Flow diversity	
	Murderers Cr.	sediment quantity	Flow diversity temperature	
	JDR Johnson Cr.	quantity	Diversity predation sediment temperature	

	Lower JDR Muddy Cr.	diversity quantity	predation temperature
Upper John Day	Canyon Cr.	quantity	Stability flow diversity sediment temperature
	Strawberry Cr.	stability diversity temperature sediment	Stability flow
	Beech Cr.	obstructions sediment	Flow diversity quantity temperature

- The ISEMP is coordinating with the Pendleton, Oregon office of the ODEQ, which has been conducting water quality monitoring in the John Day subbasin since 2002 to establish Clean Water Act target water quality standards (TMDL of pollutants). As part of their collaboration, the ODEQ will use TIR and LiDAR information, and the ISEMP will use the TMDL products to look at limiting factors in the John Day subbasin, such as water temperature. One of the ISEMP's main objectives for the TMDL in the John Day is to quantify the conditions leading to high water temperatures and build a calibrated model that will compute temperature temporally and spatially. Other ISEMP studies in the John Day will develop relationships between reach temperature distributions and salmon and steelhead productivity so that the TMDL can be used to evaluate how alternative habitat restoration efforts may affect stream temperatures and ultimately fish productivity.

- The ISEMP is prioritizing when different areas are modeled to match with research that it is relying on, such as the OSU juvenile salmon and steelhead production project. Data collection and organization for the TMDL analysis is nearly complete and analysis began in the spring of 2006. Where feasible, the TMDL-specific data collection was designed to fill-in where other organizations were not monitoring (geographic area or monitoring parameter). The geographic boundary for this effort is the John Day subbasin, and the focus has been on the John Day River and the South, North and Middle Forks, and the temperature and flow at the mouths of major tributaries to these rivers. Sediment assessments and TMDL efforts should be completed in 2007 to provide addition information on limiting factors in the John Day subbasin.

Growth potential models

The ISEMP is developing a model to map potential fish growth across stream reaches of the John Day. By combining models that estimate heat budgets based on physical inputs, bioenergetics models that use these heat budgets, and invertebrate abundance information, the ISEMP will build a model to estimate fish growth.

The Heat Source model (Boyd and Kasper 2002) used in the John Day TMDL process uses physical processes to define a heat budget for a reach. These physical processes (e.g. the rate that solar inputs heat water) are somewhat more predictable than biological interactions. Watershed Sciences is developing algorithms to process LiDAR information that can be used as direct inputs into the Heat Source model. As is done in the TMDL process, impacts of different scenarios, such as the increase of the riparian canopy through a riparian fencing project or increased discharge by purchasing instream water rights, on stream temperature can be estimated with the Heat Source model.

The rate at which respiration and the maximum consumption rate changes as a function of temperature and body size has been determined for several fish species (Hanson et al. 1997). Growth and temperature can be measured in the field, and the bioenergetics model estimates the consumption required to maintain metabolism and obtain the observed growth rates. The ecological relationships determining the amount of food consumed and thus how to predict growth is less well understood. The invertebrate information (drift and/or benthic samples) collected in the SFJD could be used to develop a relationship between prey density and temperature-dependent consumption rates. Relationships between prey density and percent maximum consumption (as estimated by the bioenergetics model) have been observed with other fishes with some success, and could be used to estimate growth potential of different stream reaches that have temperature information and invertebrate abundance estimates. Incorporated with the Heat Source model, which describes temperature regimes under restored and current conditions, these models could identify where temperature and invertebrate production limits fish production and restoration activities addressing these factors could then be prescribed for these reaches. The results of an initial analysis are presented in Chapter 7.

Alternative mark-recapture models for the evaluation of PIT-tag information collected from passive instream antennae.

Over the past 25 years, biologists have used PIT tags and mark-recapture methods extensively in fisheries research at the major hydropower facilities on the Columbia and Snake Rivers. More recently, there have been substantial increases in the use of PIT tags in small river systems as a result of recent advances and applications in PIT tag technology. In particular, PIT tag detection arrays are being installed in many tributary systems that allow for individual detection of fish marked with PIT tags as they migrate through a detection array within a river channel.

Individual-specific PIT tags, PIT tag detection arrays, and spatially explicit mark-recapture data can provide estimates of key demographic parameters across a range of size-classes and life-history forms. In particular, individual growth information, which can act as a surrogate for fitness and is critical for life-stage population models, can be quantified through marking and recapture events. The combination of marking events and PIT tag detection arrays, which can be viewed as recaptures, can provide information regarding the timing and plasticity of movement within and across temporal and spatial scales, and emigration rates, which are critical for estimates of true survival verses apparent survival. Tagging and movement data can also provide insight into the proportion of the population that exhibits resident or migratory life-history expressions. Finally, mark-recapture data can provide estimates of survival across relevant life-stages and life-history forms, which is necessary for understanding the dynamics of populations. This information can ultimately elucidate effective restoration and recovery strategies (e.g., Al-Chokhachy 2006), and be used to evaluate the effects of different land-use actions (i.e., restoration activities) on population-level factors such as migration, survival, etc. in tributary systems.

Despite the widespread use of PIT tags and PIT tag detection arrays in small streams, there have been few efforts to formally evaluate the appropriate design and analytical methods to answer relevant management and biological questions. While mark-recapture data for obligate anadromous species (i.e., Chinook) through the Columbia and Snake systems has been widely collected, differences in the behavior and life history strategies of inland salmonids may predicate the need for additional research. Furthermore, there are multiple models, each with strengths and weaknesses that can be used to estimate survival using mark-recapture data collected with PIT tag detection arrays. The choice of the appropriate model may largely be driven by the data collection methods and the life-history strategies of the populations of interest. For example, many salmonid populations (i.e., rainbow trout/steelhead) exhibit indeterminate life-history strategies (e.g., Thériault and Dodson 2003; Homel 2006) where individuals within a panmictic population may exhibit resident, fluvial, or anadromous life-history patterns. When analyzing mark-recapture data, a difficult step may be identifying the appropriate temporal scale for inference where data collection (recaptures through PIT tag detection arrays) is continuous as a result of the plasticity in life-history expression.

The ISEMP is collaborating on a mark-recapture project in the SFJD River that illustrates the data challenges and opportunities that exist in projects utilizing individual-specific mark-recapture data (i.e., PIT tags) and PIT tag detection arrays for survival analyses. Chapter 7 provides a discussion of the study system, potential research objectives, mark-recapture dataset, the challenges within different mark-recapture models to evaluate survival, and the utility of field data and simulations to design and improve future mark-recapture projects that utilize individual-specific tags and PIT tag detection arrays.

Key analysis planned

Exploring Landscape Scale Influences on In-Stream Water Temperature

- Under the ISEMP, an existing time series of in-stream water temperature data will be evaluated against the newly derived metrics of landscape complexity to assess how landscape scale factors relate to measured in-stream variables. Analysis will be carried out in conjunction with NOAA-Fisheries.

Predation and food web interactions

- Several species of native and non-native fish species live in the John Day system and very little is known about how these species interact with anadromous fish. Some of these are warm water species that are potential predators on juvenile salmonids, such as smallmouth bass, catfish, and pikeminnow, especially in the migration corridor through which all anadromous species must pass. Others, such as dace, shiners, and young pikeminnows, might compete with juveniles for food resources. If so, parr density alone may not be the most relevant response variable if inter- and intra-specific competition are equally important. Many warm water species appear to be expanding their range, which may further complicate the success of some restoration actions. Conversely, restoration actions that decrease temperature may decrease warm water species use of certain habitats and may provide an added benefit to these types of actions. Monitoring programs need to address these interactions. The ISEMP proposes collecting diets and tissue or blood (non-lethal) stable isotopes samples for all fish species and macroinvertebrates as a potential monitoring tool to describe general food web patterns. Stable isotopes can describe general prey types consumed over a period of months. Collection of these samples during times of outmigration through the lower mainstem, or at times of high thermal stress near the interface of species overlap may elucidate these food web patterns.

Estimating metrics

- The ISEMP plans to evaluate the level of effort or resolution required to estimate a metric. For example, in the South Fork IMW approximate 8,000 juvenile *O. mykiss* have been PIT tagged. These tagged fish must migrate past the rotary screw trap (set daily) and a set of PIT tag detection antennas just upstream from the trap. If the ratio of tagged to untagged fish remain relatively constant (an assumption of mark-recapture methods), then analysis of this paired information may suggest that continuous reading of the antennas can be used to estimate production of the subbasin, with much less effort spent collecting outmigrants in the screw trap. The ISEMP will also test this assumption in the Bridge Creek IMW. Further review of screw trap data may also suggest that daily operation is not required, even in the absence of antennas.

Standardize data

- Based on the results of the testing of protocols and information from current monitoring efforts, we will assess the level of effort (i.e. number of sample sizes) sufficient to detect defined differences. Status and trend monitoring information has been collected by ODFW for 2 years and therefore the ability to address inter-annual variability and its implication on sample designs is limited. We will use studies identifying causal relationships and limiting factors to help describe where monitoring efforts need to be focused. We will also conduct analyzes like the reach classification approach to develop effectiveness monitoring designs. We will continue to refine sample designs over the life of this project as new information becomes available.
- A hierarchical synthesis of relationships between environmental factors and/or how these environmental factors govern fish populations to estimate limiting factors across several scales of studies will require completion of a number of projects and thus will not be available in the near term. Therefore, other models that focus on a reduced set of potentially limiting factors (as judged by researchers in the John Day) might be constructed for short term use. For example, stream temperature patterns are a consequence of the interaction of important physical and ecological processes acting within the landscape (Ward 1985). The Heat Source model used in the TMDL process describes many of these physical processes to define a heat budget for a reach. Watershed Sciences is developing algorithms to process LiDAR information that can be used as direct inputs into the Heat Source model. As is done in the TMDL process, impacts of different scenarios, such as the increase of the riparian canopy through a riparian fencing project or increased discharge by purchasing instream water rights, on stream temperature can be estimated with the Heat Source model.

IMW Restoration Project in Bridge Creek

- The ISEMP is proposing a pilot restoration project along approximately 4 km of Bridge Creek, sufficient to cause a population-level impact to the steelhead utilizing the system. The Bridge Creek subbasin is a 710 km^2 watershed draining directly into the lower John Day River. Bridge Creek and its tributaries are utilized by a run of Middle Columbia steelhead that are part of the ecologically distinct Lower John Day population, which occupies the lower, drier Columbia Plateau ecoregion within the John Day subbasin, and are listed under the ESA. The JDSP (2005) has designated Bridge Creek as a priority watershed for restoration because its salmonid production and abundance potential is high. The JDSP also identifies habitat quantity, temperature, sediment load, habitat diversity and flow as limiting factors in Bridge Creek. Analysis of the John Day and other subbasins in the interior Columbia River Basin suggest that incision is a widespread phenomenon affecting as much as half of all the fish bearing streams in a watershed. The mainstem incision depth in Bridge Creek typically ranges from 1-3 m, sufficient to disconnect the stream from the former floodplain. This has resulted in the lowering of floodplain water tables, the loss of off-channel habitat and riparian forest and a general simplification of stream habitat. The ISEMP will monitor restoration project results, treating Bridge Creek as an IMW/restoration site. Monitoring will be designed to gather responses to the manipulation as well as covariates unaffected by the manipulation. The results will be analyzed and used to inform whether the restoration action was beneficial to the population while revealing important causal mechanisms.

Identification of causal mechanisms and limiting factors

- The John Day ISEMP has initiated or collaborated on several studies that are evaluating relationships between environmental factors and/or how these environmental factors govern fish populations across multiple scales. These projects have the potential to be synthesized in a hierarchical fashion to estimate limiting factors across several scales. We propose to use structural equation modeling and hierarchal models to synthesize this information across several scales and produce a limiting factor analysis using this set of integrated relationships to describe data collected through basin-wide monitoring.

Study site locations in the John Day subbasin

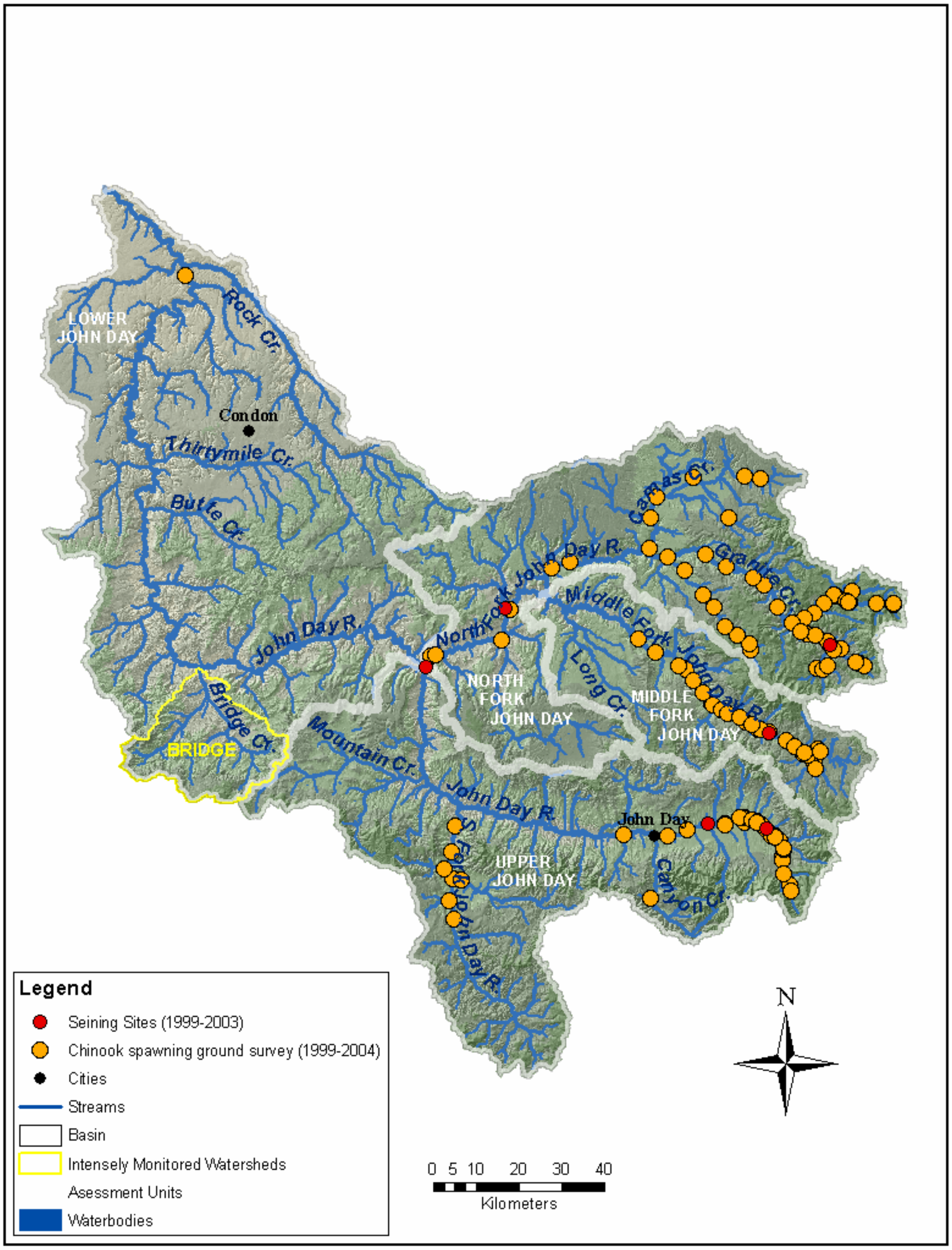


Figure 5. Locations of the fish sampling projects that are underway in the John Day subbasin, OR, with which the ISEMP is participating.

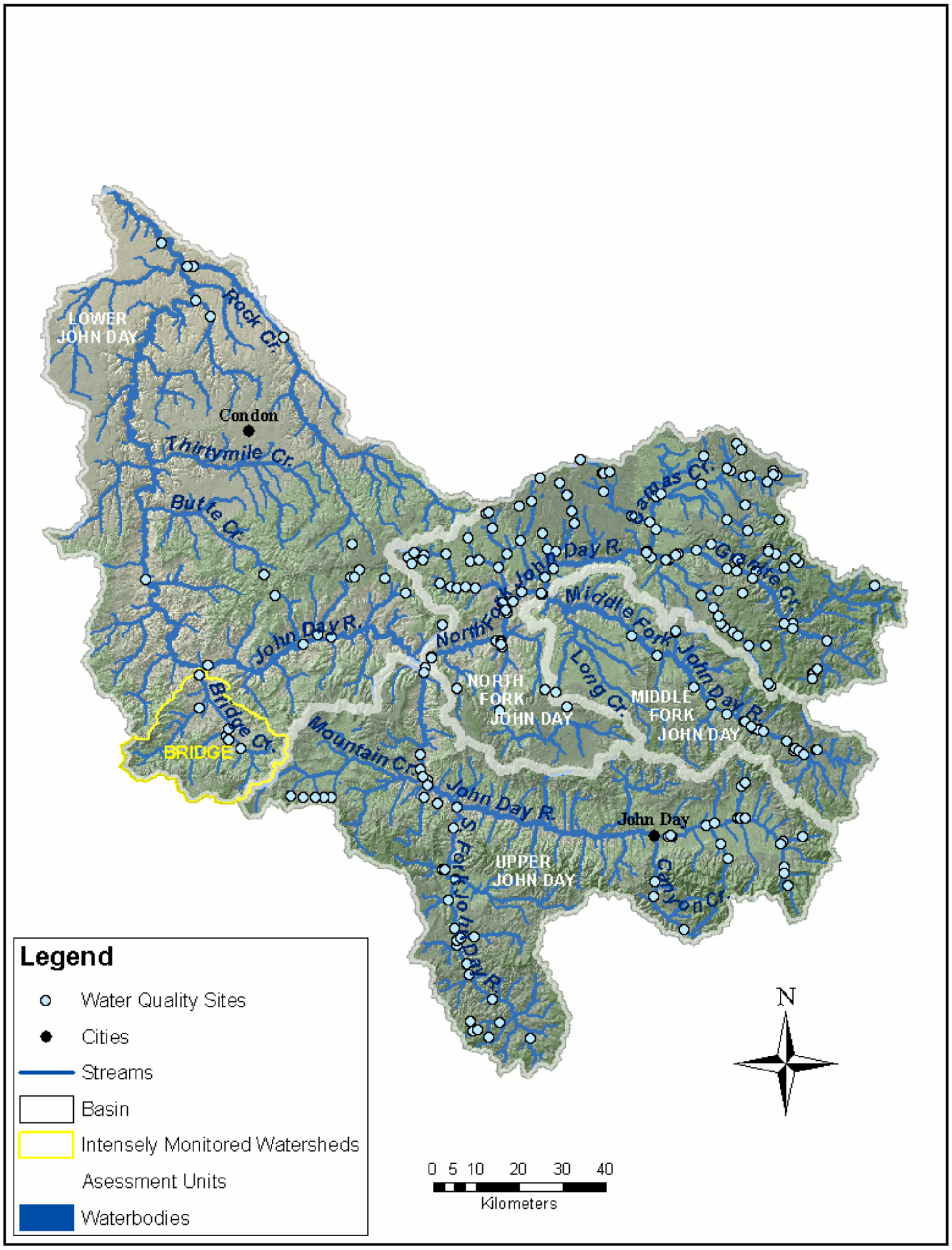


Figure 6. Water quality testing sites that are underway in the John Day subbasin, OR, in which the ISEMP is participating.

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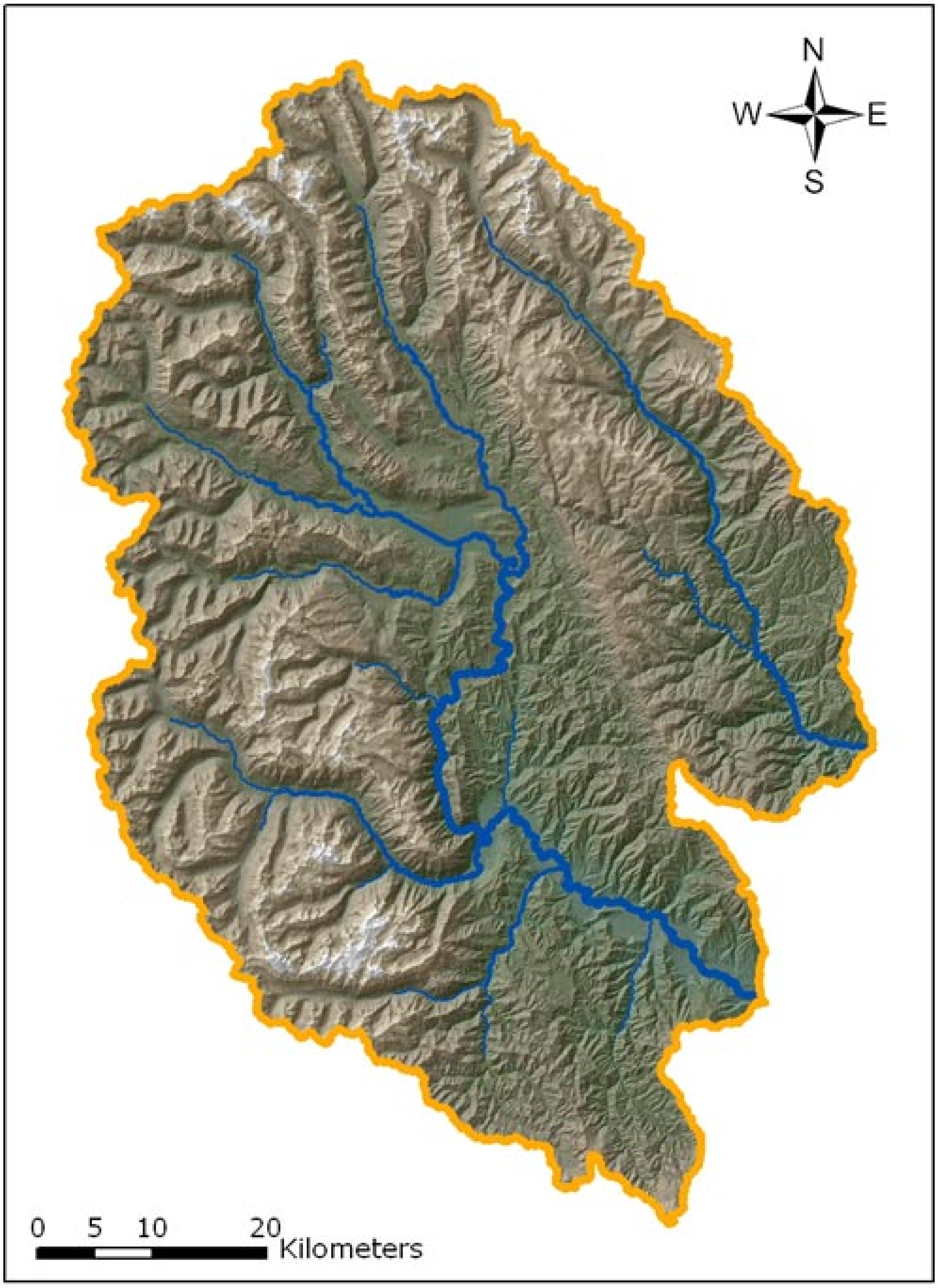
What's ahead

Continue to engage and broaden collaboration with personnel from federal, state and other local agencies, and form workgroups in the North Fork, South Fork and Upper John Day subbasins.	2007 - 2015
Organize an annual monitoring meeting to coordinate development of a basin-wide monitoring study design.	2007 - 2015
Design specifications for Bridge Creek instream structures.	2007
Begin Bridge Creek watershed restoration via aggradation of approximately 4 km of incised mainstem streambed and lower tributary reaches.	2008 - 2009
Purchase PIT tags for installation at two smolt trapping sites and in tributary habitat upstream of these sites in the Bridge Creek.	2007 - 2015
Install PIT tag arrays at six locations in the Bridge Creek.	2007 - 2015
Coordinate sampling activities, data collection, data analysis, and reporting with local researchers.	2007 - 2015
Administer project funds and subcontracts.	2007 - 2015
Develop QA/QC procedures for any new indicators developed.	2007 - 2010
Calculate estimates of population metrics (e.g., escapement) and develop methods to retrospectively apply variance to time series data (e.g., redd counts).	2007 - 2015
Develop methods to estimate population metrics generated using proposed methods/locations from existing methods/locations to enable continuation of existing time series data.	2007 - 2015
Continue development and adaptive refinement of statistical design and analytical methods.	2007 - 2015
Survey habitat conditions and collect macroinvertebrates at random and fixed locations in Bridge Creek.	2007 - 2015
Survey fish populations through snorkeling at random and fixed locations in Bridge Creek.	2007 - 2015
Identify macroinvertebrates collected in Bridge Creek.	2007 - 2015
Compile a set of water temperature monitoring sites from sites that are currently sampled by agencies within the basin	2007
Sample water quality continuously with hydrolabs at three locations in John Day.	2007 - 2015
Sample steelhead redds at random sites and index areas in Bridge Creek.	2007 - 2015
Operate smolt traps at two locations in Bridge Creek.	2007 - 2015
Operate PIT tag arrays at six locations in the Bridge Creek.	2007 - 2015
Sample stable isotopes from all fish species present and macroinvertebrate samples, plus diet samples from collected fish at random and non-random selected sites in the John Day.	2007 - 2015
Monitor grazing practices as they relate to compliance grazing guidelines throughout the John Day.	2007 - 2015

Install PIT tags at two smolt trapping sites and in tributary habitat upstream of these sites in the Bridge Creek.	2007 - 2015
Design and implement a database to capture metadata and data from project activities.	2007 - 2015
Develop, maintain, and adapt a database to house project metadata and data.	2007 - 2015
Analyze recapture data for PIT tagged juveniles generated by PIT tag arrays, repeat electrofishing, and at rotary screw and smolt traps.	2007 - 2015
Develop and adaptively update study design documentation.	2007 - 2015

CHAPTER 4: THE WENATCHEE AND ENTIAT SUBBASINS, WA



Wenatchee subbasin

The integrated status/trend/effectiveness monitoring of the steelhead and spring Chinook populations in the Wenatchee subbasin under the ISEMP began with strategy, design, and coordination in 2003, and progressed to nearly full monitoring implementation by 2006 (Table 5). The Implementation Strategy for Wenatchee Subbasin Monitoring (Ward 2005) guides this portion of the ISEMP, which established a number of scientific uncertainties associated with existing monitoring efforts that the ISEMP is attempting to clarify.

The monitoring approach in the Wenatchee subbasin focuses on aspects of status/trend monitoring and protocol comparisons, and works with what we consider to be the "traditional" approach to monitoring. In the traditional approach, many agencies with numerous and uncoordinated mandates undertake large efforts in the same geographic area but in relative isolation from each other. In the Wenatchee, the ISEMP's contribution has largely been to coordinate existing agency efforts through collaborative funding (Table 6), collaborative fieldwork, standardized data collection, and standardized data management. Funds from the ISEMP have been used to augment existing agency budgets where monitoring indicators were not already being studied and where efforts needed to be expanded to meet the ISEMP's mandates and the recommendations of the Upper Columbia Monitoring Strategy (Hillman 2006), which serves as the ISEMP's guiding document in the Wenatchee/Entiat.

In addition to status/trend monitoring, the ISEMP program in the Wenatchee is configured to work equally as well for monitoring restoration project effectiveness at the watershed scale within the limitations imposed by aspects of the Wenatchee subbasin. For example, the ISEMP monitoring work would support effectiveness monitoring relevant to existing plans to restore anadromous access to Icicle Creek, though additional monitoring elements may need to be established by project sponsors, the ISEMP, or others. Effectiveness monitoring at the watershed scale in the Wenatchee, however, may be confounded by activities such as hatchery supplementation programs or within-watershed changes in landuse. Also, the ISEMP's monitoring data is available for use by other monitoring programs, such as the effort to monitor supplementation programs.

Although monitoring implementation was most active in 2006 and represented nearly complete implementation of monitoring from 13 different categories (Table 7), new monitoring activities are planned for 2007, such as an increased effort PIT tagging at remote locations. In subsequent years, some monitoring elements will be dropped from the ISEMP program when analyses suggest that data requirements have been met. Eventually, the ISEMP's monitoring activities in the Wenatchee will include a more streamlined set compared to those listed in Table 6.

Entiat subbasin

In 2005, the CCCD, on behalf of the Entiat Watershed Planning Unit began construction of what may be the largest reach-scale habitat restoration project currently being implemented in the Upper Columbia Basin. This project, known as the "Entiat Bridge-to-Bridge Project" (B2B), is funded by the Washington Salmon Recovery Funding Board (SRFB) and includes the re-watering and reconnection of relict stream channels with the main river channel, stream grade control, placement of in-stream structures, and riparian planting – all to occur within 1.2 miles of the Entiat River from river mile 3.2 to river mile 4.4. The riparian planting element of the project began in 2005, and the instream structure and side-channel work in 2006.

With the completion of the Recovery Plan for the Entiat Subbasin, work begun in the B2B project is now being extended into the remainder of the affected habitat. The planned restoration actions will address what the Recovery Plan considers to be the primary limiting factor in the Entiat subbasin – channel complexity. The B2B project and other recovery actions are anticipated to increase adult holding habitat, juvenile rearing habitat, and spawning habitat for salmonid species, of which steelhead, spring and summer Chinook salmon, and bull trout may be affected.

The ISEMP Entiat Intensively Monitored Watershed component is measuring the extent to which the B2B and Recovery Plan actions will affect:

- Fish habitat,
- Fish habitat utilization, and
- The productivity of salmonid fishes in the Entiat subbasin.

The study is also testing aspects of the Monitoring Strategy for the Upper Columbia Basin (Hillman 2006) that pertain to effectiveness monitoring. Surveys of fish habitat and fish habitat utilization supported by this study will be synthesized with separately funded, yet compatible, agency monitoring programs to include all of the indicators specified for study in Hillman (2006). Coordination with landowners and the local Watershed Planning Unit are built into the study design.

Ideally, the study will be implemented over a 20-year period, but the duration is dependent upon restoration action implementation and funding. To start, a minimum of 5 years participation has been solicited from willing private landowners. An extended monitoring time frame is necessary to account for at least four salmonid generations (4-5 years per generation), to capture pre and post-restoration project conditions, interannual variability, long-term channel adjustments resulting from the restoration project, and possible changes to restoration project features that might arise from periodic factors like large runoff events.

This study capitalizes on the unique effectiveness monitoring opportunity in the Entiat subbasin. The Entiat B2B Project and Recovery Plan actions are sufficiently large and designed to help fix the appropriate salmon habitat limiting factors. It will likely provide measurable contributions to fish habitat, habitat utilization, and the productivity of salmonids in the Entiat subbasin. Furthermore, this restoration effort is generally not confounded by other actions and land use impacts to the extent found in other subbasins. Finally, this study firmly places monitoring within the Entiat subbasin in the framework described by the Monitoring Strategy for the Upper Columbia Basin, and helps implement monitoring actions recommended in the Entiat watershed plan (CCCD 2004).

Summary budgets for the ISEMP in the Wenatchee and Entiat subbasins

Table 5. Breakdown of the budget for the ISEMP in the Wenatchee and Entiat subbasins and Entiat IMW by year.

Subbasin *	FY03	FY04	FY05	FY06	Total
Wenatchee	$103,046	$923,334	$1,062,650	$1,401,985	$3,491,015
Entiat B2B	$0	$0	$99,674	$205,930	$305,604
Entiat IMW	$0	$49,750	$51,756	$205,800	$307,306
Total	$103,046	$973,084	$1,214,080	$1,813,714	$4,103,924

* Includes BPA and NOAA contributions to ISEMP, does not include cost-sharing by collaborators.

Table 6. An example of collaborative funding of the ISEMP monitoring elements in the Wenatchee/Entiat pilot project (fiscal year 2006).

Monitoring Category *	FY03	FY04	FY05	FY06	Total
Coordination	$41,327	$58,234	$101,348	$145,073	$345,981
Strategy/design	$61,719	$75,077	$34,350	$102,932	$274,078
Habitat/strategy protocol comparison	$0	$0	$65,626	$0	$65,626
Classification	$0	$29,573	$0	$0	$29,573
Spawner surveys	$0	$139,039	$129,597	$150,122	$418,758
Juveniles	$0	$20,917	$234,307	$332,022	$587,246
Smolt trapping	$0	$219,426	$139,410	$182,518	$541,355
PIT tagging	$0	$0	$0	$146,615	$146,615
Bugs	$0	$182,451	$237,578	$362,897	$782,926
Water quality	$0	$72,441	$55,380	$139,597	$267,417
Habitat	$0	$175,927	$216,484	$242,936	$635,348
Fine sediment	$0	$0	$0	$9,001	$9,001
Total	$103,046	$973,084	$1,214,080	$1,813,714	$4,103,924

* Includes BPA and NOAA contributions to ISEMP, does not include cost-sharing by collaborators.

Table 7. Breakdown of the ISEMP budget in the Wenatchee and Entiat subbasins and Entiat IMW by amount spent on each monitoring category.

Indicator category	BPA ISEMP FY06	NOAA ISEMP FY06	Other Programs FY06	Total by Category	Other Programs
Coordination	$132,823	$12,250	$46,000	$191,073	Agencies supporting RTT members' participation; USFS Entiat Planning/Oversight
Strategy/design	$102,932	$0	$0	$102,932	--
Macroinvertebrates	$362,897	$0	$38,924	$401,821	WDOE habitat surveys and RIVPACS modeling
Fine sediment	$5,402	$3,599	$50,000	$59,001	USFS Depth Fines Wenatchee and Entiat
Water flow sampling	$0	$0	$96,000	$96,000	WDOE instream flow gauging
Genetic sampling	$0	$0	$300,000+	$300,000+	NOAA non-ISEMP; Chelan PUD (uncertain amount)
Habitat characteristics	$242,936	$0	$0	$242,936	--
Habitat access	$0	$0	$200,000	$200,000	WDFW SSHEAR
Juveniles	$243,206	$88,816	$20,000	$352,022	USFS Contributions
PIT tagging	$40,915	$105,700	$100,000	$246,615	Chelan PUD PIT Tagging in Wenatchee
Smolt trapping	$133,518	$49,000	$317,318	$499,836	Chelan PUD Smolt Trapping Contributions; BPA non-ISEMP projects
Spawner surveys	$115,178	$34,944	$460,245	$610,367	Chelan PUD Spawning Ground Survey Contributions; other contributions
Water quality	$84,808	$54,789	$0	$139,597	
Grand Total	$1,464,616	$349,099	$1,628,487+	$3,442,201+	

Coordination

The development of local participation, collaboration and support such that simultaneous implementation, monitoring and evaluation can occur in a single adaptive experimental framework is crucial. Similarly, the maintenance of regional relationships, coordination with other ISEMP pilot projects, the development of a data management system useful for regional needs is equally important. In the Wenatchee subbasin and Entiat IMW, Terraqua, Inc., coordinates the implementation of the ISEMP, locally and regionally, under the oversight of the Upper Columbia RTT, while the CCCD coordinates scientific activities in the Entiat IMW and B2B project with landowners and local planning groups. Multiple entities have been enlisted to conduct aspects of this program, in many cases by building upon existing monitoring efforts and sharing costs with other programs, and in all cases by using the expert staff that each agency is able to provide.

Contractors
Chelan County Conservation District
Terraqua, Inc.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration
U.S. Bureau of Reclamation

Time Line

Since 2004, 14 entities have been contracted to implement components of the ISEMP. A similar breadth of participation is expected in the future.

Links to Annual Reports

- Terraqua, Inc. Annual Report 2004-2005
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/terraqua_bpa_annual_report2004_2005.doc
- Terraqua, Inc. Annual Report for the performance period 7/1/05 through 6/30/06
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/annual_report_fy05_release4.doc
- Chelan County Conservation District 2005 Annual Report
  - http://www.nwfsc.noaa.gov/research/division/cbd/mathbio/isemp/docs/cccd_bpa_annual_report_2005.doc

Budget

Contractor	Scope of Work	FY03	FY04	FY05	FY06
Terraqua	Represent interests of the ISEMP at meetings of the RTT. Coordinate electronically and in-person with entities involved in program. Attend regularly scheduled RTT meetings and, meetings with BPA and NOAA. Develop and maintain supporting documents and budgets including monitoring strategies, field manuals, protocols, and program reports. Coordinate monitoring strategies, activities, and analysis with other ISEMP pilot projects and regional monitoring forums. Represent Wenatchee/Entiat data collectors in the development of the regional data management system. Analyze data.	$41,327	$58,234	$101,348	$114,884
CCCD	Entiat B2B and IMW coordination. Landowner, community and technical staff coordination necessary for monitoring. Project information and data (results) sharing. Outreach and education to specific landowners about survey and request access permission to conduct physical habitat surveys on private land. Coordinate with WDOE and USFS to identify various survey sites and conduct reconnaissance of site feasibility.	$0	$0	$0	$25,189
	Total by fiscal year:	$41,327	$58,234	$101,348	$140,073
	Project total through fiscal year 2006:				$340,981

What's been accomplished so far

✓ Facilitated unprecedented collaboration among county, state, federal, tribal, and private agencies at the programmatic scale: for the first time agencies from all levels are working together on a joint approach to monitoring compared to the previously disjunct or competitive monitoring approach of the past.

✓ Coordinated over a dozen tribal, state, federal and private contractors implementing components of the ISEMP in the Wenatchee and Entiat subbasins, including ensuring that budgets and scopes of work were appropriately designed, scientifically defensible, and within budget.

✓ Coordinated the implementation of at least 41 ISEMP monitoring indicators in at least 27 separate contracts/agreements between at least six funding agencies (BPA, NOAA, Chelan County PUD, Upper Columbia Salmon Recovery Board (USSRB), WDFW, USFS) employing 14 contractors in 2004, 2005, and 2006.

✓ Facilitated unprecedented collaboration among multiple agencies working at the field level, for example: USFS and WDOE conduct coordinated snorkel and habitat surveys at over 50 study sites per year, while the CCCD facilitates landowner access permission affording these agencies unprecedented access to sites on private lands; this project encouraged WDFW, YN, and USFWS to standardize smolt trapping operations, data collection, and data management throughout the Upper Columbia; WDFW and USFS jointly conducted both index-area and randomized steelhead surveys in tight coordination.

✓ Explored and refined novel ways to communicate and share ideas, avoid and recover from mistakes, and manage large groups of collaborators from diverse backgrounds and agencies in a fashion that could reduce "ramp-up" time when lessons from the ISEMP are expanded to other parts of the Columbia. We are working to develop a community with a common language for monitoring, a basic set of tools and skills for data communication and management, and a shared set of goals and objectives. We feel that by actively fostering this community we will ultimately be able to progress further and faster in the design and implementation of a subbasin-scale monitoring and evaluation program. To facilitate the development of a community of practice we have developed workshops, training sessions and technology transfer approaches.

✓ Enlisted the Upper Columbia RTT as the technical advisory committee for the ISEMP in the Wenatchee/Entiat; ISEMP staff have coordinated the RTT's monitoring committee for the past 3 years.

✓ Facilitated the coordination of the Entiat restoration project planning and implementation at the subbasin scale within the monitoring framework of the ISEMP project.

✓ Coordinated protocol standardization throughout the Upper Columbia ESU, for example: analyzing differences in protocols and recommending standardized approaches between two BPA projects in the Wenatchee/Entiat and Okanogan subbasins.

✓ The CCCD is coordinating the implementation of the restoration project, landowner and Planning Unit outreach, and annual project reporting in the Entiat B2B and IMW projects. Each spring they worked with agency personnel to gain access rights to steelhead spawning survey sites on private lands. Potential survey sites located on private lands were mapped and affected landowners were identified using GIS. Over 80 access requests were mailed out to private landowners describing the purpose of the study and requesting permission to access the survey site via their property. Follow-up phone calls were made to landowners that failed to reply. Responses were recorded in tabular format and reported to USFS personnel.

What's ahead

Continue to facilitate collaboration among county, state, federal, tribal, and private agencies at the programmatic scale and at field and analytical levels in the Wenatchee.	2007 - 2015
Expand the multi-agency programmatic collaboration to the Entiat.	2007 - 2015

Strategy Design

Within the Upper Columbia Basin, Washington, several different organizations, including federal, state, tribal, local, and private entities currently implement tributary actions and conduct monitoring studies (Hillman 2006). In the Wenatchee and Entiat subbasins the scope of the monitoring work being implemented is large, and is complicated by the participation of several entities operating under multiple funding sources. It is in this arena that the ISEMP is working to develop a monitoring strategy that reduces redundancy, increases efficiency, and meets the goals and objectives of the various entities.

Funding Agency

Bonneville Power Administration

Contractors

BioAnalysts, Inc.

Terraqua, Inc.

Time Line

Work began in 2004. Maintenance and revision of strategies will continue into the future.

Budget

Subbasin	Contractor	Scope of work	FY03	FY04	FY05	FY06
Wenatchee/Entiat	BioAnalysts	Strategy/Design/Analysis	$61,719	$62,722	$26,934	$85,262
Wenatchee/Entiat	Terraqua	Strategy: Implementation Strategy for Wenatchee and Entiat	$0	$12,355	$7,416	$17,670
		Total by fiscal year:	$61,719	$75,077	$34,350	$102,932
		Project total through fiscal year 2006:				$274,078

Links to Annual Reports/Documents

- Upper Columbia Basin Monitoring Strategy (Hillman 2006)
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/ucb_monitoring_strategy2104.pdf
- Monitoring Strategy for the Upper Columbia Basin, Appendix A: An Implementation Strategy for Wenatchee Subbasin Monitoring
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/isemp_impstrat_document.doc
- Entiat Effectiveness Monitoring Study: Monitoring the Effectiveness of habitat restoration actions in the lower Entiat River (Bridge to Bridge proposal)
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/entiateffmon_summaryofb2b.pdf
- BioAnalysts, Inc. Annual Reports 2004 to 2005, 2005-2006
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Release 1 Annual Report 2004-2005.doc

- o http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Release 1 Annual Report 2005-2006.doc

What's been accomplished so far

✓ Completed a Monitoring Strategy for the Upper Columbia (which includes Wenatchee/Entiat and two other subbasins).

✓ Completed an Implementation Strategy for the ISEMP in the Wenatchee that describes how the ISEMP will implement and analyze monitoring activities over the next 20 years.

✓ Developed, in the Upper Columbia Monitoring Strategy, a list of 67 monitoring indicators, and identified a similar list of protocols to measure these indicators, that are monitored by the ISEMP in the Wenatchee.

✓ Designed sampling regimes for each of the 67 indicators/protocols, often at multiple spatial and temporal scales, and have been implementing the monitoring of these indicators since 2004.

✓ Developed a "living" Tracking Document that captures all institutional decision-making since the inception of the ISEMP in the Wenatchee. This record will be crucial in light of the adaptive design of each monitoring element: as we learn, we change the monitoring work adaptively, and this document provides a clear record of these changes and the underlying rationales. This project tracking tool is an easy-to-read/easy-to-use web-based tool that functions something like a weblog or chat room, with the ability to sort topics by thread, date, and many other parameters. The target is to have a working, on-line project tracking tool by early 2007.

✓ Completed a study design for the effectiveness monitoring of the B2B restoration project in the Entiat.

✓ Developed and initiated effectiveness monitoring of the B2B habitat restoration project in the Entiat at the reach-scale. Much of this work (e.g. snorkel/habitat surveys of restoration sites) will provide "pilot" knowledge when designing watershed-scale monitoring of habitat actions in the Entiat. Other elements of this work (e.g. initiation of habitat monitoring at an annual panel of sites in 2005 and 2006) will be directly useful in the implementation of watershed-scale monitoring of habitat actions in the Entiat.

✓ The ISEMP has been designed and implemented to quantify the effects of changes resulting from restoration actions between watersheds and is currently operating in a manner to capture "pre-treatment" data in anticipation of future habitat action implementation. While no watershed-scale habitat restoration actions have been implemented to date, they may occur in the future. However, the ISEMP is currently implemented to detect changes resulting from, for example: the differential impacts of hatchery programs on populations in the various watersheds of the Wenatchee subbasin; and differential preservation/conservation actions at the watershed-scale. We anticipate, but have no control over, the development of watershed-scale restoration actions. For example, several agencies are beginning to design a watershed-scale habitat restoration action in Nason Creek with predicted impacts at a magnitude that the ISEMP is designed to resolve.

✓ Developed a standardized approach to lay out spatial sampling using the random but spatially balanced frame from the EPA's Generalized Random Tessellated Sampling. Terraqua, Inc. and the NWFSC worked with USFS and WDOE personnel to generate a tool for site selection for random steelhead spawning surveys and basin-wide stream habitat surveys. This approach is a potential advance in the location of sampling sites by incorporating in-stream reach habitat data in conjunction with fish distribution data to balance monitoring study sites within the basin among anadromous and non-anadromous streams. The merits of this approach are being tested through its application in the Wenatchee pilot, with results expected in 2 to 3 years.

✓ During the period 2004-2006, BioAnalysts, Inc., provided technical advice and reviews on status/trend and effectiveness monitoring within the Upper Columbia Basin (Wenatchee subbasin). During 2004-2005, BioAnalysts' work improved coordination of monitoring activities in the Upper Columbia, revised and improved the sampling frame, clarified and refined measuring protocols, and identified potential weaknesses in the monitoring strategy that needed to be addressed during the 2005/2006 field work season. Most of the work conducted by BioAnalysts in 2005-2006 focused on providing technical input on revising monitoring designs, indicators, and protocols. The Upper Columbia Monitoring Strategy was modified based on information gained from other monitoring programs (e.g., PNAMP, CSMEP, Okanagan Basin Monitoring and Evaluation Program, Aquatic and Riparian Effectiveness Monitoring Plan, and PIBO), preliminary results from the John Day Protocol Study, and results from monitoring within the Wenatchee subbasin. We also updated the sampling design, statistical design, sampling methods, and monitoring indicators in the Upper Columbia Monitoring Strategy. The work conducted by BioAnalysts was well under budget and on time.

What's ahead

Revise, as necessary, the Monitoring Strategy for the Upper Columbia and the Implementation Strategy for the Wenatchee.	2007 - 2015
Complete an Implementation Strategy for ISEMP in the Entiat.	2007 - 2015
Expand the Entiat effectiveness monitoring study design (and include this in the Implementation Strategy) to appropriately monitor changes resulting from the planned implementation of nearly 80 habitat actions in the Entiat under the Recovery Plan.	2007 - 2015
Expand the use of the Tracking Document to include ISEMP work conducted in the Entiat.	2007 - 2015
Continue to promote protocol standardization throughout the Upper Columbia ESU based on analytical results of protocol comparisons being conducted under ISEMP	2007 - 2015
Expand the monitoring of this list of indicators in the Entiat as a first step in implementing pre-treatment monitoring of the Entiat Recovery Plan habitat action implementation	2007 - 2015

Ecological Classification

Prior to the ISEMP program, landscape variables and watershed conditions in the Wenatchee and Entiat subbasins had not been systematically studied and were largely unknown, despite the fact that models of habitat restoration assume that overall salmonid production is largely driven by freshwater habitat conditions that may be directly influenced by landscape and watershed factors. Under the ISEMP, landscape-scale ecological variables and watershed conditions were characterized throughout the Wenatchee subbasin in 2004, and are currently being integrated into analyses of fish production and fish habitat utilization. The UCSRB extended this work from the Wenatchee subbasin to encompass the entire Upper Columbia ESU so that a complete coordinated dataset now exists for the entire ESU.

Funding Agencies
Bonneville Power Administration for Wenatchee
National Oceanic and Atmospheric Administration
Upper Columbia Salmon Recovery Board for Entiat/Methow/Okanagan

Contractor
Pacific Biodiversity Institute

Time Line

The baseline classification work was done in 2004 and need not be repeated on an annual basis. It should serve adequately at least for the first 5-year period of the ISEMP's implementation. Certain landuse classifications may need periodic revision on 5 to 10 year cycles.

Figure 7. Strahler stream order for the Wenatchee River subbasin (from UCESU-2sept2006b.pdf)

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	Pacific Biodiversity Institute	GIS classification work	$0	$29,573	$0	$0
	Pacific Biodiversity Institute	GIS methodological report preparation	$0	$0	$0	$17,000
		Total by fiscal year:	$0	$29,573	$0	$0
		Project total through fiscal year 2006:				$46,573

* The UCSRB contributed $86,000 to extend the classification work funded by the ISEMP to the Entiat, Methow, and Okanogan basins.

Link to Annual Report

- Pacific Biodiversity Institute Upper Columbia Evolutionary Significant Unit Draft Report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/UCESU-18sept2006.doc

What's been accomplished so far

The data collection process in the Wenatchee subbasin was used as a testing scenario for evaluating the data reduction process. Efforts so far have focused on spatial data compilation and collection. Pacific Biodiversity Institute (PBI) was contracted to delineate the landscape and stream network using traditional classification schema from which it assembled GIS layers representing eco-regions, land ownership, and geology. The classification of habitat in the Upper Columbia Basin draws together ecoregional, drainage basin, valley, and reach scale classifications with detailed mapping of riparian vegetation and land use from satellite and airborne imagery. Additionally, Strahler order, gradient, Naiman valley type, Rosgen channel type, and riparian vegetation were determined for all stream segments in the basin. Riparian vegetation was classified from ASTER satellite images and further delineated using aerial photos. These traditional classification schemas provide landscape and site level context for interpreting site restoration and are based on a solid foundation within the scientific literature. A comprehensive data manual is available to help users understand the data, its potential applications, and avoid problems that often result from the misapplication of GIS datasets.

As a result of PBI's work considerable insights were gained into:

- Additional classification approaches that might be employed in the Upper Columbia ESU or other parts of the Columbia Basin;
- How the data might be best applied to salmon recovery monitoring efforts and to the prioritization of watershed and stream restoration efforts oriented toward achieving salmon recovery;
- The problems (and opportunities) that arise when applying a methodology developed in one area to another geographic area, and
- The costs and opportunities involved in expanding ecological classification work to other areas.

GIS layers produced include:

- **Regional setting classification**. The PBI produced these classification variables (ecoregion, physiographic province and geologic district) by bringing together existing data produced by other agencies. Other than clipping the original datasets to the boundary of the Upper Columbia ESU region no other modifications were made to the original datasets.
- **Basin-level classification**
  - *Land ownership***.** The PBI used the Washington State DNR managed public lands (MPL) dataset, along with the WA DNR managed lands dataset to calculate ownership acreages within each subbasin or analysis region. Land ownership was described as: (1) federal by agency, (2) state by agency, and (3) private for all non-state or federal lands.
  - *Basin relief*. Barring large-scale geologic changes in macro-topography, the basin relief calculations should remain valid regardless of elevation dataset updates. The 10-meter DEM datasets offer sufficient detail to make accurate calculations of basin elevation statistics. Basin area calculations should also remain valid unless future renditions of NOAA's HUC 6 layer contain drastic alterations of some of the subwatershed boundaries.
  - *Drainage density*. The SSHIAP 1:24,000 hydrography data was used along with PBI's customized version of NOAA's HUC 6 dataset to calculate drainage densities for our analysis regions.
  - *Stream Order***.** Stream order was calculated using Strahler's methods.
- **Valley segment classification.** The methods used to produce this classification variable were complex and required the development of original methods and approaches. Clear input parameter breaks, based on Naiman's parameter descriptions for each valley segment type, were created.
- **Channel segment classification.** The methods used to produce this classification variable were complex and required the development of new methods and approaches that attempted to mirror the original Rosgen field-based classification method.
- **Riparian vegetation classification.** Standard methods were used, including aerial photography interpretation of vegetation and land use and vegetation mapping using ASTER satellite classifications.
- **Road/riparian index classification**.

Key Analysis Planned

Trend monitoring

- Specific time intervals for repeating the classification process will be determined during the course of data analysis after the first 5-year rotating panel of habitat sampling has been completed. While most variables will not need to be reclassified at annual or 5-year time scales, variables subject to change at sub-decadal scales, such as riparian, road, and channel classification may require re-classification at relatively more frequent intervals than, say, valley segment classification. Variables at the regional scale many not need future re-classification, unless advancements in the science underlying these variables are made, because they are unlikely to change at time scales relevant to the ISEMP.

Effectiveness monitoring

- Using landscape classification and watershed condition as a guide for site selection, the ISEMP will select control sites that match treatment sites as closely as possible to enable the effectiveness evaluation of habitat restoration actions. The identification of control sites should consider possible covariates at the landscape and watershed scales.
- Explore advances in remote sensing tools and improvements in the analysis of spatial data.
- Examine the assumptions of the site-selection weighting functions to their applicability in light of data from the first 5-year rotating panel. Habitat monitoring sites were probabilistically chosen using a process that weighted streams by gradient and stream order as determined from landscape classification work.
- Compare the relative accuracy of ground- and remote-based channel classification and describe the accuracy in terms of costs per unit length of stream. Channel classification has traditionally required expensive ground-based field measurements. In 2004, the ISEMP funded the exploration of remote-based channel classification using GIS tools. GIS analysis is likely less sensitive to channel-scale variability but can be inexpensively applied to whole subbasins.

Steelhead Redd Surveys

The number of adults in a stream or watershed is a function of all the factors that affect the life history of the population; spawning escapement is the number of adults that spawn in a stream or watershed (Hillman 2006). The ISEMP is coordinating annual index spawning ground counts that estimate the total number of steelhead redds in selected stream reaches in the Wenatchee subbasin and in the Entiat IMW. In addition, the ISEMP is developing an annual estimate of the total number of steelhead redds in at least 25 probabilistically-selected stream reaches that represent the entire Wenatchee subbasin.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

Chelan County Conservation District

United States Fish and Wildlife Service

United States Forest Service – Wenatchee National Forest

United States Forest Service -Entiat Ranger District

Washington Department of Fish and Wildlife

Time Line

In the Wenatchee, surveys at randomized sites began in 2004, while surveys at index reaches preceded the ISEMP program by several years. In the Entiat, complete index-reach surveys began under the ISEMP in 2005 but started in selected areas about 10 years ago. Survey work runs from March through mid-June. Data is examined on a yearly basis. Studies to compare protocols should run for a minimum of 3 years to generate estimates of interannual variability and will likely need to be implemented for more than 3 years due to low encounter rates of steelhead redds in probabilistic surveys. Surveys to detect trends in abundance should run for up to 20 years.

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	CCCD	Reconnoiter steelhead random sites	$0	$2,326	$1,615	$584
Wenatchee	WDFW	Steelhead index sites	$0	$21,377	$23,217	$26,047
Wenatchee	USFS	Steelhead random sites	$0	$90,460	$79,890	$89,131
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFWS	Steelhead redd surveys	$0	$24,875	$24,875	$0
Entiat IMW (intensively monitored watershed and	USFWS	Steelhead redd surveys	$0	$0	$0	$25,418

comprehensive restoration)						
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFS-Entiat Ranger District	Steelhead redds in Mad River	$0	$0	$0	$8,942
		Total by fiscal year:	$0	$139,039	$129,597	$150,122
				Project total through fiscal year 2006:		$418,758

Links to Annual Reports

- USFS steelhead redd surveys 2004-2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/usfs_bpa_annual_report2004_2005_steel.doc
- USFS random site steelhead redd surveys 2004-2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/ann_rpt_steel05_BPA_draft.doc
- WDFW Integrated Status & Effectiveness Monitoring Program Expansion of Existing Smolt Trapping Program and Steelhead Spawner Surveys Draft Annual Report 2004
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdfw_bpa_annual_report2004_2005.doc
- WDFW Integrated Status & Effectiveness Monitoring Program Expansion of Existing Smolt Trapping Program and Steelhead Spawner Surveys Draft Annual Report 2005
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2005_wdfw_draft_imw_annual_report.doc
- USFS –Entiat Ranger District 2006 Mad River Rainbow/Steelhead Trout Spawning Surveys
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2006_SH_spawn_survey_report.doc
- USFS –Entiat Ranger District 2006 Mad River Rainbow/Steelhead Trout Spawning Surveys data and figures
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2006_SH_redd_data&graph.doc

What's been accomplished so far

- The WDFW was contracted by the ISEMP to estimate the total number of steelhead (*Oncorhynchus mykiss)* redds in selected streams within the Wenatchee subbasin by conducting index spawning ground counts and assessing their accuracy and precision.

- The USFS Wenatchee National Forest was contracted by the ISEMP to estimate the total number of steelhead redds within the Wenatchee subbasin by conducting spawning ground counts at probabilistically selected sample sites.

- For more than a decade the USFS-Entiat Ranger District has been conducting redd counts to expand subbasin-specific knowledge of steelhead spawner numbers, timing, and distribution, and establish a steelhead spawning index reach on the Mad River. Beginning in 2006, the USFS-Entiat Ranger District received additional funding from NOAA through the

ISEMP, and adopted the Upper Columbia Monitoring Strategy guidelines for sampling frequency and intensity.

- With funding from NOAA through the ISEMP, the USFWS began conducting more extensive spawning ground surveys of the Entiat River in 2003, following the protocol in the Upper Columbia Monitoring Strategy. The extended surveys have continued since and are expected to continue into the future to support the Entiat IMW.

Figure 8. A steelhead hovers over its redd in the Entiat River. The ISEMP is coordinating and funding index spawning ground counts that will generate estimates of the total number of steelhead redds in selected stream reaches. (Photograph courtesy of the USFWS Mid-Columbia Fishery Resource Office).

USFS-Wenatchee National Forest Random Site Steelhead Surveys

Steelhead surveys were conducted at 25 randomly-selected one-mile reaches in anadromous-accessible waters throughout the Wenatchee subbasin from 2004-2005 to (1) contrast with existing index reach steelhead surveys, (2) quantify the proportion of spawning occurring outside of annually monitored reaches, and (3) document potential changes in steelhead distribution, which might be occurring simultaneously with changing redd densities in annually monitored reaches. Random-site surveys also help to confirm the upper limits of spawning. Survey results included the description of previously undocumented redd locations in Beaver Creek, Chumstick Creek, and Mission Creek. In addition, every random site sampled in the mainstem Mission Creek contained steelhead redds, suggesting the Mission watershed may be a good candidate for an additional index survey in the less-documented lower Wenatchee subbasin.

Distinct differences were found in species assemblages and species/habitat relationships between steelhead spawning sites. Strong habitat and temporal relationships were also found, suggesting that these factors should be addressed when extrapolating from sampled sites to larger areas (e.g. basin-wide). New steelhead activity was observed at three of seven locations (six reaches plus one training site) in the first year alone.

WDFW steelhead redd surveys

Funded by the Chelan County PUD, the WDFW began limited steelhead spawning surveys in selected streams in the Wenatchee subbasin in 2000 to determine the efficacy of a supplementation program in increasing the number of natural spawners. In coordination with the ISEMP, the scope of the surveys has been expanded to include all tributaries in the Wenatchee subbasin with a significant steelhead spawning population, and to ensure surveys are conducted on a weekly basis. Steelhead spawning escapement of selected tributaries was estimated using index area redds counts within known core-spawning areas as described in Hillman (2006), with weekly index-reach surveys and a single survey of larger reference reaches, which could be comprised of one or more index-reaches.

In 2004 and 2005, steelhead began spawning during the first week of March in the Wenatchee River and progressed upstream as water temperatures increased. Based on preliminary data, spawning activity appeared to begin once a mean daily stream temperature reached 4 ^{o}C. In 2004, peak spawning in the Wenatchee River occurred the third week of April and peaked in Nason Creek and the Chiwawa River during the fourth week of April. In 2005, peak spawning in the Wenatchee River occurred the second week of April and peaked in Nason Creek and the Chiwawa River the third week of April.

In 2004, few steelhead redds were found in the Wenatchee River below Tumwater Dam. In contrast to previous years, only 36.6% of the steelhead redds found above Tumwater Dam were located in the Wenatchee River (54.3% in 2003, 62.6% in 2002, and 62.0% in 2001). Of those redds found in the Wenatchee River above Tumwater Dam, only 53.3% were located in the uppermost index area, much lower than that observed in 2001 (86%), 2002 (95%), and 2003 (98.4%). In 2005, the number of steelhead above Tumwater Dam increased 33.4% in 2005 over the 2004 run escapement.

In 2004, steelhead spawning in the Chiwawa River was similar to previous years with the majority of steelhead (73.5%) observed spawning in 1st and 2nd order tributaries rather than the mainstem Chiwawa River. A significantly higher proportion of redds were found in Nason Creek compared to 2003 (P<0.01). Furthermore, the distribution of redds in Nason Creek was significantly different (i.e., more redds found farther upstream) than observed in 2003 (P<0.01). A similar trend was also observed in Peshastin Creek. Additional effort was made to survey areas other than traditional spawning areas within Peshastin Creek, Nason Creek, and the Chiwawa River to determine if spawning may be present and/or to identify potential barriers to fish passage. The results indicate little to no evidence of adult steelhead activity above existing spawning areas. There was evidence of resident *O. mykiss* spawning in the upper most portions of the Peshastin River basin. A continued effort is needed to further define the spawning distribution of steelhead with the Wenatchee River subbasin.

Excellent survey conditions in 2005 afforded an opportunity to quantify the amount of steelhead spawning that occurs upstream of the current survey reaches. As time permitted, single additional surveys were conducted at the end of the spawning season in areas upstream of steelhead spawning areas within Peshastin Creek, Nason Creek, and the Chiwawa River to determine what, if any, spawning may be present. The results of these efforts suggest no steelhead spawning activity above existing spawning areas surveyed, although the potential use of these areas in the future cannot be ruled out.

The high proportion of redds found within the index areas (86%) upstream of Tumwater Dam suggests that index areas can be used to monitor trends in steelhead abundance and distribution, although a slightly better relationship exists between the run escapement and total redds counts versus index redds counts. General conclusions and recommendations include:

- Current steelhead spawning ground methodology in the Wenatchee River subbasin is feasible and can be conducted with reasonable accuracy provided surveys are conducted when river conditions are appropriate.
- Hatchery steelhead may disperse throughout the basin and spawn in streams in which no releases have occurred. Hatchery rearing and release methodology may influence both subsequent stray rates and/or dispersal patterns. The origin of spawning adult steelhead should be determined whenever feasible.
- A high proportion of steelhead spawn in the 8 km reach of the Wenatchee River immediately below Lake Wenatchee. Although this reach contains more suitable spawning substrate than other reaches of the Wenatchee River, implications regarding early life stage survival should be investigated further (i.e. tributary versus mainstem spawners).
- Of those steelhead found spawning in the Chiwawa River, almost all utilized the lowest 12 km of the mainstem or small tributaries located in that reach. Low temperatures ($<5^oC$) in the upper watershed may be a limiting factor, which prevents steelhead from utilizing high quality spawning habitat.
- Steelhead in Nason Creek utilized more of the available spawning habitat than steelhead in the Chiwawa River. However, the lack of suitable 1st and 2nd order tributaries in the Nason Creek Basin force all fish to spawn in the main river. Additional surveys should be conducted to confirm this hypothesis.
- Continued expansion of survey areas will determine the extent of spawning distribution and allow for refinement of survey methods. A methodology for estimating steelhead redds outside of the survey area is necessary to develop a subbasin estimate.
- Expanded temperature monitoring above, below, and within existing steelhead spawning areas may provide insight into steelhead distribution and help explain underutilization of quality spawning habitat.
- Radio tagging adult steelhead (particularly females) at Tumwater Dam may provide critical insight to the consistent proportion of unaccounted female steelhead over Tumwater Dam. This information would also assist with calculating fallback rates, prespawn mortality rates and determining spatial and temporal spawning distribution of hatchery and wild fish within the upper Wenatchee subbasin.

USFS-Entiat Ranger District steelhead spawning surveys

Spawning surveys were conducted on the lower Mad River (RM 0-7) and Roaring Creek (RM 0.5-2) in the spring of 2006. Preliminary surveys were initiated in late-February and consisted of weekly spot-checks of easily accessible, known spawning locations. More extensive surveys were initiated after first spawning activity was observed (March 29, 2006) and continued on April 4, 12, 20, 28, and May 5, 7 & 12 to encompass the peak of the steelhead spawning season in the Entiat/Mad Rivers. A total of 25 steelhead redds were identified in the Mad River between rivermiles 0 and 7 (Figure 9), consisting of 23 definite redds (52 percent with spawners present) and 2 probable redds (Table 8).

The results of the spawning ground surveys likely underestimated steelhead spawning in the Mad River in 2006 due to increasing stream flow at the end of April and May that hampered repeat surveys of the upper segment of the index reach. The 2006 redd count (25 redds) is close to the seven-year average (27 redds/year) for the Mad River index reach. Steelhead spawning in the Mad River appeared to peak in late April 2006, one week later than expected from prior years' observations.

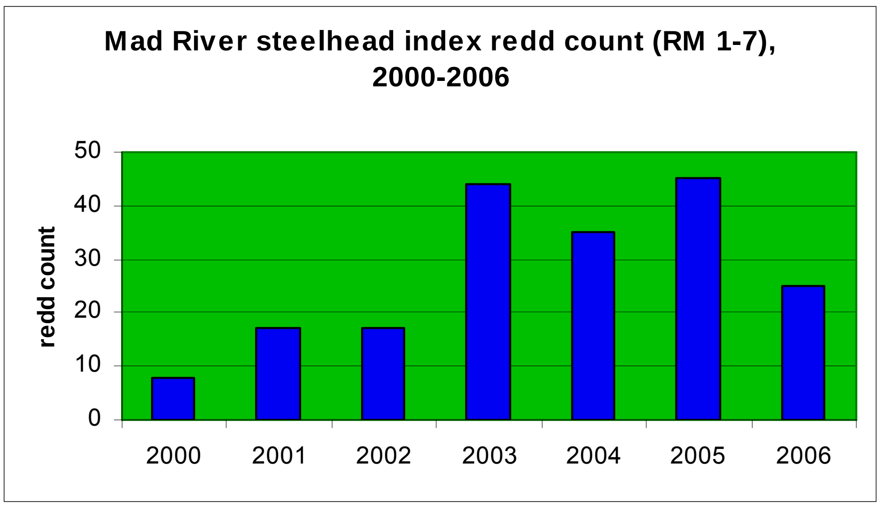


Figure 9. Mad River steelhead index redd count, 2000-2006.

Table 8. Steelhead/Rainbow trout redd counts on the Mad River, 1997 through 2006.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Definite Redds	8	No data	0	3	15	14	38	26	44	23
Probable Redds	Not distinguished	No data	3	5	2	3	6	9	1	2
River Mile surveyed	1 to 3	No survey	1 to 4	1 to 10	1 to 10	1 to 7	1 to 7	1 to 7	1 to 7	1 to 7

USFWS Entiat River steelhead productivity monitoring and evaluation project

In 2005, the USFWS Mid-Columbia River Fishery Resource Office (MCRFRO) used funds from the ISEMP to augment steelhead redd surveys in the Entiat River. Staff conducted an extensive redd survey in the main Entiat River (from Rkm 0.3 to 44) to assess the natural productivity of the Entiat River steelhead population and provide insight into steelhead spawn timing, redd numbers, and spawning distribution. Weekly spawning ground surveys throughout the anadromous portions of the main Entiat River were carried out from March to June. MCRFRO staff documented 228 steelhead redds in 2005 and 111 in 2006, thus providing the first extensive assessment of steelhead spawning in the main Entiat River. This expanded survey documented approximately half the annual redds in areas previously not surveyed in 2003 and 2004.

Key Analysis Planned

Status monitoring

- Determine if index spawning ground counts adequately characterize the abundance of steelhead spawning by estimating error in abundance estimates from index spawning ground counts based on findings from redd surveys in probabilistically-selected reaches.
- Determine if spawning ground counts in index reaches adequately characterize the distribution of steelhead spawning and if statistically or biologically significant numbers of steelhead spawn in reaches outside of the index reaches. This will be accomplished by comparing the number and distribution of steelhead redds from index and probabilistically selected stream reaches.
- Determine the extent to which steelhead of hatchery origin spawn naturally in the wild by describing the spatial extent of naturally spawning hatchery fish, the fraction of natural spawners comprised of hatchery fish, and the range of spawning behavior of hatchery fish.

Trend monitoring

- Determine if interannual variability in spawning distribution affects our ability to detect abundance trends and what the minimum sampling time frame is before trends can be predicted. This will be accomplished by geo-referencing steelhead redds in index and probabilistically selected stream reaches to better understand the natural variability in the distribution of steelhead spawning.
- Develop a sufficiently strong relationship between index reach surveys and probabilistic surveys that can be used to convert historic index reach-based abundance estimates into a more accurate time series of steelhead abundance. This will be accomplished by using correlation analysis to develop the relationship between abundance estimates generated from probabilistic and index reach-based surveys.

Effectiveness monitoring

- Determine if the habitat preservation/conservation measures implemented on and near National Forest lands affect the abundance and distribution of steelhead redds in the Wenatchee subbasin. This will be accomplished by comparing steelhead redd abundance and distribution between watersheds with high versus low preservation/-conservation efforts.

- Re-evaluate which sampling universe should be used for steelhead redd surveys.
- Determine if index and spatially balanced sampling can be combined to optimize data collection for indicators as temporally variable as steelhead redds by assessing spatio-temporal variance patterns of index areas and comparing them with spatially balanced samples.
- Determine what the cost/benefit (cost/information gained) relationship is for index surveys as compared to probabilistic sampling by comparing costs and the amount and quality of information gained from both types of surveys.
- Determine the optimum sampling frequency for steelhead redd surveys by characterizing the visual "life span" of steelhead redds surveyed in index reaches and applying any new knowledge to optimize the cost effectiveness of periodic surveys at probabilistic sampling sites.
- Determine if probabilistic surveys can be improved by enhanced spatial coverage or more frequent temporal coverage and what the cost/benefit tradeoffs of the number of sites surveyed, the number of times a site is surveyed, and the length of surveyed sites is by assessing the spatial distribution of individual redds, redd "life span," and survey cost information.

What's ahead

Sample steelhead redds at random sites and index areas in Wenatchee subbasin.	2007 - 2015
Sample steelhead redds at random sites and index areas in Entiat subbasin.	2007- 2010

Juvenile Surveys

The evaluation of fish abundance and distribution through snorkeling surveys at probabilistically selected locations is a critical component to status, trend, and effectiveness monitoring (Hillman 2006). The abundance, distribution, and size of juvenile anadromous salmonids in the Wenatchee and Entiat subbasins has not been systematically studied and is largely unknown, despite the fact that models of habitat restoration assume that overall production is largely driven by how many juveniles exist, which habitats they reside in, and how well they grow during their freshwater residence. Similarly, the evaluation of fish abundance at control and treatment sites is critical to restoration project effectiveness monitoring.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

BioAnalysts, Inc.

Chelan County Conservation District

United States Fish and Wildlife Service

United States Forest Service Wenatchee National Forest

Yakama Nation

Time Line

The USFS conducted a pilot snorkeling study at randomly selected sites in 2004 and began annual daytime and nighttime snorkeling observations in 2005 throughout the Wenatchee subbasin that continued in 2006. Similar work at randomly selected sites in the Entiat by BioAnalysts and Yakama Nation began in 2006. Day and night snorkeling surveys have been conducted at control and treatment sites in the Entiat subbasin, seasonally in summer, fall, and winter, by USFWS in 2005 and 2006. Data from probabilistic surveys is examined on a yearly basis and studies should be implemented for at least one complete 5-year rotating panel to generate estimates of interannual variability. Studies will likely need to be implemented for more than 5 years due to unknown but possibly high variability in juvenile fish metrics. It may take many years (10 to 20) to begin to form relationships between juvenile fish abundance, distribution, and growth. Sampling at effectiveness monitoring sites will likely need to continue for at least 20 years.

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	USFS	Day snorkeling	$0	$16,264	$106,822	$122,782
Wenatchee	USFS	Night snorkeling	$0	$0	$78,736	$39,835
Wenatchee	CCCD	Recon for snorkel/habitat	$0	$4,653	$3,231	$1,167
Entiat IMW (intensively monitored watershed and	Yakama Nation	Day snorkeling at status/trend sites	$0	$0	$0	$19,280

comprehensive restoration)						
Entiat IMW (intensively monitored watershed and comprehensive restoration)	BioAnalysts	Day snorkeling at status/trend sites	$0	$0	$0	$28,535
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFWS	Snorkel at effectiveness sites	$0	$0	$0	$0
Entiat B2B	USFWS	B2B-snorkel	$0	$0	$45,518	$120,424
		Total by fiscal year:	$0	$20,917	$234,307	$332,022
		Project total through fiscal year 2006: $587,246				

Links to Annual Reports

- USFS snorkeling survey 2004-2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/usfs_bpa_annual_report2004_2005snork
- USFWS Effectiveness Monitoring Program-Entiat River Bridge to Bridge Snorkel Surveys, 2005-2006.
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Draft_Entiat Effectiveness Monitoring Bridge to Bridge Snorkel 2005_2006.doc
- CCCD reconnaissance report for snorkeling surveys
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/cccd_bpa_annual_report_2005.doc

What's been accomplished so far

Status/Trend- Wenatchee Subbasin

The USFS-Wenatchee National Forest conducted day and night snorkeling surveys or three-pass electrofishing samples at 50 probabilistically located sites (the same sites that are surveyed for habitat conditions) in the Wenatchee subbasin in 2005 and 2006 (a subset of sites was sampled in 2004). A subset of the 50 probabilistically located sites (12 sites in three watersheds within the Wenatchee subbasin) was sampled repeatedly from July through mid-October to investigate temporal variation across the sampling season. Clear differences were found in species assemblages and species/habitat relationships between sites, as well as strong habitat and temporal relationships, suggesting that these factors should be addressed when extrapolating from sampled sites to larger areas (e.g. basin-wide). Other results include:

- Abundance estimates of juvenile steelhead and Chinook, and of other species, varied between day and night snorkels. At most sites, juvenile abundance/observability increased at night (22% – 1,767%). At two sites, where an outmigration event was occurring, juvenile abundance decreased at night (33-64%) (See Chapter 7 for analysis of day/night snorkeling data).
- Preliminary data based on a few sites suggests that for juveniles, side channels are an order of magnitude more densely populated than pools and riffles.
- Juvenile Chinook and juvenile *O. mykiss* exhibited strong but complex diurnal patterns. Juvenile Chinook were more abundant at night at three sites in Nason Creek, and more abundant during the day at two sites in Peshastin Creek. At one Nason Creek site juvenile Chinook were only seen at night; at another they were 50% more abundant at night, and at

another they were 20 times more abundant at night. It is likely that these differences relate to differences in habitat and cover at the three sites, e.g., the most extreme difference in day/night abundances in Nason Creek occurred at the sites with least cover.

- In Peshastin Creek, juvenile Chinook were 20% more abundant during the day. Peshastin smolt-trap and flow data indicate that a small spike in flow and in outmigration occurred on the days Peshastin Creek was snorkeled.
- Outmigrating Chinook and steelhead may migrate more at night and may have been more observable by day, holding in pocket water behind boulders.
- Peshastin Creek did not offer the type of cover preferred by juvenile Chinook and steelhead in Nason Creek.
- In Nason Creek, nearly all juvenile Chinook and steelhead were associated with one of three types of cover: 1) woody debris, 2) large boulder bank rip-rap or 3) a bankside area with protruding underwater fine roots, and in some cases also underwater branches and/or undercut bank. Juvenile steelhead also used an additional form of cover that juvenile Chinook did not use: extremely low depths (typically 4 cm of water or less) often in very small habitat areas (less than one square meter) such as tiny alcove pools or shallow streambanks.
- Juvenile Chinook and steelhead were tightly associated with these cover types during the day. At night they were still associated with this cover but not as tightly; most were within a meter of the cover at night versus within centimeters of the cover during the day; and at night a few were found even farther from cover.
- In Peshastin Creek, where the banks are armored with substrate, underwater roots do not protrude, and woody debris abundance is very low, juvenile Chinook and steelhead occurred in small (typically 2 - 8 individuals) uni- or bi-species schools in the quieter water behind boulders.

Status/Trend – Entiat IMW

Beginning in 2006, an annual panel of 25 status/trend monitoring sites was established to assist in quantifying the effectiveness of the anticipated Recovery Plan restoration actions. Terraqua conducted habitat surveys at these sites in 2006 (and a subset of 10 were surveyed in 2005) and Yakama Nation and BioAnalysts crews conducted snorkel surveys in 2006[1]. Methodology and planned analyses are similar to the status/trend snorkeling in the Wenatchee subbasin. However, additional emphasis will be placed on comparing trends at these sites with trends at effectiveness monitoring sites.

USFWS Entiat River B2B Snorkel Surveys, 2005-2006

The USFWS conducted snorkel surveys at 11 sites and over three seasonal periods during 2005 to 2006 to evaluate fish habitat utilization associated with in-stream restoration work planned for 1.2 miles (approximately 2000 meters) of the lower Entiat River (the B2B reach, Figure 10). Day and night surveys were conducted during the summer period (August), while night surveys were conducted during the fall (October) and winter (March) surveys.

[1] One of the 25 sites could not be snorkeled due to a forest fire that started before snorkel crews could reach the site.

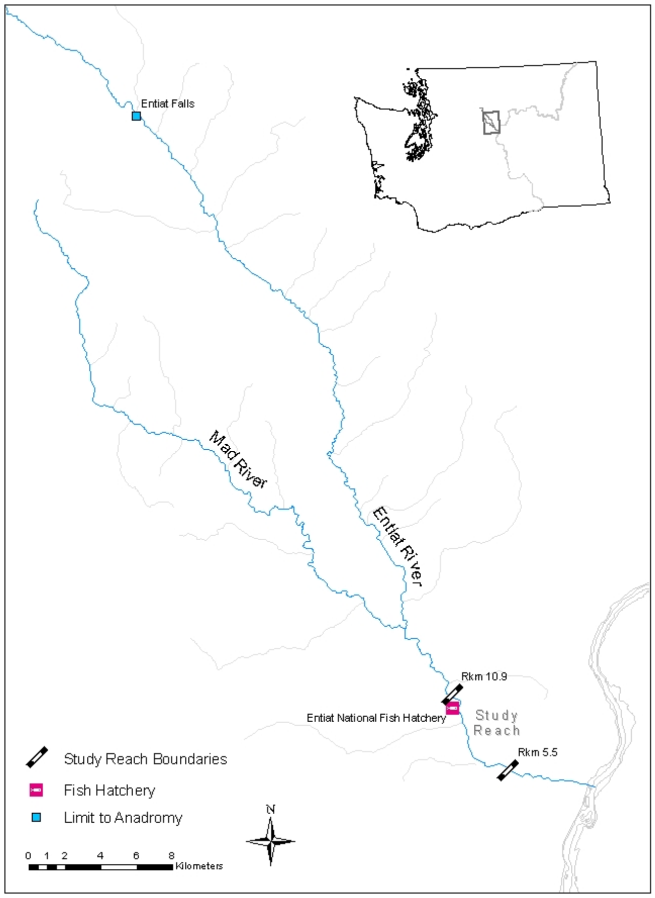


Figure 10. Bridge-to-Bridge study reach map of the Entiat River watershed from Rkm 5.2 to 10.9.

A total of 33,403 fish from 13 species/genus were enumerated. Rainbow trout were the overall most common fish observed and comprised 40% of fish enumerated followed by Chinook salmon (22%) and mountain whitefish (13%)(Table 9). For fish identified to species or genus, rainbow trout composed 39 % of the total observed count followed by Chinook salmon (22 %), mountain whitefish (13%), and dace sp. (8%). Unidentified species/genus fish composed 15% of the observed fish and were primarily juvenile or small fish observed in water too shallow to snorkel along the river margins. The remaining 3% of fish identified to species/genus were composed of bull trout, coho and sockeye salmon, cutthroat trout, lamprey, and pikeminnow, redside shiner, sculpin spp., and sucker spp.

For seasonal time periods and time of day snorkeled, rainbow trout were observed in the greatest numbers in the summer-day, and the fall and winter night surveys. Chinook salmon were the most common during the summer-night survey followed by rainbow trout. The number of unknown fish decreased markedly during the fall and winter surveys. The total numbers of

Chinook salmon, dace spp., mountain whitefish, and sculpin spp. observed increased during summer-night surveys compared to the summer-day surveys, while the number of rainbow trout decreased during the summer-night snorkel.

The greatest number of fish encountered by site was primarily at existing control sites where habitat modifications have been in place. Further analysis is needed to address whether there are statistical differences between sites.

Table 9. The number of fish species observed by period and time of day during snorkel surveys in the Entiat River during 2005-2006.

Fish species	Summer day	Summer night	Fall night	Winter night	Total
Bull trout	1	1	4	0	6
Chinook salmon	2,025	3,584	1,497	172	7,278
Coho salmon	10	1	3	0	14
Cutthroat trout	7	1	4	0	12
Dace spp.	458	1,604	712	41	2,815
Lamprey	1	6	3	10	20
Mountain Whitefish	1,580	2,545	294	18	4,437
Pikeminnow	4	8	0	0	12
Rainbow trout	4,073	3,287	4,154	1,529	13,043
Redside shiner	0	2	0	0	2
Sculpin spp.	16	241	144	34	435
Sockeye salmon	0	0	1	3	4
Sucker spp.	155	68	37	1	261
Unknown fish	3,141	1,903	9	11	5,064
Grand Total	11,471	13,251	6,862	1,819	33,403

Fish densities were studied at 11 control/treatment site-components at 7 treatment or control locations. The goal for this analysis was to determine if the B2B effectiveness monitoring conceptual study design was supported by the first year of data. In this conceptual design, it was anticipated that control and pre-treatment sites will look the same until the treatments (restoration projects) are implemented, at which time the post-treatment sites should behave more like sites that currently have undergone restoration treatments (i.e. "pre-existing treatment sites").

After one year of data, the hypotheses that (a) sites with pre-existing treatments should have higher fish densities than control or pre-treatment sites, and (b) that control and pre-treatment sites should have similar fish densities, were rejected. Salmonid densities at sites where side channel and main channel habitat were combined did not vary as expected (where sites with pre-exiting treatments [PC] were predicted to have greater densities than control [C] or sites not yet treated [T] (Figure 11). However, salmonid densities in side channels were much greater than in main channels, suggesting that the presence/absence of side channels needs to be controlled for (Figure 12). When only main channels were compared, both hypotheses (a) and (b) appear to be supported, suggesting that our conceptual study design is valid: within sites, salmonid densities were much greater in side-channel habitat as compared to main channel habitats (Figure 13). Salmonid densities were greatest at those main-channel sites (Dinkelman and Jon Small) where the main channel had previously been treated with restoration projects than at all other sites where the main channels were untreated, particularly in summer and fall.

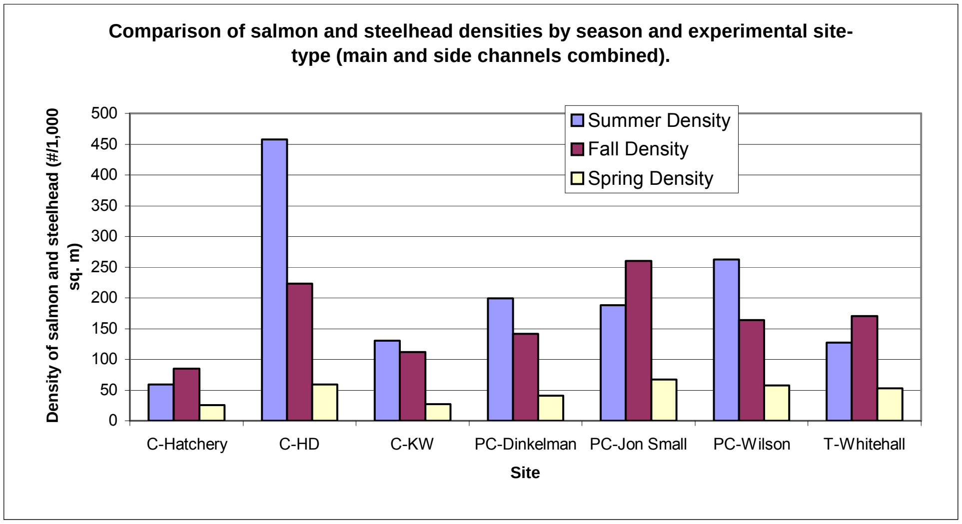


Figure 11. Comparison of salmon and steelhead densities by season and experimental site-type (main and side channels combined) in the Entiat Bridge-to-Bridge restoration project 2005 - 2006.

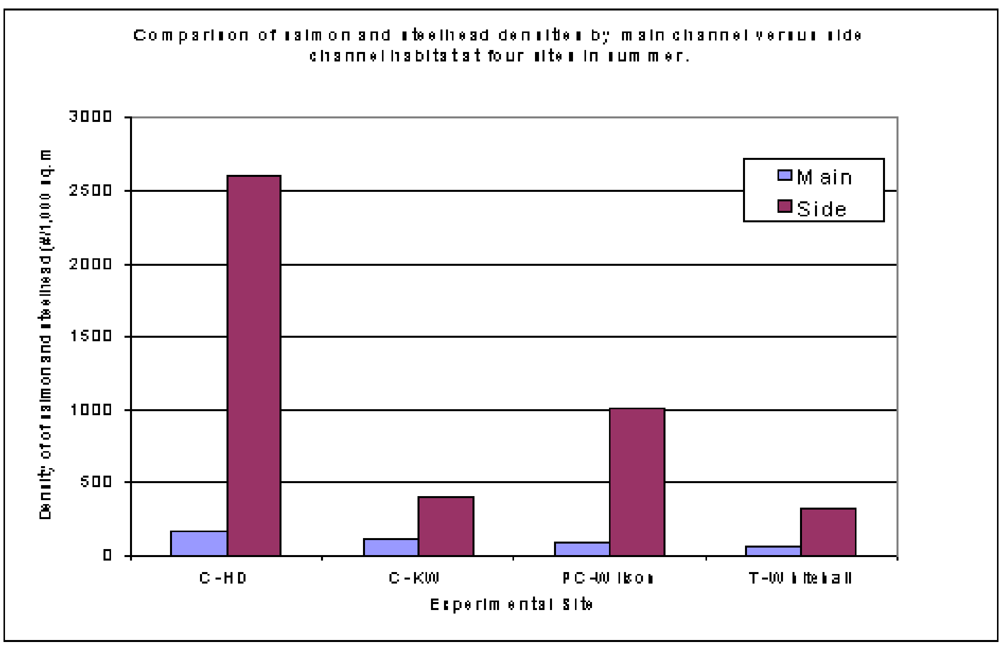


Figure 12. Comparison of salmon and steelhead densities by main channel versus side channel habitat at four sites in summer in the Entiat Bridge-to-Bridge restoration project 2005 - 2006.

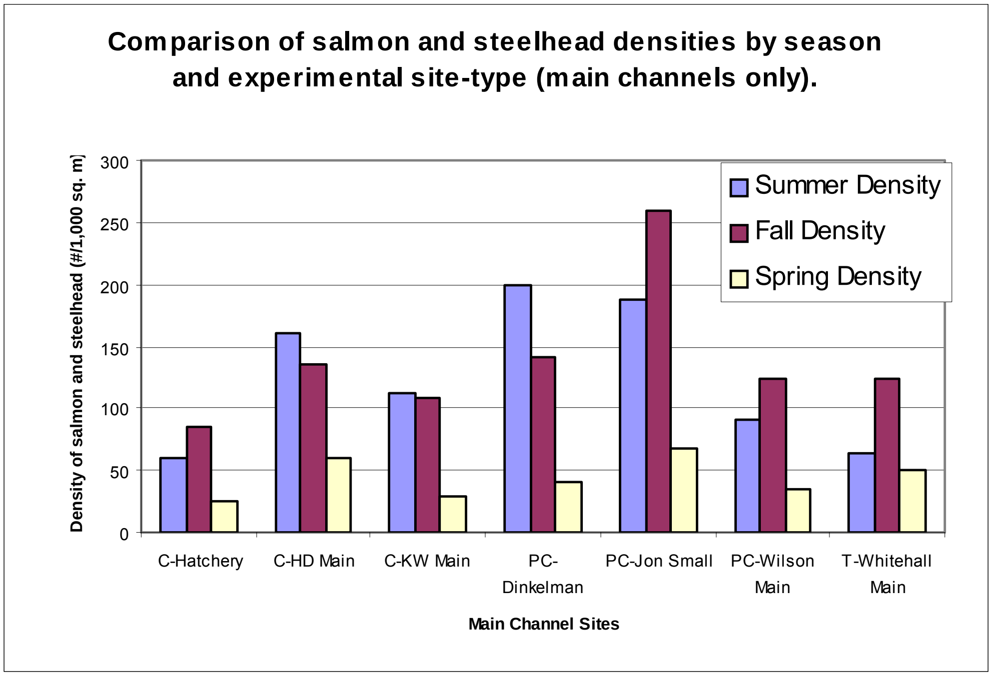


Figure 13. Comparison of salmon and steelhead densities by season and experimental site-type (main channels only) in the Entiat Bridge-to-Bridge restoration project 2005 - 2006.

It is recommended that the B2B portion of the study continue within the context of subbasin-scale effectiveness monitoring to be implemented in 2007, and that more formal intervention analyses be performed to test these hypotheses when additional data has been collected.

Key Analysis Planned

Status monitoring

- Quantify the number, species, and size of fish present within each of the 50 probabilistically located sites snorkeled per year.

Trend monitoring

- Generate stratified correlations between key habitat metrics and fish habitat utilization metrics (i.e. abundance, distribution, and size of juvenile anadromous salmonids) to determine the interannual variation in the abundance, distribution, and size of juvenile anadromous salmonids in the Wenatchee subbasin.
- Generate stratified correlations between key habitat metrics and fish habitat utilization metrics (i.e. abundance, distribution, and size of juvenile anadromous salmonids) to determine relationships between habitat metrics (e.g. channel conditions, water quality, landscape classification) and the abundance, distribution, and size of juvenile anadromous salmonids.

Effectiveness monitoring

- Develop a clear understanding of the magnitude and variability in the abundance, distribution, and size of juvenile anadromous salmonids by quantifying the number, species, and size of fish present within each site surveyed. Repeated surveys will give us an understanding of the variation that can be expected at particular sites. These surveys will generate the control conditions against which to compare treatment conditions at future restoration sites, particularly because the sites at which snorkeling will occur have been classified and can be statistically stratified to reflect conditions at most, if not all, possible treatment sites.
- Depending on the needs of the Chelan County PUD Hatchery Program, information regarding juvenile salmonid abundance, distribution, and size among supplemented and non-supplemented watersheds can be made available to provide a context for comparison with egg-to-smolt survival estimates and to partition variation in those estimates that is likely to be observed.
- Depending on the needs of the CCPUD Hatchery Program, information regarding the ecological response in non-target taxa in streams with hatchery supplementation could be available from snorkeling surveys conducted on an annual basis throughout supplemented and non-supplemented watersheds. These surveys include information on all fish species and may eventually yield a sufficient base of observation upon which to draw conclusions regarding impacts of supplementation on non-target taxa.
- Information on all fish species collected during annual snorkeling surveys will be analyzed for the effects of habitat restoration projects.
- Compare ISEMP- and NOAA-funded day- and nighttime snorkeling data with similar data collected at nighttime to determine how time of day affects the results of snorkeling observations.
- Resurvey a random sample of at least 10 percent of the sites surveyed in each subbasin on an annual basis to quantify measurement error.
- Snorkel observations by other monitoring programs (e.g. studies of coho salmon by ODFW) sample only pools because this “pool-only” approach is cost-effective and works when pool habitat contains the majority of all juveniles, especially during summer low-flow conditions. Snorkel data collected in 2005 and 2006 will be used as a pilot study to determine the relative use of pool and non-pool habitat by fish in the Wenatchee subbasin. A “pool-only” or other types of cost-effective approaches may be more formally tested if pilot data so warrants.

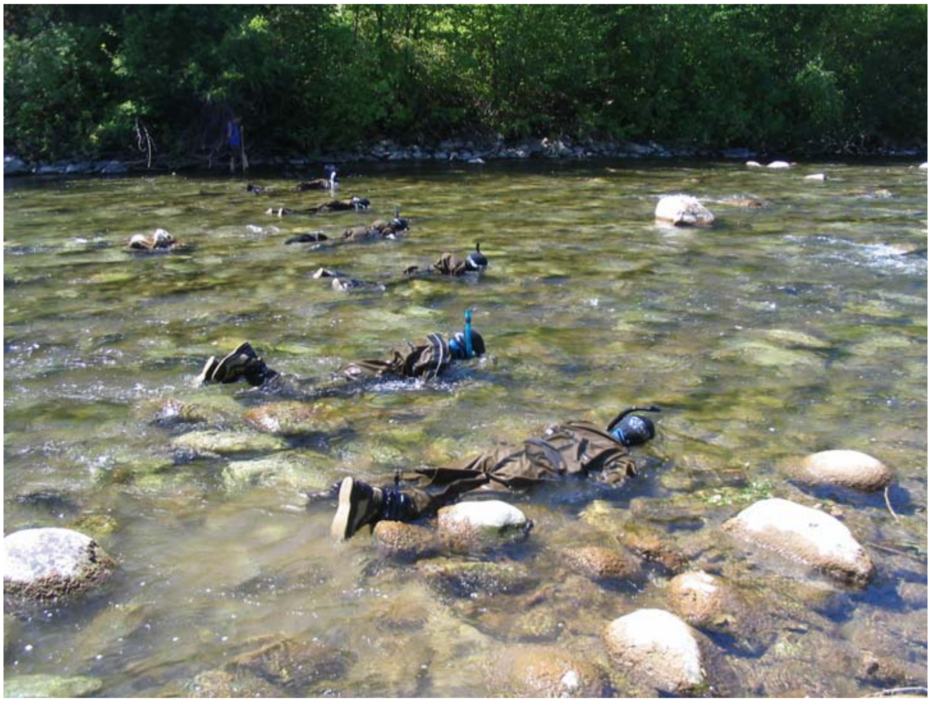


Figure 14. A USFWS crew conducts a daytime snorkeling survey as part of the Entiat River Bridge-to-Bridge Effectiveness Monitoring program. Surveys evaluate fish habitat utilization associated with in-stream restoration work planned for 1.2 miles (approximately 2,000 meters) of the lower Entiat River referred to as the "Bridge to Bridge" reach. (Photograph courtesy of USFWS Mid-Columbia Fishery Resource Office).

What's ahead

Conduct reconnaissance and obtain landowner permission for 50 random locations used in snorkel and habitat surveys in Wenatchee subbasin	2007 - 2015
Survey fish populations through snorkeling at 50 locations plus 5 re-samples per year in the Wenatchee subbasin	2007 - 2015
Conduct reconnaissance and obtain landowner permission for 50 random locations used in snorkel and habitat surveys in Entiat IMW	2007 - 2015
Survey fish populations through snorkeling at 25 locations plus 5 re-samples per year in the Entiat IMW	2007 - 2011
Survey fish populations seasonally (3 times/year) through snorkeling at B2B treatment and control sites. Add additional treatment and control sites as part of the effort to expand effectiveness monitoring throughout the Entiat IMW.	2007 - 2015

Smolt Trapping

Smolt abundance is an estimate of the total number of smolts produced within a watershed or basin for an entire population or subpopulation (Hillman 2006). Through the ISEMP, smolt trapping programs have been expanded to include more floating screw traps operated for longer duration to collect downstream migrating smolts. In the Entiat subbasin, smolt trapping that once targeted only spring Chinook has been expanded to also count steelhead emigration at the subbasin scale.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

United States Fish and Wildlife Service

Washington Department of Fish and Wildlife

Yakama Nation

Time Line

Annual smolt trapping was expanded to encompass the entire outmigration season from March through December and additional smolt traps were added at necessary locations starting in 2004. The USFWS has operated a trap continuously in Peshastin Creek since 2004 and in 2006 another trap was added near the mouth of the Entiat to improve the efficiency of the original trap and to allow for quantification of salmon and steelhead at the subbasin scale. The smolt trapping programs are expected to have duration of 10 to 20 years. In the Entiat subbasin, the USFWS began operation of a smolt trap upstream of the treatment reach in 2004 and will continue this operation indefinitely.

Budget

Subbasin	Contractor	Location	FY03	FY04	FY05	FY06
Wenatchee	WDFW	Lake W.	$0	$63,168	$29,812	$35,637
Wenatchee	WDFW	Monitor	$0	$72,029	$29,812	$35,637
Wenatchee	Yakama Nation	Nason	$0	$18,366	$54,912	$62,244
Wenatchee	USFWS	Peshastin	$0	$40,988	$0	$0
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFWS	Smolt trap at Entiat Mouth	$0	$0	$0	$49,000
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFWS	Smolt trap at RM 6	$0	$24,875	$24,875	$0
		Total by fiscal year:	$0	$219,426	$139,410	$182,518
					Project total through fiscal year 2006:	$541,355

Links to Annual Reports

- WDFW Expansion of Existing Smolt Trapping Program and Steelhead Spawner Surveys Draft Annual Report 2004 Performance/Budget Period: March 1st, 2004 – February 28th, 2005
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdfw_bpa_annual_report2004_2005.doc
- WDFW Expansion of Existing Smolt Trapping Program and Steelhead Spawner Surveys Draft Annual Report 2005, Performance/Budget Period: March 1st, 2005 – February 28th, 2006
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2005_wdfw_draft_imw_annual_report.doc
- Yakama Nation Expansion of Existing Smolt Trapping Program in Nason Creek 2004 Draft Annual Report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/yakama_nason_bpa_annual_report2004-2005.doc
- USFWS Peshastin Creek Smolt Monitoring Program Annual Report March 2004 – December 2004
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/usfws_annual_report2004_2005.doc

Figure 15. USFWS personnel set up a rotary screw trap in Peshastin Creek in the spring of 2004. The trap will generate estimates of spring Chinook and steelhead smolt production and describe variability in run-timing. (Photograph courtesy of the USFWS Mid-Columbia Fishery Resource Office).

What's been accomplished so far

A comprehensive trapping program consisting of six traps located throughout the Wenatchee subbasin and two in the Entiat subbasin that are funded by the ISEMP and cooperating agencies is underway (Table 10).

Table 10. Current smolt trap locations within the Wenatchee and Entiat subbasins.

Trap Location	Rkm	Year started	Funding Agency
Lower Wenatchee – 2 traps	16	2000 & 2005*	SRFB & CCPUD; BPA
Upper Wenatchee – 2 traps	90	1997 & 2005*	CCPUD; BPA
Chiwawa River	1	1993	CCPUD
Nason Creek	1	2001	BPA
Peshastin Creek	10	2004 only	BPA
Entiat River	11	2004	USFWS, BPA
Entiat River	1	2006	NOAA

* The second date refers to the year that a second trap, funded by ISEMP, was installed at these sites to improve trapping efficiencies.

- As part of the ISEMP, and also funded by CCPUD and SRFB, the WDFW began annually estimating the smolt production of spring Chinook salmon and steelhead for the Wenatchee subbasin and smolt production in the Lake Wenatchee (sockeye, spring Chinook, steelhead) and Chiwawa River (spring Chinook, steelhead) watersheds in 2004.
- As part of the ISEMP, and partly funded by BPA, the Yakama Nation began annually estimating spring Chinook salmon and steelhead smolt production for the Nason Creek watershed and describing the temporal variability of outmigrating spring Chinook and steelhead within Nason Creek.
- As part of the ISEMP, and partly funded by BPA, USFWS ran a smolt trap in the Peshastin Creek watershed in 2004 to estimate the smolt production of spring Chinook salmon and steelhead and describe the temporal variability of outmigrating spring Chinook and steelhead within Peshastin Creek. The USFWS also began operation of a smolt trap upstream of the B2B treatment reach in the Entiat subbasin in 2004 and will continue this operation indefinitely.

WDFW Smolt Production Study

The WDFW was contracted to estimate the smolt production of spring Chinook *O. tshawytscha* salmon and steelhead for the Wenatchee subbasin with the aim of increasing not only the scope, but also the accuracy and precision of smolt production estimates for the entire Wenatchee subbasin. Previously, the limited scope of the upper Wenatchee smolt monitoring program (i.e., for sockeye only) prohibited estimating smolt production of other species (e.g. spring Chinook and steelhead) that spawn in the Little Wenatchee and White River watersheds (tributaries of Lake Wenatchee). Furthermore, the trap efficiency at both the upper and lower Wenatchee River locations had been determined to be inadequate to provide smolt production estimates of steelhead and spring Chinook with the desired level of precision. With additional funding from the ISEMP, the trapping period of the upper Wenatchee smolt monitoring program was increased to encompass the entire spring Chinook emigration period and provide an additional smolt trap and personnel (beginning in 2005) at each location to increase the capture efficiency and provide a higher level of precision (Figure 16).

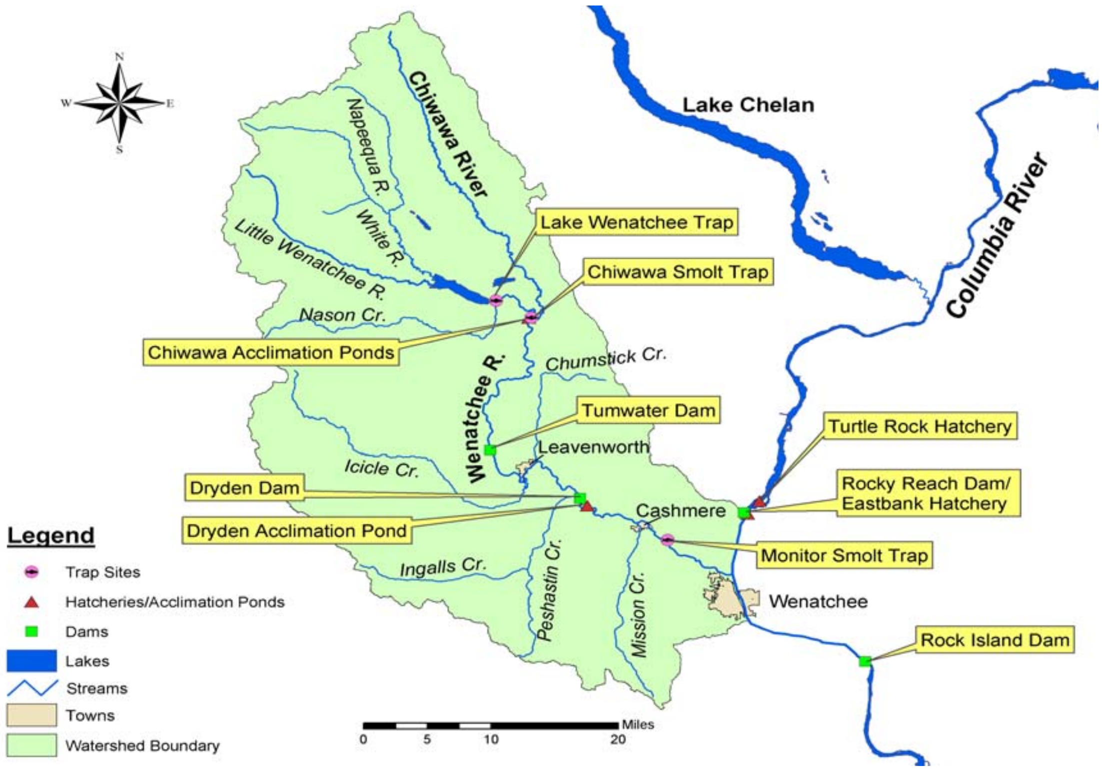


Figure 16. Location of the upper Wenatchee (Lake Wenatchee Trap) and lower Wenatchee River (Monitor Smolt Trap) smolt traps.

The Upper Wenatchee Smolt Trap

The upper Wenatchee River smolt trap was located approximately 0.5 km below the outlet of Lake Wenatchee (Figure 16). In 2004, the trap was operated nightly between 3 March and 18 November. A total of 355 yearling spring Chinook smolts and 55 juvenile steelhead were captured during the sampling period. One steelhead fry was also captured during trapping. Due to the low numbers of spring Chinook and steelhead captured, wild sockeye smolts were used as a surrogate for mark/recapture efficiency trials. Eleven mark/recapture efficiency trials were conducted during the sampling period and 10,949 marked sockeye were released into Lake Wenatchee, of which 72 were recaptured. A delay in migration and subsequent recapture of the marked fish from Lake Wenatchee negatively affected the relationship between discharge and trap efficiency (i.e., unequal probability of recapture). Therefore, the pooled trap efficiency (0.7%) was used to calculate the spring Chinook and steelhead smolt production estimate. The smolt production estimate (95% C.I.) for spring Chinook and steelhead was 50,857 (± 1,957) and 143 (± 32), respectively.

In 2005, the trap operated nightly between 5 March and 30 June. A total of 61 yearling spring Chinook smolts and 36 juvenile steelhead were captured during the sampling period. A total of 826 steelhead fry were also captured during trapping. Due to the low numbers of spring Chinook and steelhead captured, wild sockeye smolts were used as a surrogate for mark/recapture efficiency trials. Two mark/recapture efficiency trials were conducted during the sampling period and released 1,869 marked sockeye (i.e., caudal fin clip) into Lake Wenatchee, of which 17 were recaptured. A delay in migration and subsequent recapture of the marked fish from Lake Wenatchee negatively affected the relationship between discharge and trap efficiency (i.e., unequal probability of recapture). Therefore, the pooled trap efficiency (0.91%) was used to calculate the spring Chinook and steelhead smolt production estimate. The smolt production estimate (95% C.I.) for spring Chinook and steelhead was 6,706 (± 595) and 110 (± 52), respectively.

Lower Wenatchee River Smolt Trap

The lower Wenatchee River smolt trap was located at the West Monitor Bridge (rkm 9.6) (Figure 16). In 2004, the trap was operated nightly between 12 February and 29 July and captured 1,061 wild spring Chinook and 360 juvenile steelhead. A total of 131 steelhead fry were also captured. Low daily numbers of spring Chinook and steelhead captured precluded their use for mark/recapture trials. Hatchery Chinook and hatchery coho were used as surrogates for mark/recaptures trials, which were conducted at various levels of river discharge or if the trap position had changed. Ten mark/recapture efficiency trials were conducted during the sampling period with 4,776 marked hatchery Chinook and coho released into the Wenatchee River, of which 45 were recaptured. Smolt production estimates were calculated using separate regression models (independent variable = river discharge) for each of the two trap positions. In some cases, efficiency trials from previous years (i.e., 2001-2003) were used in the regression model to increase sample size. Hatchery coho and hatchery Chinook will be used as surrogates in trap efficiency trials until the relative abundance of wild spring Chinook and steelhead increases or trap efficiency significantly increases (e.g., a second trap) to perform species-specific efficiency trials. The 2004 smolt production estimate for wild spring Chinook and steelhead was 198,012 and 42,733, respectively.

In 2005, the trap operated nightly between 18 February and 13 July. A total of 333 wild spring Chinook, 246 juvenile steelhead, and 183 steelhead fry were captured. Low daily numbers of spring Chinook and steelhead captured precluded their use for mark/recapture trials so hatchery Chinook and hatchery coho were used as surrogates. Trails were conducted at various levels of river discharge or if the trap position had changed. Five mark/recapture efficiency trials were conducted during the sampling period and 2,301 marked yearling salmon (i.e. hatchery Chinook and coho) were released, of which 24 were recaptured. Smolt production estimates were calculated using separate regression models for each of the two trap positions. In some cases, efficiency trials from previous years (i.e., 2001-2004) were used in the regression model to increase the sample size in the model. The 2005 smolt production estimates (95% CI) for wild spring Chinook and steelhead was 70,738 (±9,514) and 41,192 (±7,104), respectively.

Yakama Nation Steelhead Monitoring in Nason Creek

In the fall of 2004, in coordination with the ISEMP and many other agencies, the Yakama Nation Fisheries Resource Management program began an extended (from 3 months per year to

9 months per year) smolt trapping effort that monitored the downstream migration of Upper Columbia River Spring Chinook Salmon and Upper Columbia Steelhead in Nason Creek, a tributary to the Wenatchee River (Figure 17). This was the first year the Nason Creek smolt trap was operated for the purpose of generating population estimates for juvenile spring Chinook and steelhead in Nason Creek.

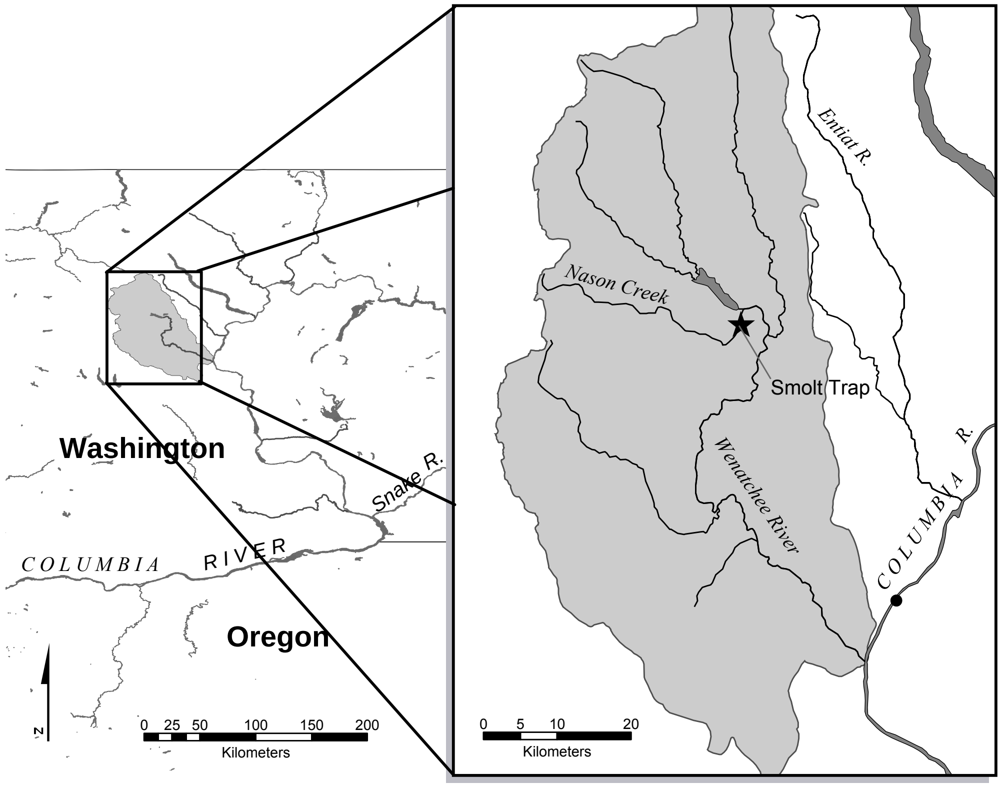


Figure 17. Location of the Nason Creek smolt trap, Wenatchee subbasin, WA.

In 2004, the spring trapping period began on March 8th and ended on June 16th and the fall period began on September 3rd and ended on November 24th. During the spring, 336 yearling (2002 brood) spring Chinook salmon, 172 wild steelhead smolts and 283 steelhead parr were collected. A total of 8 mark-recapture trap efficiency trials were performed using hatchery coho smolts as a surrogate species over a range of stream discharge stages. A pooled trap efficiency of 3.9% was used to estimate the population size of both spring Chinook and steelhead smolts. It is estimated that 9,084 (± 410 95%CI) yearling spring Chinook and 4,955 (± 258 95%CI) steelhead smolts emigrated past the trap during the spring sample period between March 8th and June 19th of 2004.

During the fall, 1,458 subyearling (2003 brood) spring Chinook salmon and 690 steelhead parr were collected. A total of 7 mark-recapture trap efficiency trials were conducted, 5 using spring Chinook and 2 with steelhead parr, over a range of stream discharge stages. A pooled trap efficiency of 20.3% was used to calculate the emigration of spring Chinook and

18.8% was used for steelhead parr during the fall trapping period from September 3rd through November 24th. It was estimated that 7,899 (± 341 95%CI) subyearling spring Chinook and 4,071 (± 509 95%CI) steelhead parr migrated downstream past the trap during the fall sample period of 2004. If movements of steelhead parr between March 8th and June 19th are assumed to be fish emigrating from Nason Creek, the total population estimate using the pooled trap efficiency (3.9%) is 7,742 (± 339 95%CI).

Preliminary conclusions based on 2004 data regarding emigration timing of spring Chinook and steelhead within Nason Creek is that there appear to be two distinct emigrations of spring Chinook: a spring group of yearlings which overwintered and a subyearling group of migrants in the fall. Nason Creek steelhead emigrate at different life stages, some as smolts in the spring and others as parr throughout the year.

USFWS Peshastin Creek Smolt Trapping Program

In 2004, the ISEMP worked with the USFWS MCRFRO on a one-year study to monitor smolt production in Peshastin Creek and to study/recommend optimized allocation of sampling effort. An instream rotary screw trap was utilized to capture downstream migrant juvenile fishes and was operated for 208 days of complete sampling from March through November. Technical methodologies followed protocols specified in Hillman (2006).

A total of 8,955 individuals were sampled throughout the trapping season. Spring Chinook and steelhead/rainbow trout represented 48.2% (4,319) and 48.0% (4,302) of the total catch, respectively. The remaining catch consisted of 112 bull trout, 58 coho salmon, 155 sculpin, and 9 adult fall-back salmonids (Figure 18).

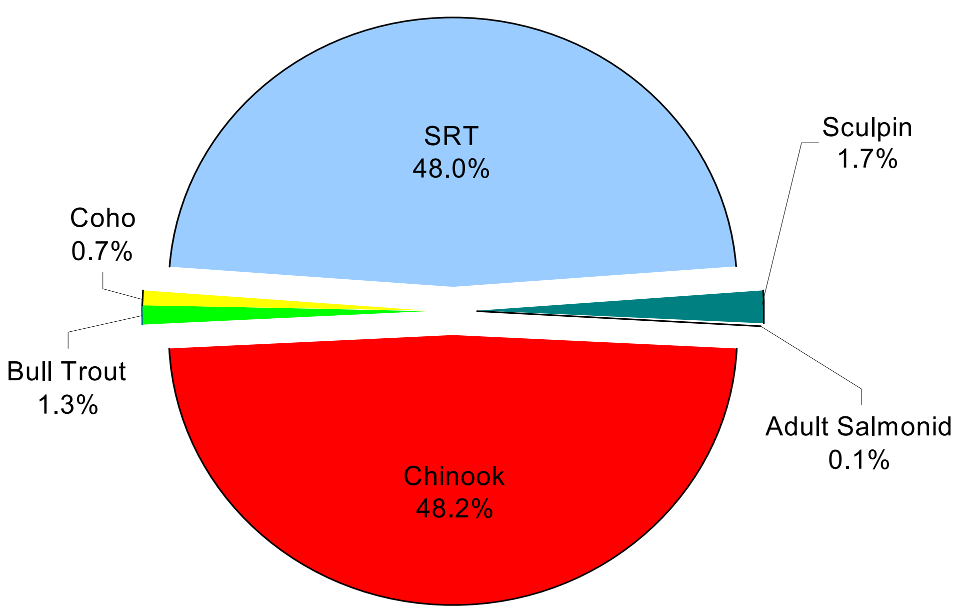


Figure 18. Relative abundance of fish captured in the Peshastin Creek smolt trap, 2004, Wenatchee subbasin, WA.

Trapping was successful and 1,712 juvenile Chinook were fitted with PIT tags for future analysis of survival and migration timing through the Columbia River hydro-corridor. An additional 314 spring Chinook were captured at the trap site by seine net and PIT-tagged on August 20 (Table 11).

Table 11. Peshastin Creek catch summary for 3/18/04 to 11/21/04.

Species	Total captured	Total PIT tagged	Number released for efficiency	Number recaptured
Spring Chinook	4,319	1,712	1,508	466
Steelhead/Rainbow Trout	4,302	0	195	42
Coho Salmon	58	2	0	0
Bull Trout	112	0	0	0
Sculpin spp.	155	0	0	0
Hatchery Chinook Jack	2	0	0	0
Adult Steelhead	1	0	0	0
Adult Chinook	6	0	0	0
TOTALS	8,955	1,714	1,703	508

Steelhead and rainbow trout data were combined because both forms of *O. mykiss* are present in Peshastin Creek and undistinguishable by visual examination during most of their freshwater phase. In 2004, the permits did not allow for tagging of steelhead. In 2004, there were a total of 248 individuals large enough (≥65mm) to PIT-tag in the spring stratum, 412 individuals large enough to PIT-tag during the summer stratum, and 2,312 steelhead/rainbow trout individuals were large enough to PIT-tag during the fall stratum.

It is estimated that 66,395 (± 20,147, 95%CI) sub-yearling (age 0) Chinook and 16,082 (± 3,982, 95%CI) steelhead/rainbow trout, representing three age-classes, emigrated from Peshastin Creek during the 2004 sampling period. Steelhead/rainbow trout age-0, age-1, age-2 are estimated to represent 52% (8,419), 42% (6,770), and 6% (893) of the population estimate, respectively. Only one yearling (age-1) spring Chinook was captured in the 2004 season. Therefore, a production estimate for this age class could not be generated.

Recommendations to improve future trap operation include:

- Begin trapping in early-March to document low over-winter emigration rates prior to prevalence of spring conditions;
- Operate the trap seven days a week during the spring and fall to capture all potential pulses in emigration, and
- Conduct or acquire consistent and reliable monitoring of stream characteristics to provide greater precision in which to relate trap efficiency tests towards generating sound daily emigration estimates.

USFWS Entiat River rotary screw trap

Located at river km 11 below the Entiat National Fish Hatchery, a rotary screw trap has been run five days a week by a two-person crew except during periods of high flows, excessive debris, or extreme weather. From September 1, 2005 to May 16, 2006, with NOAA-ISEMP funding, the trap ran a total of 112 days (109 complete, 3 incomplete), but was not run during December, January, and February due to ice, or from May 17 to August 24 due to high temperatures and lack of funding. During that time, 4,118 spring Chinook juveniles marked with PIT tags, of which 2,340 were sub-yearlings emigrating in the fall and 1,778 were yearlings emigrating in the spring. In addition, 1,683 steelhead juveniles were marked with PIT tags, of which 187 were juveniles emigrating in the fall and 999 were juveniles emigrating in the spring.

Key Analyses Planned

Status Monitoring

- Determine if smolt trapping can provide reliable estimates of steelhead smolt/outmigrant abundance by expanding smolt trapping efforts to include all seasons when juvenile steelhead migrate and improving trapping efficiency.
- Determine steelhead life history strategies and outmigration timing in the Wenatchee subbasin.
- Determine life-stage specific survival rates to gauge effectiveness of habitat restoration actions using mark-recapture studies for a minimum of 3 years.

Trend Monitoring

- Compare outmigration patterns between subbasin watersheds.
- Determine how various sampling regimes and expression of various life history strategies confound understanding of smolt outmigration timing and production estimates.

Effectiveness Monitoring

- Identify physical or biological covariates/factors that explain differences in smolt production between watersheds.
- Compare relative contributions to smolt production of specific watersheds versus the entire subbasin, and determine how this and annual variability affects our ability to detect changes stemming from habitat restoration actions.
- Characterize the effectiveness of spring Chinook outplanting efforts by the Leavenworth National Fish Hatchery.
- Examine spatial patterns/variability and estimate the affects of temporal sampling on estimators developed from smolt trapping. Develop adaptive rules for more efficient allocation of sampling effort in future years.

What's ahead

Operate smolt traps at four locations in Wenatchee	2007 - 2015
Install rotary screw traps in lower mainstem Entiat	2006 and 2007
Operate smolt traps at two locations in Entiat	2007 – 2015

PIT Tag Deployment

PIT tags are used in mark-recapture studies to generate estimates of abundance of smolts passing through screw traps. The ISEMP has designed a PIT tagging program that will compare habitat use, life-history, and life-stage specific survival rates between spring Chinook and steelhead salmon sub-populations that rear in tributary streams, such as Nason Creek and Chiwawa River, to those that rear in the mainstem Wenatchee River. In the Entiat, PIT tags will also be used for life-history studies and within-subbasin survival rate studies related to effectiveness monitoring of planned restoration actions. PIT tags will be detected at multiple locations within the Wenatchee and Entiat subbasins at detection arrays to be built with funds from the ISEMP in 2006, as well as at other locations throughout the Columbia River where PIT tag detection methodologies are in practice.

Funding Agencies

Bonneville Power Administration
Chelan County Public Utility District
National Oceanic and Atmospheric Administration

Contractors

BioAnalysts, Inc.
United States Fish and Wildlife Service
Washington Department of Fish and Wildlife
Yakama Nation

Time Line

A pilot project in the Wenatchee and Entiat was initiated in 2006 with plans to continue to at least 2016.

Figure 19. PIT tagging the small smolts is delicate work. The PIT tag is inserted into the fish using a hypodermic needle while another member of the field crew waits to scan the PIT tag once it's inserted (lower left of picture).

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	BPA	Cost of pit tags	$0	$0	$0	$40,915
Wenatchee	Yakama Nation	Deployment of PIT tags at Nason screw trap and at remote locations	$0	$0	$0	$0
Wenatchee	BioAnalysts	Fish capture for PIT tags at remote locations	$0	$0	$0	$10,700
Wenatchee	WDFW	PIT tag detector array and deployment at remote locations	$0	$0	$0	$95,000
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFWS	PIT tag deployment	$0	$0	$0	$0
		Total by fiscal year:	$0	$0	$0	$146,615
		Project total through fiscal year 2006:				$146,615

Link to Protocol

- Interim Protocols for the Capture, Handling, and Tagging of Wild Salmonids in the Upper Columbia River Basin using Passive Integrated Transponder (PIT) Tags (Working draft for 2006)
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/PIT Tagging Protocol_2006WorkingDraft_060411.doc

What's been accomplished so far

- The ISEMP coordinated the development of interim protocols for the capture, handling, and tagging of wild salmonids in the Upper Columbia River Basin using PIT Tags (Working draft for 2006). These protocols were developed by several collaborating agencies working throughout the Upper Columbia to insure that survival of PIT-tagged fish is not biased by previously non-standardized capture, handling, and tagging protocols.

- In 2005, the USFWS MCRFRO operated a rotary screw at river mile 7 in the Entiat River and used angling methods to capture and PIT tag 1,840 juvenile steelhead. The survival and migration timing of these juvenile steelhead through the Columbia River hydrosystem will be assessed through DART and PITAGIS. Returning adult PIT tagged fish will provide information on the smolt to adult survival.

- Under the ISEMP's coordination, multiple collaborators sampled and tagged wild fish at both smolt traps and non-smolt trap (remote) locations in 2006. PIT tags were deployed at smolt traps where large numbers of wild steelhead and spring Chinook were encountered to tag as many fish as possible to achieve large sample sizes quickly and to correspond with predicted high escapements. Steelhead and spring Chinook were caught at non-trap locations using electrofishing, angling, herding into fyke nets, or other capture methods within Nason Creek, Upper Wenatchee River, Chiwawa River, and Peshastin Creek. Sampling occurred in July and August when smolt trap operations are suspended due to low flows.

Macroinvertebrate Sampling

Macroinvertebrate communities are a key component of aquatic food webs. As an important component of the diet of anadromous salmonids they are likely to play a crucial role in determining the productivity of salmonids in freshwater. Thus invertebrate composition and their transport from headwaters to downstream habitats are key attributes of freshwater productivity (Hillman 2006). We need a better understanding of how macroinvertebrate communities co-vary with the abundance, distribution, and size of juvenile salmonids. Under the ISEMP, macroinvertebrate data is being collected at the same probabilistic sites where fish and habitat data is also being collected.

Funding Agency
Bonneville Power Administration

Contractors
Rhithron, Inc.
Terraqua, Inc.
United States Forest Service Wenatchee National Forest-Pacific Northwest Research Station & University of Alaska
Washington Department of Ecology

Time Line

Macroinvertebrate data will be collected for at least 5 years from July through mid-October and analyzed for relationships at least once after every 5-year rotating panel design, or more frequently if necessary. The need to continue macroinvertebrate data collection will be evaluated after the first 5 years. A headwaters productivity study was conducted from April through October 2004 to 2006.

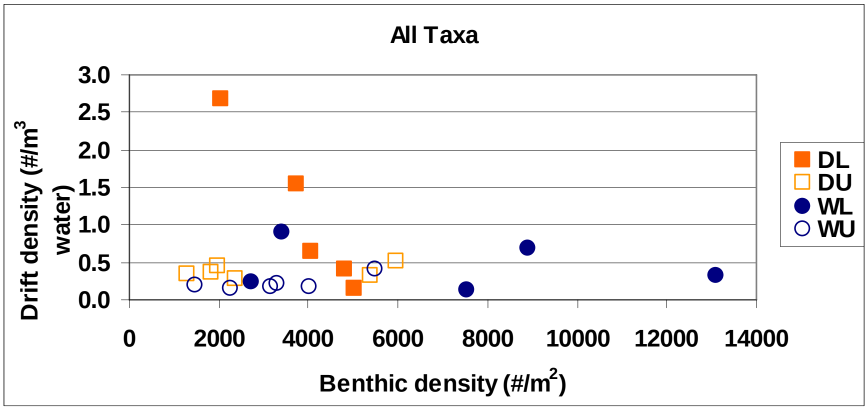


Figure 20. The relationship between benthic invertebrate density and corresponding drifting invertebrate density in the Wenatchee subbasin in different habitat types (DL = dry logged; GU = dry unlogged; WL = wet logged, and WU = wet unlogged)(From Polivka et al Final draft BPA Report).

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	Terraqua	Collect macroinvertebrates at 5 repeat sites	$0	$303	$193	$220
Wenatchee	WDOE	Collect macroinvertebrates at 50 sites	$0	$10,571	$12,526	$12,962
Wenatchee	Rhithron	Macroinvertebrate identification	$0	$12,903	$19,901	$28,115
Wenatchee	USFS-PNW	Headwaters study	$0	$53,082	$112,488	$184,312
Wenatchee	Univ. AK-F	Headwaters study	$0	$105,591	$88,258	$131,547
Entiat B2B	Terraqua	B2B-bug collect	$0	$0	$2,206	$1,754
Entiat IMW (intensively monitored watershed and comprehensive restoration)	Terraqua	Status/trend random bug collect	$0	$0	$2,006	$3,987
		Total by fiscal year:	$0	$182,451	$237,578	$362,897
		Project total through fiscal year 2006:				$782,926

Links to Annual Reports

- USFS Final draft report: Monitoring headwater stream condition and determining factors that affect invertebrate and material transport to downstream fish habitats
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/usfs_bpa_annual_report2004_2005.doc
- Pacific Northwest Research Station, USDA Forest Service Annual Report 2004-2005: Developing monitoring protocols for assessing productivity and watershed condition in headwater subcatchments of the Wenatchee Basin
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/usgs_final_report2005_wipfli_binckley_050928.doc
- WDOE 2004 habitat characterization and macroinvertebrate sampling annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdoe_bpa_annual_report2004_2005.pdf
- WDOE 2005 habitat characterization and macroinvertebrate sampling annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdoe_2005_annual_report.doc
- Terraqua, Inc. 2005 Annual Report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/annualreportfy05release4.doc

What's been accomplished so far

Headwaters Productivity Study

In an effort to link food-web productivity in low-order streams to downstream fish populations the ISEMP is examining the transport of macroinvertebrates from fishless subcatchments to downstream habitats. The ISEMP contracted with the USFS-Pacific Northwest Research Station and University of Alaska - Fairbanks to develop monitoring protocols for assessing productivity and watershed condition in headwater subcatchments of the Wenatchee Basin.

The USFS- Pacific Northwest Research Station is currently developing a headwater stream monitoring program that focuses on food web productivity (i.e., the amount of arthropod biomass and organic detritus produced in dry and moist forest headwater ecosystems and exported to downstream fish habitats) as an integrator of the processes and environmental constraints driving aquatic ecosystems. The goals of this work are to:

1) Develop and test methods for monitoring headwater stream condition at subcatchment and stream-reach scales;
2) Determine effects of land-use (timber harvest and roading) and, biogeoclimatic environment (ecological sub-region, ESR) on the biological productivity of subcatchments, and
3) Use this information to relate watershed condition of fishless subcatchments to fish communities in downstream habitats.

The study was designed to compare macroinvertebrate community composition and production in ESR 4 (dry ecoregion) and ESR 11 (wet ecoregion). The selection of 60 headwater stream sites within the Wenatchee subbasin was completed by November 2004. In each ecoregion, 15 low impact (little past logging and presence of roads) and high impact (recent logging and roads) sites were sampled in 2004 and 2005.

Sixty stream sites within the Wenatchee subbasin were sampled to determine invertebrate productivity and investigate invertebrate-fish relationships. The streams were sampled bimonthly from February-June 2005 to collect aquatic invertebrate and organic/inorganic drift in a subset of streams. An approximately equal number of streams were sampled from each category (wet and dry ecoregion crossed with low and high impact), though only 20 were sampled in February due to access limitations in the winter.

In September and November 2004, and February, April, June, and August 2005 with coordination from the ISEMP, the USFS collected aquatic invertebrate and organic/inorganic drift in either a subset of streams (September to February) or all sites (April, June, August). An approximately equal number of streams were used from each category (wet and dry ecoregion crossed with low and high impact), when subsets of sites were sampled. Replicates were streams within each land-use and ecoregion (n = 15), and streams were sampled continuously for invertebrates and detritus over a 24-h period. A total of 254 drift samples have been collected to date, with 23 sites sampled in September 2004, 31 in November 2004, 20 in February 2005, and all 60 sites sampled in April, June, and August 2005.

As of September 2006, almost three quarters of the study has been completed. Preliminary data analysis suggest that:

- Headwater production transported downstream reflect both land-use surrounding headwater streams (e.g., timber harvest) and the environmental setting in which they are embedded.

- Many parameters vary across broad ESRs and land-use categories, but these were not necessarily the same factors that were correlated with invertebrate and material transport.
- Drift composition was not always a strong predictor of underlying benthic communities, and some species responded differently to biogeoclimatic setting and land-use in terms of their tendency to enter drift. These differences can have important consequences for food resource availability in fish habitats.
- Fish density, but not fish condition, was positively correlated with invertebrate drift (Figure 21).

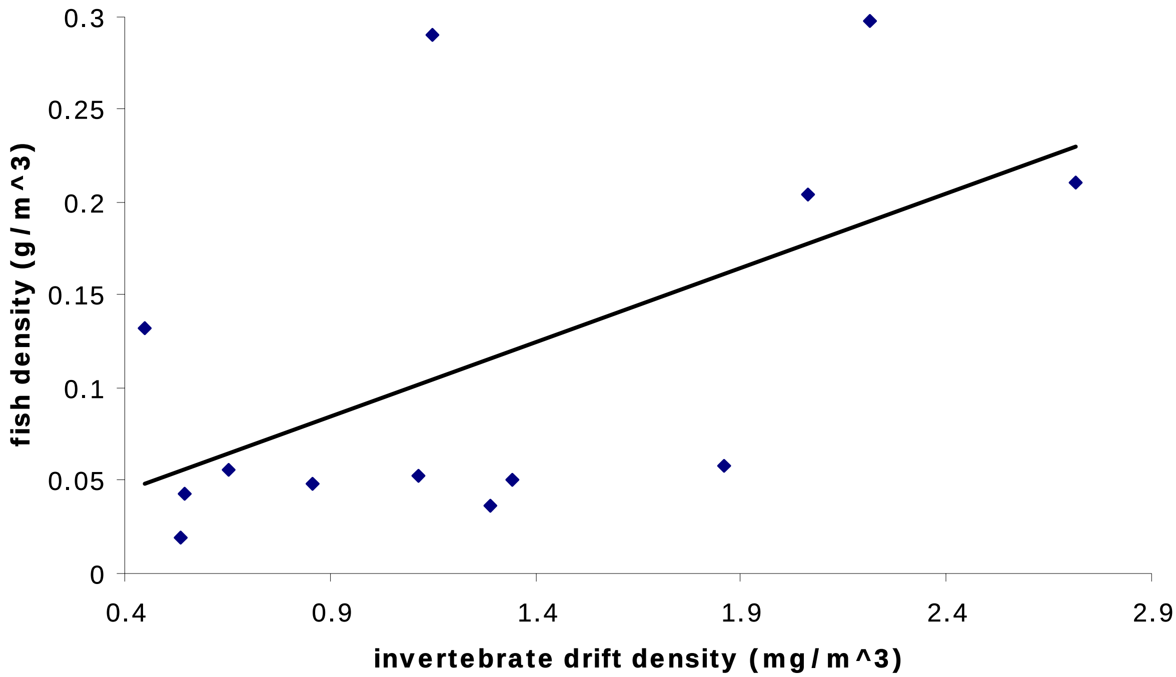


Figure 21. Invertebrate drift biomass and corresponding fish abundance at 12 of 16 study streams sampled in June and July 2006 in the Wenatchee subbasin, WA. Fish abundance log-transformed prior to analysis. Regression equation: Log fish abundance = 0.32(drift biomass) -1.51 ($R2 = 0.34$; $p = 0.04$).

Continued sample processing (from the 2006 field season), data analysis, completion of fish studies, and integration of satellite imagery data from the sites will produce a rigorous set of monitoring protocols that will be predictive of how headwater stream transport influences downstream consumers.

Basin-wide macroinvertebrate sampling

From 2004 through 2006, working in coordination with the ISEMP, the WDOE sampled macroinvertebrate communities annually from riffle habitats at 50 sites probabilistically located throughout the Wenatchee subbasin and Terraqua collected similar samples at an annual panel of sites in 2005 and 2006. Of these sites, five sites per year were re-measured to assess measurement variability. Rhithron, Inc. processed the macroinvertebrate samples at the end of each field season. Starting in 2005 macroinvertebrates have also been sampled at 11 sites along the Entiat River as part of the B2B project and the data is in the ISEMP data management system.

Key Analysis Planned

Status monitoring

- Determine how macroinvertebrate communities co-vary with the abundance, distribution, and size of juvenile salmonids.
- Determine to what extent food web productivity in low-order, fishless subcatchments influences the status of fish populations.

Trend monitoring

- Analyze the temporal covariance of sympatric fish and macroinvertebrate communities to determine if any covariance influences variation in salmonid survival and production.
- Determine how food web productivity in low-order subcatchments varies over time.

Effectiveness monitoring

- Depending on the needs of the Chelan County PUD Hatchery Program, compare macroinvertebrate surveys conducted on an annual basis throughout supplemented and non-supplemented watersheds for potential impacts of hatchery supplementation.
- Depending on the implementation and evaluation of specific habitat restoration projects, analyze macroinvertebrate community structure for the effects of habitat restoration projects.
- Since the influence of landscape-scale habitat restoration actions would be most immediately detectable at the level of food web productivity in low-order streams, determine if combined field studies of watershed productivity and fish condition are a cost-effective means for restoration effectiveness monitoring in the upper reaches of drainage networks. Develop methods for monitoring subcatchment condition and productivity, determine land-use effects on subcatchment condition and productivity, and link variation in subcatchment condition and productivity with the productivity of downstream fish populations.
- Quantify macroinvertebrate measurement error.
- Conduct correlation analysis to determine if macroinvertebrate species composition correlates with any salmonid habitat or population processes.

What's ahead

Collect macroinvertebrates at 50 locations plus 5 re-samples per year in the Wenatchee	2007 - 2015
Collect macroinvertebrates at 25 locations plus 5 re-samples per year in the Entiat (a subsample was started in 2005, expanded in 2006, and to be continued in 2007)	2007 - 2015
Collect macroinvertebrates at 13 B2B treatment and control sites	2007 - 2015

Identify macroinvertebrates collected in Wenatchee subbasin	2007 - 2015
Identify macroinvertebrates collected in Entiat subbasin (a subsample was started in 2005, expanded in 2006, and to be continued in 2007)	2007 - 2015

Water Quality

The response of anadromous salmonids to habitat restoration actions may be confounded by watershed-specific conditions, particularly water quality. Water quality is measured using habitat, macroinvertebrate and juvenile salmonid surveys as indicators (Hillman 2006). While water quality in the Wenatchee and Entiat subbasins has been studied for a variety of regulatory, compliance, and other scientific reasons, water quality sampling under the ISEMP will contribute to a better understanding of watershed-specific variation in water quality.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration

Contractors
Chelan County Conservation District
United States Forest Service-Entiat Ranger District
United States Forest Service-Pacific Northwest Science Laboratory

Time Line

Water quality sampling in the Wenatchee subbasin began in 2004 under the ISEMP. Data has been examined on a yearly basis. Sampling needs to be implemented for at least one complete 5-year rotating panel to generate estimates of interannual variability and may need to be implemented for more than 5 years due to unknown variability in water quality metrics. Water quality has been monitored in the Entiat subbasin for the past 13 years.

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	CCCD	Water quality	$0	$72,441	$55,380	$84,808
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFS-PNW	pH monitoring/ water quality	$0	$0	$0	$50,562
Entiat IMW (intensively monitored watershed and comprehensive restoration)	USFS-Entiat Ranger District	Water temperature	$0	$0	$0	$4,227
		Total by fiscal year:	$0	$72,441	$55,380	$139,597
		Project total through fiscal year 2006:				$267,417

Link to Annual Report

- CCCD 2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/cccd_bpa_annual_report_2005.doc

What's been accomplished so far

Beginning in 2004, water quality in the Wenatchee subbasin has been sampled annually by the CCCD in two ways: (a) water temperature, turbidity, conductivity, pH, and dissolved oxygen measurements are being collected on an hourly basis using automated meters and (b) ammonia, nitrite, nitrate, total nitrogen, total phosphorus and orthophosphate measurements are being collected on a monthly basis using laboratory-analyzed water samples. Sampling locations, which include the Wenatchee River at Monitor, the Wenatchee River at the outlet of Lake Wenatchee, and near the mouths of the Chiwawa River, Nason Creek, and Peshastin Creek, are sites that reflect the integrated conditions of major watersheds within the subbasin. Smolt trapping is also being conducted at these sites.

In addition to monitoring efforts, water samples are collected once a month to examine ambient nutrient levels at each study site. Parameters analyzed included total phosphorus, nitrate-nitrite, ammonia, orthophosphate, and total persulfate nitrogen. Replicate samples are collected at one site (20% replication rate) during each sampling run to assess field sampling precision.

During April and May 2005, a new Hydrolab 4a minisonde was deployed at the Peshastin Creek site to collect simultaneous data in conjunction with the existing data logger. The minisonde was calibrated and maintained on a weekly basis for a period of three weeks. A second meter was deployed to gauge the accuracy of the existing meter and to test for potential bias. The minisonde was deployed at each of the four remaining sites for similar comparison tests in 2006.

A draft document describing the water quality characterization methods utilized by the District for the ISEMP projects was completed in November 2005. Also in November 2005, work began to ensure the data was in a compatible format for the intended data management system and to conduct an initial data analysis.

In the Entiat subbasin, the USFS maintains a longitudinal network of automated thermometers throughout the mainstem Entiat River, including meters near treatment and control reaches. The USFS maintains three stream gages in the watershed, one near the treatment reach and one in the uppermost control reach. Starting in 2006, funds from the ISEMP have been used to continue water temperature monitoring when existing USFS funds were cut. Additional automated thermometers may be deployed by the USFWS at specific monitoring locations. Beginning in 2006, the ISEMP began funding a USFS-PNW study of pH in the Entiat subbasin because pH has been identified as exceeding the federal Clean Water Act 303(d) standards and because there is insufficient information to determine the spatial and temporal extent or potential causes of this excess. Finally, although habitat complexity is believed to be the primary limiting factor in the Entiat, results of the Entiat IMW study could be confounded if pH influences fish productivity. This investigation should elucidate any pH-fish relationships.

Key Analysis Planned

Status monitoring

- Contribute to a better understanding of watershed-specific and temporal variation in water quality.
- Determine if five continuous water quality monitoring meters sites is sufficient to characterize spatial variability of water quality in the Wenatchee subbasin or should additional sites be added and/or some sites dropped.
- Determine if water quality is a possible factor for stratification of control and treatment sites in effectiveness monitoring depending on inter-watershed variation in water quality.

Trend monitoring

- Water quality sampling under the ISEMP will contribute to a better understanding of temporal variations in water quality in the Wenatchee subbasin by sampling water quality at integrator sites on an annual basis. Sampling frequency can be adjusted after consideration of at least one year of data collection. Data will be examined on a yearly basis for at least 3 years to determine if sampling frequency at some or all sites needs adjustment.

Effectiveness monitoring

- Water quality will be considered as a possible factor for stratification of control and treatment sites in effectiveness monitoring depending on inter-watershed variation in water quality since water quality in particular may confound the response of anadromous salmonids to habitat restoration actions. The allocation of control sites used in the "observational studies" statistical design for effectiveness monitoring may need to be stratified by water quality. This analysis will depend on the implementation and evaluation of specific habitat restoration projects.
- Provide information regarding inter-watershed variation in water quality to provide context for comparison with egg-to-smolt survival estimates and to partition variation in those estimates that is likely to be observed. Inter-watershed variation in water quality, particularly if it affects the productivity of juvenile salmonids during freshwater residency, may confound analyses of supplementation-based restoration actions being studied as part of the Chelan County PUD Hatchery Program. This analysis will depend on the needs of the Chelan County PUD Hatchery Program.
- Hatchery supplementation may trigger ecological responses (e.g. nutrient enhancement), although our ability to measure such responses is unknown. Water quality measurements in supplemented and non-supplemented watersheds may eventually yield a sufficient base of observation upon which to draw conclusions regarding impacts of supplementation on nutrient levels. This analysis will depend on the needs of the Chelan County PUD Hatchery Program.
- Determine the most cost effective sampling frequencies for water quality by examining data after six months and one year to assess need to change sampling frequencies. Consult established protocols. Questions to be addressed include: should water grab samples be made monthly, quarterly, or annually? Do automated meters need to be

deployed year-round? Meter bias, especially for dissolved oxygen, may drift over time, perhaps as quickly as within 4 days of meter calibration. Is this drift a problem? How frequently should meters be recalibrated?

What's ahead

Sample water quality continuously at five locations in Wenatchee	2007 - 2015

Habitat quality, channel condition and riparian condition

Wenatchee and Entiat subbasin habitat quality, and channel and riparian conditions have not been systematically studied and are largely unknown, despite the fact that models of habitat restoration assume that overall salmonid production is largely driven by freshwater habitat conditions. In addition, the relationships between habitat metrics and the abundance, distribution, and size of juvenile anadromous salmonids are largely unquantified and poorly understood. To measure habitat quality, and channel and riparian conditions, the ISEMP is sampling populations consisting of all fish-bearing streams within the Wenatchee hydrologic unit watershed with a gradient less than 12% based on a 5-year rotating panel (Hillman 2006).

Funding Agency

Bonneville Power Administration

Contractors

Terraqua, Inc.

United States Forest Service Wenatchee National Forest

Washington Department of Ecology

Time Line

Beginning in 2004, WDOE sampled habitat quality, and channel and riparian conditions annually from July through mid-October at probabilistically located sites in the Wenatchee and, beginning in 2005, Terraqua similarly sampled an annual panel of sites in the Entiat. Also beginning in 2005, Terraqua began habitat data collection for the B2B pilot effectiveness monitoring study. At least 5 years of sampling will be needed at probabilistically located sites and ideally sampling should occur over the next 10 to 25 years to begin to form relationships between habitat indicators and juvenile fish metrics, and to completely capture variability in habitat/channel/ or riparian conditions due to the long periodicity in factors affecting habitat quality, channel condition, and riparian condition (e.g. land use, forest fires, flood events). CCCD made contacts with private landowners to secure permission to access stream habitat on private lands.

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	Terraqua	5 repeat habitat surveys	$0	$3,740	$2,377	$2,708
Wenatchee	WA DOE	Habitat surveys	$0	$130,380	$154,491	$159,871
Wenatchee	USFS	Reconnaissance	$0	$41,808	$7,667	$9,546
Entiat B2B	Terraqua	B2B-habitat	$0	$0	$27,212	$21,637
Entiat B2B	Terraqua	Status/trend random habitat surveys	$0	$0	$24,738	$49,175
		Total by fiscal year:	$0	$175,927	$216,484	$242,936
					Project total through fiscal year 2006:	$635,348

Links to Annual Reports

- WDOE 2004 habitat characterization and macroinvertebrate sampling annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdoe_bpa_annual_report2004_2005.pdf
- WDOE 2005 habitat characterization and macroinvertebrate sampling annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/wdoe_2005_annual_report.doc
- Terraqua, Inc., 2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/annual_report_fy05_release4.doc
- CCCD 2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/cccd_bpa_annual_report_2005.doc

What's been accomplished so far

Wenatchee subbasin

In advance of the each field season (2004 through 2006) the USFS-Wenatchee National Forest and CCCD reconnoitered 50 probabilistically chosen sampling sites among stream reaches within the Wenatchee River basin. The WDOE habitat crews and USFS snorkel crews also met to coordinate the season's sampling schedule and establish coordination protocols. During July through September of each year, the WDOE sampled habitat indicators using the protocol described in Hillman (2006). Of these 50 sites, 5 sites were re-sampled to measure variability. Habitat measurements were closely coordinated with fish population assessments by USFS Wenatchee National Forest Service staff in most reaches.

Entiat subbasin

In 2005 and 2006, Terraqua conducted habitat surveys using the protocols of the Upper Columbia Monitoring Strategy at 11 restoration project control/treatment sites in conjunction with 3 snorkel surveys and at 25 randomly located annual-panel sites[2], also in conjunction with snorkel surveys, beginning in 2006. Habitat data collected at these sites is in the ISEMP data management system and has been linked with snorkel data also collected at these sites.

Complete protocols are implemented once a year in coordination with the late-July snorkel survey conducted by the USFWS. Two additional habitat surveys of limited scope are conducted to support snorkel surveys in late February and November. 2005 was the first year of data collection for the B2B pilot effectiveness monitoring study.

Key Analyses Planned

Status Monitoring

- Determine how habitat quality and channel and riparian condition vary over space and time. Frequency distributions of habitat indicators will be tested to determine if statistically significant differences exist between watersheds for each habitat indicator.

[2] Ten sites sampled in 2005 were expanded to the full annual panel of 25 sites in 2006 and subsequent years.

Trend monitoring

- Determine interannual variation in habitat quality, channel condition, and riparian condition data in the Wenatchee subbasin.
- Quantify relationships between habitat metrics (e.g. channel conditions, water quality, landscape classification) and the abundance, distribution, and size of juvenile anadromous salmonids. Test the extent of correlation between habitat indicators and fish indicators within and between baseline reaches and sampling reaches using a hierarchical modeling framework.

Effectiveness Monitoring

- Use habitat quality, and channel and riparian condition measures to generate the control conditions against which to compare treatment conditions at future restoration sites.
- Information regarding habitat conditions among supplemented and non-supplemented watersheds will be made available to the Chelan County PUD Hatchery Program to provide context for comparison with egg-to-smolt survival estimates and to partition variation in those estimates that is likely to be observed.
- Compare the performance of the probabilistic sampling framework with other sampling frameworks that have been, or are still being, implemented within the Wenatchee subbasin; in particular, compare habitat results using the probabilistic sampling framework with habitat results obtained through the USFS Hankin-and-Reeves stratified sampling designs.
- Quantify habitat survey measurement error.
- Describe variation in habitat quality, channel condition, and riparian condition data and analyze the statistical power of variously sized samples.

What's ahead

Survey habitat conditions and collect macroinvertebrates at 50 locations plus 5 re-samples per year in the Wenatchee	2007 - 2015
Survey habitat conditions and collect macroinvertebrates at 25 locations in the Entiat (a subsample was started in 2005 to be expanded in 2006 or 2007)	2007 - 2015
Survey habitat conditions and collect macroinvertebrates at 13 B2B treatment and control sites. Add additional treatment and control sites as part of the effort to expand effectiveness monitoring throughout the Entiat IMW	2007 - 2015
Conduct reconnaissance and obtain landowner permission for 50 random locations used in snorkel and habitat surveys in Wenatchee subbasin	2007 - 2015
Conduct reconnaissance and obtain landowner permission for all locations on private land used in snorkel and habitat surveys in Entiat subbasin	2007 - 2015

Fine Sediment Sampling

Fine sediment is an important measure of habitat quality (Hillman 2006) and is a natural component of streambeds; however, elevated levels of fines resulting from accelerated erosion (e.g., from roads, clear cuts, grazing, fire) can adversely affect salmonid spawning and rearing success. The ISEMP is coordinating with agencies involved in long-term fine sediment sampling as part of the ongoing status/trend baseline studies in the Wenatchee subbasin and in the Entiat subbasin in order to continue the time series of pre-project data collection before the B2B Habitat Restoration Project is implemented. Alternative protocols for sampling fine sediment are also being explored by the ISEMP.

Funding Agencies

United States Forest Service

National Oceanic and Atmospheric Administration

Contractor

Terraqua, Inc.

United States Forest Service

United States Forest Service-Entiat Ranger District

Time Line

The USFS Entiat Ranger District has been collecting fine sediment data in the Wenatchee and Entiat for the past 13 years. Starting in 2006, the ISEMP began to help fund McNeil core samples in the Wenatchee and Entiat subbasins.

Budget

Subbasin	Contractor	Scope of Work	FY03	FY04	FY05	FY06
Wenatchee	Terraqua	Alternate fine sediment methods exploration	$0	$0	$0	$5,402
Wenatchee	USFS	McNeil core sample/fine sediment	$0	$0	$0	$0
Entiat IMW	USFS-Entiat Ranger District	McNeil core sample/fine sediment	$0	$0	$0	$3,599
		Total by fiscal year:	$0	$0	$0	$9,001
		Project total through fiscal year 2006:				$9,001

Links to Annual Reports

- USFS-Entiat Ranger District 2004 sediment monitoring annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/2004_sed_mon_rpt.doc
- Terraqua, Inc., 2005 annual report
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/annual_report_fy05_release4.doc

USFS-ERD 2005 Sediment Monitoring Report: Entiat and Mad Rivers

In 2005, all four sampled Entiat River reaches and the Mad River were within the Forest Plan Standard for fine sediment. The results from four Entiat River reaches (48 samples) show sample mean percent fines ≤1.0 mm in salmonid spawning habitat were variable by reach, with all four reaches increasing from 2004. Results from the Mad River (12 samples) indicate sample mean percent fines ≤1.0 mm in salmonid spawning habitat increased compared to 2004. The 13-year trend of fine sediment levels in the Entiat and Mad Rivers has been variable and may be explained by annual precipitation and runoff. Higher flows of longer duration tend to favor fine sediment transport rather than deposition. Water-year 2005 was relatively typical as depicted in the 2004-05 hydrograph (Figure 22).

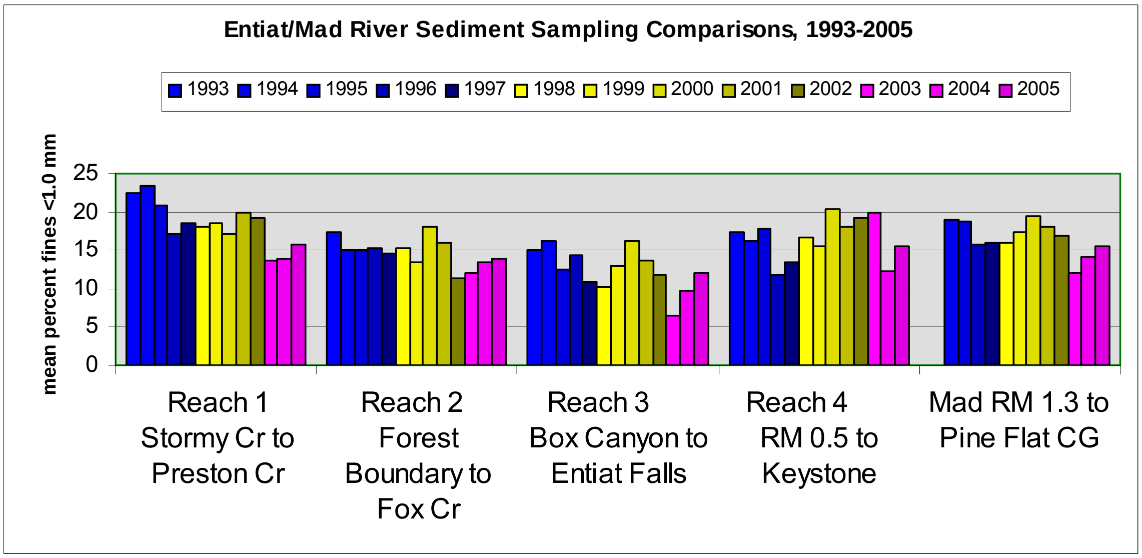


Figure 22. Levels of fine sediment in the Entiat and Mad Rivers at five sampling locations from 1993-2005.

Key Analysis Planned

The protocol for measuring depth-fine sediment as described in the Upper Columbia Monitoring Strategy (i.e. McNeil core sampling) has not been successfully implemented under the ISEMP as designed, primarily due to its high cost, low return on useable data, and limited suitability to a small proportion of habitat sample sites. In 2005, Terraqua, Inc. explored the use of an experimental protocol for sampling depth-fine sediment based on previous research by Garrett and Bennett (1996) and DeVries et al. (2002). The experimental protocol was tested at two reference sites in the Entiat subbasin.

The experimental protocol was almost immediately found (a) not to be applicable for use at the full range of sample sites likely to be encountered in the Wenatchee and Entiat rivers, and (b) not to be cost effective to implement in conjunction with other Upper Columbia Monitoring Strategy habitat sampling. For example, sampling at the easier (low gradient of about 2%) of the two sites took three-person days of labor, while valid sampling at the other site (moderate gradient of about 3%) could not be completed in one day with a crew of three. Also, at the more difficult site and other sites that were reconnoitered that would be typical of the full range of sites likely to be encountered, it became quickly apparent that this technique could not be implemented without heavy machinery and exorbitant cost. While testing was unable to determine whether the experimental protocol might give an ecologically meaningful signal regarding the annual transport/deposition of fine sediment as hypothesized, further development of this experimental protocol was stopped in light of cost and applicability issues. Furthermore, an ecologically meaningful signal is unlikely using this technique in the locations where we need to employ it according to Dr. Rick Woodsmith, geomorphologist with the USFS-Pacific Northwest Research Laboratory and member of the Upper Columbia RTT, who was consulted during the testing process.

After learning first hand the type of data that we are seeking, and understanding the drawbacks to the authorized McNeil core sampling of fine sediment, Woodsmith developed a proposal that would likely provide us with tools that could be used as a fine sediment surrogate. However, the cost of this proposal is high. Therefore, it is recommend that McNeil core sampling be reconsidered– particularly because of the existence, made known to Terraqua through collaboration with Entiat Subbasin ISEMP partners in June, 2006, of a multi-site, 13 year time-series of McNeil core samples collected by the USFS – by conducting additional analysis of spatial and temporal variability in McNeil core sample data collected at sites which integrate watershed-scale conditions. It is our hope that McNeil core sampling at integrator sites (like the sites used for watershed-scale smolt trapping and water quality monitoring in the Wenatchee) can provide us with adequate watershed-scale signals. If this is the case, we will recommend that the Upper Columbia Monitoring Strategy be revised to drop the concept of sampling depth-fines at randomly located sites. If our analysis of McNeil core sampling suggests it is not adequate for our needs, we will (a) re-evaluate our needs or (b) consider Woodsmith's proposal more closely. This analysis is underway as of August 2006.

ISEMP study site locations in the Wenatchee and Entiat subbasins

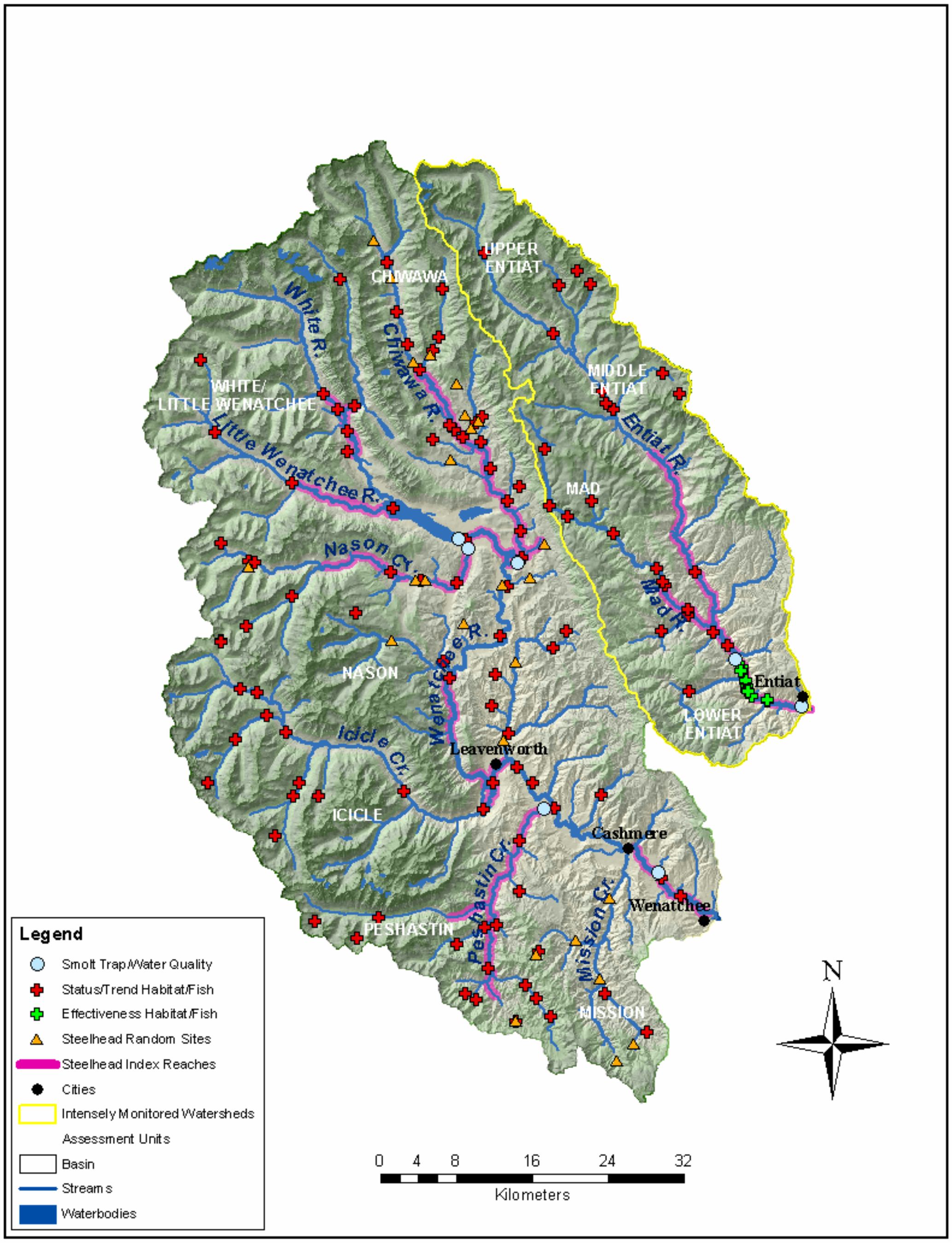
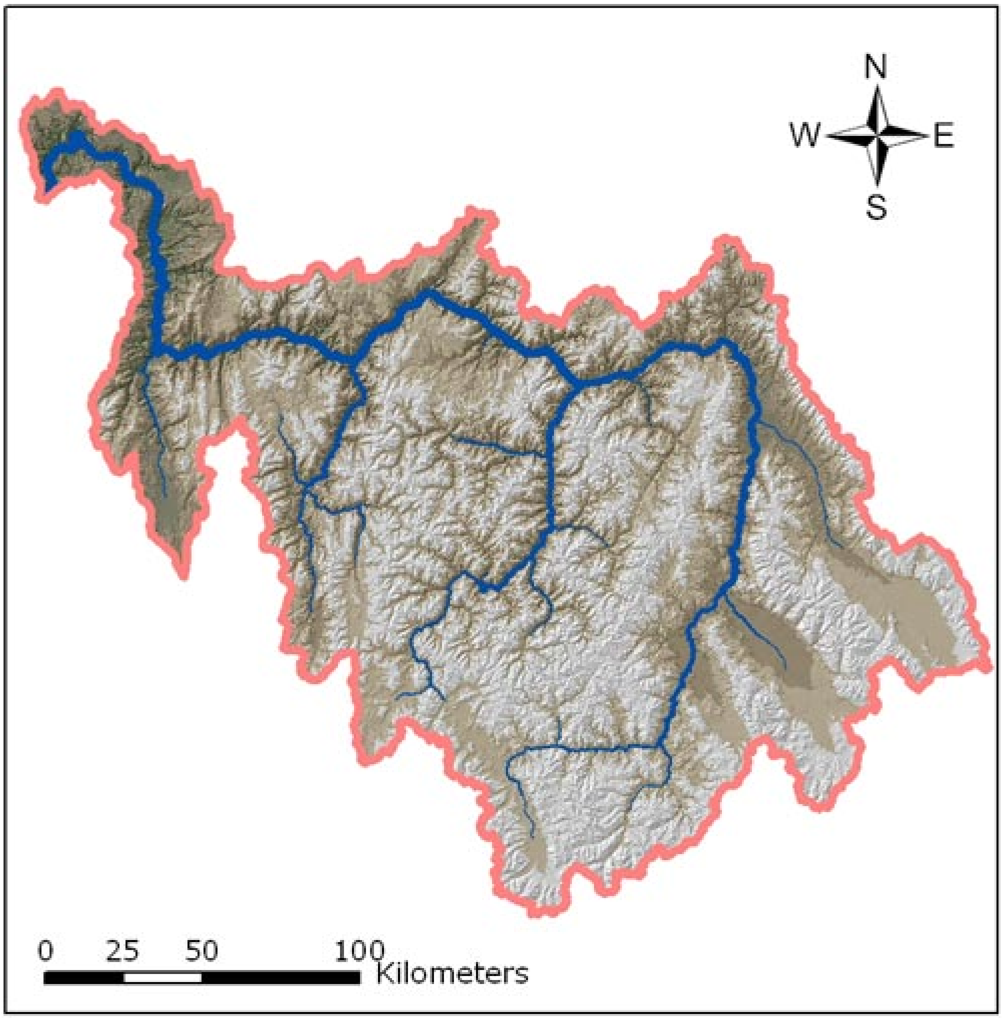


Figure 23. Sampling locations of smolt trapping/water quality sites, habitat/fish status/trend and effectiveness sites, and steelhead random sites and steelhead index reaches in the Wenatchee and Entiat subbasins.

CHAPTER 5: SALMON RIVER SUBBASIN, ID



Background

Implementation of the ISEMP in the Salmon River subbasin will test whether a design-driven monitoring plan can be superimposed upon existing monitoring and monitoring infrastructure to address status, trend, and effectiveness questions at multiple spatial scales while simultaneously improving the information value of those projects. In the South Fork Salmon River (SFSR), which represents a significant contribution to Snake River spring/summer Chinook salmon production, the ISEMP will implement a habitat and population status and trend monitoring project. This site was selected because ongoing monitoring activities have substantial time series data and present an opportunity to evaluate sampling alternatives in a "common garden." Habitat actions and effectiveness monitoring in the Lemhi River form an IMW initiative to assist the recovery of salmon and steelhead through strategic application of habitat restoration. Thus the Lemhi watershed was selected for implementation of an ISEMP habitat action effectiveness monitoring project.

The SFSR supports stocks of native summer-run Chinook salmon and B-run steelhead (Matthews and Waples 1991). Historically, the SFSR was the single most important summer Chinook salmon spawning stream in the Columbia River Basin, accounting for approximately 50% of the summer Chinook salmon redds enumerated in Idaho (Mallet 1974). Declines in natural escapement within the SFSR have paralleled those of other Snake River stocks, resulting in their listing under the ESA. The Interior Columbia River Basin Technical Recovery Team (ICBTRT) identified three populations of spring/summer Chinook salmon in the SFSR, including the mainstem SFSR, the Secesh River, and the East Fork SFSR (ICBTRT 2003), which together form a single Major Population Group (MPG).

The ICBTRT also identified two steelhead populations in the SFSR (one in the Secesh River, and the other inhabiting the mainstem and East Fork of the SFSR)(ICBTRT 2003). The ICBTRT commented on the inadequacy of existing data to determine: 1) spawner distribution; 2) general life history information, and 3) population and stream-level abundance data (ICBTRT 2003). While a substantial number of RME projects are currently underway in the SFSR, primarily aimed at assessing the effectiveness of artificial propagation at increasing the abundance of adult spring/summer Chinook salmon, these ongoing activities, managed by the NPT and IDFG, utilize substantial infrastructure and primarily address sub-populations[3]. These subpopulation level estimates may or may not adequately represent the larger populations, and data currently cannot be aggregated to yield an MPG level population estimate due to gaps in existing data collection (e.g., in the lower mainstem SFSR area). In addition, much of the available data for steelhead and resident salmonids is collected opportunistically by projects targeting spring/summer Chinook salmon, and it is unclear how effectively these data portray the status and trends of these non-target species/life-histories. Finally, the SFSR lacks an integrated and standardized habitat monitoring component.

Juvenile and Adult Abundance Estimation

The primary purpose of the ISEMP in the SFSR is to determine whether innovative methods can be employed to increase the accuracy and precision of juvenile and adult abundance

[3] For example, the Johnson Creek component of the EFSFSR spring/summer Chinook salmon population, the Lake Creek component of the Secesh River spring/summer Chinook salmon population, and the upper mainstem SFSR component of the mainstem SFSR spring/summer Chinook salmon population.

estimates for summer Chinook salmon at the subpopulation, population, and major population group scales and for steelhead at the subpopulation and population scales. This task will be achieved in two ways:

- Small-scale studies will evaluate and attempt to improve upon existing monitoring and evaluation programs, and
- A large-scale monitoring and evaluation project will provide juvenile and adult abundance and survival estimates via proportional partitioning of SFSR-wide adult escapement and juvenile abundance estimates.

Habitat Status and Trend Monitoring

In addition, the ISEMP will develop a habitat status and trend monitoring program for the SFSR based on:

- Fixed and randomly selected sample locations, and
- Habitat attributes and sampling methodologies under development by the PNAMP.

The monitoring program development work piloted in the SFSR hinges on the ability to perform retrospective statistical analyses to provide variance estimators for historical time series data, and the development of statistical relationships between estimators derived from proposed versus existing infrastructure and analytical methods. Thus, the ISEMP SFSR project is moving beyond the side-by-side protocol/indicator/metric tests underway in the ISEMP's Wenatchee and John Day subbasins to experiment with an entirely new status and trends monitoring approach, designed top-down from the resource data management needs.

Lemhi IMW

The ISEMP will be conducting a habitat action effectiveness monitoring program (the Lemhi IMW) to identify and quantify the effects of classes of habitat actions (e.g., channel reconnection, flow augmentation, physical changes in channel morphology etc.) on the abundance, productivity/survival, condition, and distribution of anadromous and resident salmonids within the Lemhi watershed. Habitat restoration activities will be guided by the Lemhi Conservation Plan (LCP), an evolving document that has benefited from a wealth of information on historical productivity, life-stage specific survival, and carrying capacity (Bjornn 1978); contemporary juvenile density, abundance, distribution, and the distribution and magnitude of adult spawning (Venditti et al. 2005); and habitat attributes (Trapani 2002) including habitat and discharge relationships (Sutton and Morris 2005) available for the Lemhi. Aggressive ongoing and proposed habitat actions targeted to address the limiting factors deduced by these studies are anticipated to result in measurable biological responses, both in terms of physical habitat attributes (e.g., quality and quantity of accessible habitat) and life stage specific fish vital rates (survival/productivity, distribution, and abundance), both at the scale of individual reaches and at the scale of the watershed. These habitat actions are the primary mechanism intended to stimulate the delisting of the ESA listed, ICBTRT identified population of spring/summer Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) as well as bull trout (*Salvelinus confluentus*) populations that reside in the Lemhi River subbasin.

The Lemhi River in central Idaho is a tributary to the upper Salmon River. There are a total of 31 tributaries to the Lemhi River containing habitat believed to be important for the persistence of fish in the Lemhi basin. With the exception of Hayden Creek and Big Springs

Creek, all are dewatered in their lower reaches in most years and therefore isolated from the Lemhi River. Grassroots concern over the widespread habitat degradation within the Lemhi River watershed resulted in its designation as a Model Watershed (e.g., ISCC 1995). A primary focus of the LCP is to re-establish tributary connectivity so fish may access habitat in these watersheds. The LCP proposes to reconnect at least 10 tributaries - four in the first 5 years of the plan (Phase I) – and six more over the next 30 years (Phase II) should the original four reconnections prove beneficial.

Funding Agency
Bonneville Power Administration

Contractor
Quantitative Consultants, Inc.

Time line

The Salmon River basin pilot project was initiated in August 2005. A coordinator, Quantitative Consultants, Inc., was selected for the Salmon River basin in 2005, whereupon investigations into potential design consideration for the Lemhi and South Fork Rivers began. Coordination began in earnest in FY2006.

Budget

Contractor	Scope of Work	FY06
Quantitative Consultants, Inc.	Develop an IMW and RME plan for the Salmon River basin; coordinate and promote sharing of information, data, and equipment; facilitate regularly scheduled meetings with the Research Monitoring and Evaluation Technical Oversight Committee and other interested parties; produce regular status reports and annual report; manage and administer projects.	$64,000

Links to Annual Reports

- Salmon Subbasin Pilot Projects Monitoring and Evaluation Plan
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/salmon_river_pilot_project_study_design.doc
- Independent Scientific Review Panel Review of Salmon Subbasin Pilot Projects Monitoring and Evaluation Plan
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/isrp_review_salmon_study_design20061.doc
- Lemhi River Site Surveys
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Lemhi site survey.doc
- Salmon ISEMP watershed model development: Adding stochasticity to the Life History Model Structure
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/Salmon ISEMP Watershed Model Development.doc

What's been accomplished so far

Initiating the ISEMP in the Salmon River basin has focused on two major issues – which part of the geographically large and diverse basin should be included in the pilot work, and how to balance status and effectiveness components if they are not collocated.

Coordination

We have formed and convened regular meetings of a Research Monitoring and Evaluation Technical Oversight Committee with members representing the NPT, IDFG, NOAA Fisheries, the Shoshone-Bannock Tribes, the USFWS, and the Idaho Department of Water Resources. The committee was instrumental in guiding study objectives and in providing existing data. The current discussions on location and design are focusing on the Lemhi River and SFSR as two locations in which differing degrees of design and implementation effort will be applied.

Identifying information gaps

The Lemhi River offers the opportunity, through the Lemhi River Habitat Conservation Plan (HCP) discussions, to speed up the ISEMP coordination and monitoring by joining an existing forum that has done considerable work in the area of large-scale habitat restoration action and limiting factor assessment. Monitoring the implementation of the Lemhi HCP as an IMW to assess the population level impact of the HCP on Chinook and steelhead is a major gap that the ISEMP will fill.

In the SFSR, status monitoring for fish populations, in particular for Chinook, are well developed through the work of the NPT and IDFG. Currently there are limited opportunities for effectiveness monitoring in the South Fork due to a lack of suitably scaled projects, but there are major gaps in the status monitoring program in that little or no habitat data is collected in conjunction with the fish data. Therefore, the Salmon River ISEMP will focus on the design of monitoring programs that build on current programs and plans, specifically to address watershed scale effectiveness monitoring design and implementation issues in the Lemhi and integrating habitat and fish status monitoring in the SFSR.

Study Design Development

Study design efforts in the SFSR and Lemhi are based on a modification of a watershed model (based on Sharma et al. 2005) that views fish vital rates (survival/productivity, abundance, and condition) as a function of the quantity and quality of available habitat. These functions are constructed using both coarse (e.g., GIS) and fine (e.g., reach) scale habitat measures (Figure 24). Once validated via the collection of empirical data within habitat classes, the model provides a statistical framework to assess the effects of different classes of habitat actions on life-stage specific vital rates (productivity/survival and condition) of anadromous and resident salmonids; or as a means to relate fish vital rates to existing or available habitat (i.e., to link habitat status and trends to status and trends of population productivity).

The information needs of the watershed model are addressed by a model-based sampling design that yields reach specific and aggregated estimates of life-stage specific juvenile abundance, productivity/survival, condition, and distribution as well as adult escapement across habitat classes and within treated and untreated stream reaches. Within the context of habitat action effectiveness monitoring, the use of tandem extended length PIT tag detection arrays within the study design provides information necessary to determine whether habitat actions (e.g., channel reconnection) have increased population connectivity, and whether anadromous salmonids utilize newly available habitat. Within the context of habitat and population status and trend monitoring, the detailed information on fish movement and survival, afforded by PIT tag detection arrays, enables the evaluation of mechanistic linkages between habitat attributes and fish vital rates.

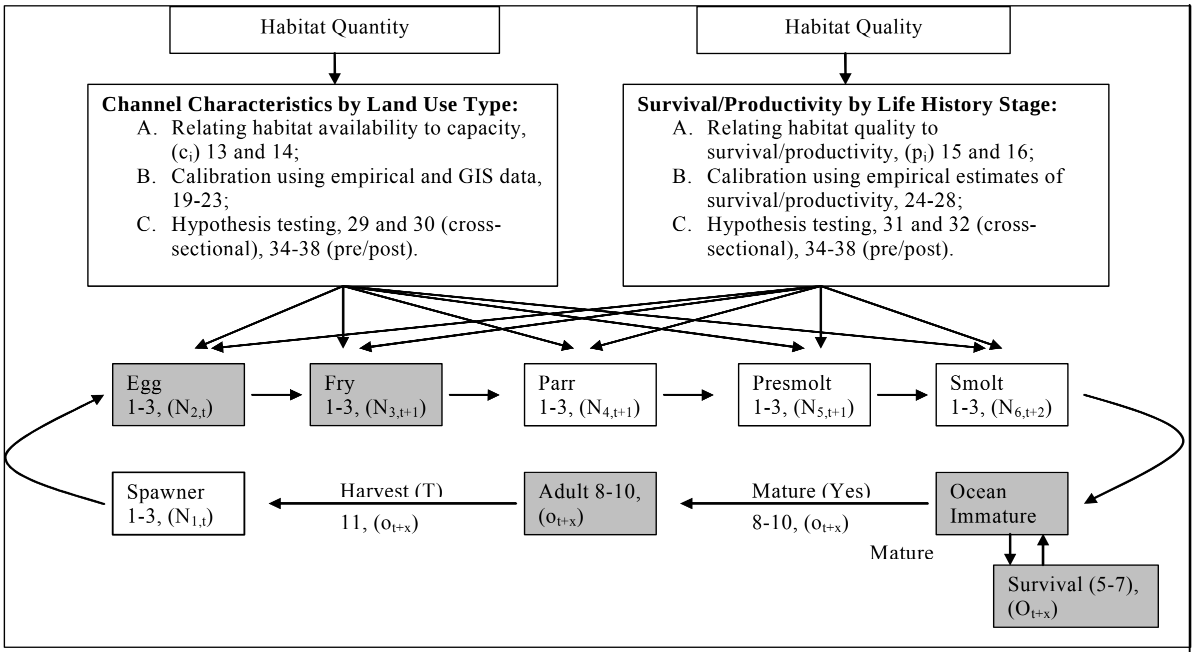


Figure 24. Schematic illustrating how the model develops relationships between habitat quantity (capacity) and quality (survival/productivity) and stage-based abundance, productivity, and survival. Grey boxes indicate those life stages for which metrics will be inferred, notation in parentheses refers to model parameters, and numbers within the boxes refer to equations developed in the study design (QCI 2005).

Watershed model development: Adding Stochasticity to the Life History Model Structure

The watershed model, summarized in the previous section, developed a deterministic framework to describe how either empirical data on habitat features and population attributes could be used independently and/or or in concert with GIS (or remote sensing data such as satellite imagery) to describe the quantity and quality of available habitat and the influence of those factors on the growth rate of a population or group of populations of interest. However, to assess uncertainty in recovery trajectories (or the range of potential effects of proposed habitat improvement projects) requires the addition of a stochastic element to the model. Thus, the ISEMP developed a stochastic component using a simulation technique to generate the distribution of key variables as described by their variance in repeated measures. Those distributions are then sampled iteratively.

Hypothetical examples were developed to demonstrate the potential application of large-scale and local climatic data for predictive purposes within the watershed model. The examples highlight an important contribution to management that could be obtained by implementing the ISEMP in the SFSR, which would provide data at a spatial scale and temporal resolution capable of evaluating the efficacy of such an approach. If practical and sufficiently precise, the ISEMP could develop relationships, using a number of mechanistic relationships between climate data and productivity (e.g., the influence of snow-pack on habitat availability and water temperature, or the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO) on ocean survival), enabling predictions of smolt production from 12 to 18 months in advance of emigration on a stock specific basis. Since freshwater habitat is easier to sample than the estuarine or marine environment, and has a finite capacity that can be calculated using a rich statistical literature, freshwater life-stages are ideal for the incorporation of climatic indicators for the purpose of stock assessment and management.

The watershed model developed for the ISEMP in the SFSR (QCI 2005) provided a model-based analytical framework accompanied by information requirements that specified a sample design and intensity. In 2007 the ISEMP proposes to code the stochastic features developed into the model. In both the SFSR and Lemhi, preexisting monitoring efforts provide a subset of the model's information needs relative to adult and juvenile salmonid abundance and, to a more limited extent, habitat quality and quantity. Likewise, existing monitoring programs provide information on large-scale climatic features such as snow-pack, instream flow and temperature, ENSO, and PDO. Despite the fact that existing salmonid data do not provide life-stage specific juvenile abundance and survival data, it is possible to evaluate the precision of productivity estimators generated using large-scale and local climatic data, and to test the newly developed stochastic features of the watershed model. However, without the life-stage specific juvenile abundance and survival data, the functional relationships between the large-scale and local climatic indices, habitat availability, habitat restoration actions, and juvenile production will remain untested. Likewise, because adult escapement must be estimated from redd counts, adult escapement estimates generated by the model cannot be calibrated. Despite these weaknesses, an evaluation of existing data may be sufficient to indicate whether the incorporation of climate-based mechanistic indicators can provide sufficiently precise productivity estimates and/or improve predictions based solely on locally derived empirical data.

In order to evaluate the efficacy of climate-based mechanistic productivity predictions we propose to implement a forward-looking analysis of juvenile productivity for Lemhi River spring/summer Chinook salmon using available spring/summer Chinook salmon smolt abundance estimates generated by the Idaho Supplementation Studies project (1992-ongoing; Lutch et al. 2005), in concert with habitat data collected by the BLM and others (e.g., Trapani et al. 2004) for the Lemhi watershed, and snow-pack, ENSO, and PDO indices. In short, we will use snow-pack indices from 1990 to 1992 and redd counts from 1991 to predict egg recruitment. Likewise, snow-pack from winter 1991 to 1992 will be used to estimate rearing habitat availability from 1991 to 1992, which is hypothesized to influence smolt emigration in 1993. These estimates will proceed iteratively through the period of available data (smolt emigration in 2006). Annual smolt abundance predictions from the watershed model will then be compared to annual empirical estimates obtained from the operation of the rotary screw trap on the lower Lemhi River. We recognize that water management (e.g., irrigation withdrawal) in the Lemhi watershed might serve to decouple the relationship between snow-pack and instream flow. Thus we will also examine the relationship between realized instream flow and snow-pack. Likewise, if data permit, we will examine the influence of snow-pack on water temperature as an additional explanatory variable.

As mentioned previously, data are insufficient to fully parameterize the watershed model. Thus, the exercises proposed are most appropriately viewed as model development. Model testing proposed for 2007 will enable an evaluation of model sensitivity (e.g., precision of estimators as assumptions regarding the magnitude of mechanistic relationships are varied) and will stimulate the generation of a number of hypothetical mechanistic relationships that can be tested with data once the ISEMP study design is implemented in the Salmon River.

Site surveys

Implementation of a habitat action effectiveness monitoring project in the Lemhi River watershed, as described in QCI (2005) will require the deployment and operation of:

- An adult capture facility on the lower Lemhi River mainstem;
- A rotary screw trap on Hayden Creek near its confluence with the mainstem Lemhi River; and
- Up to five PIT tag detection arrays at mainstem and tributary locations.

The efficacy and feasibility of the proposed designs were evaluated through site surveys and meetings with local field biologists in 2006. Two potential adult capture sites, one location for a rotary screw trap, and numerous sites for the installation of PIT tag detection arrays were identified (e.g., Figure 25 and Figure 26).

Figure 25. The existing lower Lemhi River rotary screw trap located at rkm 9 on the mainstem Lemhi River.

Figure 26. Proposed site for rotary screw trap placement on Hayden Creek at rkm 0.5.

Similar to the Lemhi, the habitat and population status and trend monitoring project proposed for the SFSR will also require additional infrastructure. The preferred study design relies on myriad existing projects and requires the deployment and operation of:

- A juvenile and adult sampling and enumeration capability in the lower mainstem SFSR;
- An acoustic imaging camera in the lower Secesh River; and
- PIT tag detection arrays located in the Secesh River, the East Fork SFSR and the mainstem SFSR above the confluence with the East Fork SFSR.

An alternative design also relies on myriad existing projects and requires the deployment and operation of:

- Adult enumeration facilities (i.e., acoustic imaging cameras) in each of the major tributaries (Secesh River, East Fork SFSR, and the mainstem SFSR above the confluence with the East Fork SFSR) as near as possible to their confluences with one another, and
- PIT tag detection arrays located in the Secesh River, the East Fork SFSR, and the mainstem SFSR above the confluence with the East Fork SFSR.

A preliminary SFSR site survey conducted in October 2006 suggested that the lower SFSR presents logistical challenges that significantly reduce the probability of successfully implementing the ISEMP's preferred study design. However, the Elk Creek bridge site in the lower SFSR might be a useful location for an acoustic imaging camera. The preliminary site survey successfully identified sites in the upper SFSR and tributaries sufficient to implement the

ISEMP's alternative design, including the deployment of acoustic imaging cameras and PIT tag detection arrays. However, final site selection will likely require that preliminary sites be revisited during spring high flow conditions. Likewise, we recommend that the lower SFSR be aerially surveyed to determine conclusively whether sites exist that might enable the implementation of the ISEMP's preferred study design.

South Fork Salmon River

The implementation of the ISEMP in the SFSR will emphasize status and trend monitoring development to take advantage of a developed monitoring infrastructure and historical data collection efforts.

The ISEMP completed a coordinated study design for the SFSR in September 2005 (QCI 2005), which was positively reviewed by the Independent Science Review Panel (ISRP) in early 2006 (ISRP 2006-1). The design utilizes information from existing projects and proposes additional monitoring effort and infrastructure in the SFSR that will:

- Generate habitat and population status and trend information at multiple spatial scales (e.g., reach, population, and MPG for Chinook salmon, steelhead and resident salmonids (e.g., resident rainbow trout));
- Evaluate the precision-versus-cost relationship of alternative data collection methods;
- Organize ongoing collection, analyses, and databases activities with standard data collected, protocols, analyses, and the data management tools developed by the ISEMP;
- Develop a statistical framework to enable precision estimates for historic time series data that lack variance estimators;
- Develop statistical relationships between new monitoring techniques and historical techniques to enable the continuation of historical time series data while implementing more precise and/or cost effective methods; and
- Evaluate the efficacy of a template for habitat and population status and trend monitoring at the reach, population, and MPG scale that is amenable to implementation in less intensively monitored areas.

A trial implementation of a subset of the monitoring activities and infrastructure to evaluate feasibility and information quality that could be expected from long-term implementation was planned for 2006 but was not funded. Additional progress towards evaluating the efficacy of the study design cannot be made without implementing the approved study plans for Lemhi IMW and SFSR over a trial period from 2007 to 2009.

Lemhi River IMW

Since multiple habitat actions may be collocated, assessing the individual affects of classes of habitat actions will require a modeling approach. In addition, because the LCP plans for a phased implementation approach, wherein the effectiveness of Phase I habitat actions are used to identify and prioritize Phase II actions, a model-based approach will be useful for conducting *a priori* simulations to estimate the potential effects of different suites of proposed Phase II habitat actions.

A statistical framework was developed for the ISEMP implementation in the Lemhi (QCI 2005) that includes the following components:

- A watershed model was developed and tested to evaluate survival, productivity, and carrying capacity by life-stage as a function of habitat availability and quality, with a simulation component to estimate life-stage specific benefits from increased habitat availability and/or quality.
- A study design was developed that utilizes reach-specific empirical measures of productivity, juvenile survival, condition, and distribution across habitat classes, in treated and untreated areas, to determine whether tributary reconnection and other habitat actions have provided high quality habitat that benefits fish productivity (e.g., survival, growth etc.).
- A study design was developed that evaluates the movement and distribution of anadromous and resident salmonids to address the following questions:
    - Are anadromous fish utilizing reconnected habitat?
    - Have the reconnections changed the distribution and connectivity of resident fish?

A trial implementation of a subset of the monitoring activities and infrastructure to evaluate feasibility and information quality that could be expected from long-term implementation was planned for 2006 but was not funded. However, NOAA-Fisheries and Quantitative Consultants continued the ISEMP study site selection and model development by assimilating GIS datasets pertinent to site selection and simulations. In 2005, land use and land cover within riparian areas was summarized in the Lemhi basin to determine habitat availability and current land use across the entire Lemhi River watershed. In 2006, these analyses were expanded to evaluate the sensitivity of simulations to changes in the geographic extent of land use and land cover (e.g., solely riparian habitat versus the entire watershed). Likewise, the simulated benefits of alternative management actions were re-evaluated to determine their sensitivity to differing geographic extents of land use/land cover data.

Key Analysis Planned

South Fork Salmon River

Status and trend data

- Generate habitat and population status and trend data for spring/summer Chinook salmon at the reach, population, and MPG spatial scales; and for steelhead and resident salmonids (e.g., rainbow trout) at the reach and population scale. Compare the precision and reliability of estimates generated using proposed methods to existing methods following standardization of data. Allocate habitat sampling effort to fixed (trend) and probabilistically (status) selected sites, building when possible on existing fixed site surveys. A response design and habitat attributes will be selected consistent with the results of the habitat protocol comparison project (PNAMP 2005).
- Leverage substantial existing infrastructure and effort to evaluate and validate alternative designs capable of providing status and trend information at multiple spatial scales for relatively minimal additional cost.

Estimate adult abundance

- Supplement existing infrastructure within the SFSR with a combination of additional juvenile and adult sampling devices and PIT tag detection arrays to enable estimates of juvenile and adult Chinook salmon and anadromous steelhead abundance at the scale of the SFSR MPG and individual populations (for spring/summer Chinook salmon), and reaches (in the case of Lake Creek spring/summer Chinook salmon), and at the population level for steelhead. Validate abundance, productivity, and life-stage specific survival estimates generated by the proposed infrastructure through comparisons with estimates derived from existing and proposed infrastructure.

Juvenile abundance and survival estimates

- Estimate population specific and aggregate estimates of juvenile abundance and survival for spring/summer Chinook salmon and steelhead using information obtained from the recapture of juveniles PIT tagged during seining surveys in each major tributary.
- Estimate the efficiency of rotary screw traps and PIT tag detection arrays.

Adult escapement estimates

- Operate a series of acoustic imaging cameras to visualize returning adult spring/summer Chinook salmon and steelhead to generate adult escapement estimates.
- Use the validated adult escapement estimates generated by the ISEMP proposal to evaluate the utility of the IDFG and NPT redd count time series as a measure of relative abundance. Observed variance in the relationship between escapement and IDFG redd counts will be used, if possible, to retrospectively evaluate the precision of the time series. If a significant relationship can be developed, managers could elect to implement escapement methods developed by this proposal as a possible replacement for single pass or extensive redd surveys.

Develop cross walks

- Develop relationships between proposed and existing estimators to enable and encourage managers to replace existing facilities with the ISEMP's proposed infrastructures if they prove reliable.

Evaluate and validate alternative designs

- Evaluate the efficacy of the proposed infrastructure for providing juvenile and adult abundance, survival, and productivity estimates independently of all existing SFSR infrastructure. If implementation and validation of proposed infrastructure and estimates are reliable and provide adequate precision, the deployment of a similar study design and associated infrastructure may enable reach, population, and MPG level status and trend monitoring, for relatively low cost, in locations that currently lack such estimators (e.g., the Middle Fork Salmon River). The proposed design and associated infrastructure will be evaluated for its potential as a template that can be applied at similar geographic scales elsewhere, and/or whether it can be applied at larger geographic scales (e.g., at the scale of the Snake River Basin).

Lemhi River

Adult escapement

- Generate escapement estimates for anadromous salmonids and adfluvial residents (e.g., rainbow trout) by modifying an existing mainstem irrigation diversion to serve as a trap, enabling adults to be PIT tagged, or as a location for a video monitoring station. Aggregate escapement will be partitioned into reach specific estimates via the interrogation of PIT tagged adults at mainstem and tributary PIT tag detection arrays. If adults cannot be captured at the diversion, video weirs or DIDSON arrays will be used to partition adult escapement.

Juvenile abundance, survival, and distribution

- Operate an additional screw trap in Hayden Creek[4] and extend the operating period of the existing screw trap in the upper Lemhi mainstem to better estimate steelhead emigration. These efforts will be useful in generating population level juvenile emigrant abundance estimates, estimating survival from earlier life-stages, and in determining the proportion of juvenile production that occurs in Hayden Creek.
- Generate estimates of pre-migratory juvenile abundance and survival in reconnected versus currently available habitat using PIT tags and visual marks, deployed via seining at fixed and probabilistically selected sites throughout the Lemhi watershed (e.g., in currently available, reconnected, and isolated habitat). Recaptures of PIT tagged juveniles will occur during repeat electrofishing surveys, at PIT tag detection arrays, and at rotary screw traps.
- It is anticipated that PIT tags can be deployed in both anadromous and resident salmonids (e.g., rainbow trout). Juvenile survival will be estimated by evaluating overall systemwide recapture efficiency, generated by common PIT tag detections at upper and lower screw traps, determining the fraction of fish that passed PIT tag detection arrays, and via repeat seining surveys. Juvenile distribution and movement will be evaluated by scrutinizing recaptures of tagged fish during repeat seining surveys, by interrogations at extended length PIT tag detection arrays, and via capture at rotary screw traps.

Habitat Sampling

- Habitat sampling effort will be allocated to fixed (trend) and probabilistically (status) selected sites. A response design and habitat attributes will be selected consistent with the results of the habitat protocol comparison project (PNAMP 2005). Because the design requires estimates of habitat availability for specific life-stages of juvenile resident and anadromous salmonids, habitat surveys will incorporate temporal replication to achieve seasonal estimates of habitat availability.

Evaluation

- Evaluate effectiveness of habitat actions by comparing potential productivity (capacity), survival, and realized productivity within sites before and after the

[4] Hayden Creek is a potential reference stream for actions in the mainstem and upper Lemhi.

implementation of habitat actions; comparing potential productivity (capacity), survival, and realized productivity across treatment and reference sites within the Lemhi watershed and among different treatment types and extents using a cross-sectional design; and by continuously assessing changes in population growth rate over the course of the LCP implementation at the scale of the Lemhi watershed using a combination of empirical survival (via PIT tag interrogation and visual marking and recovery) and modeling.

- Determine if tributary reconnections changed habitat availability and what the affects what the affects of tributary reconnections are on estimates of carrying capacity generated for each life stage (i.e., potential productivity). Since the sampling design will provide multiple replicate estimates of stage-based abundance and survival within land-use classifications, we can implement a binomial test using Generalized Linear Models (GLM; R software) with the logit link to determine whether carrying capacity varies as a function of land-use and whether reconnections changed survival/productivity, using a pre/post test.
- Determine if other habitat actions (e.g., creation of pool habitat) changed stage-based productivity/survival. As data are cross-sectional (e.g., measures are replicated under varying flows), and assuming a given watershed variable of interest has sufficient contrast, then we can show how manipulations in a certain watershed trait (e.g. flow or predator-density) will affect potential productivity.
- Determine if tributary reconnections changed fish distribution. Measures of juvenile abundance by life history stage corrected for spawner abundance within a given habitat classification will be used in a pre/post treatment analysis. For each life cycle stage and location, a model is implemented in GLM (R-software), and the results are analyzed using an Analysis of Covariance.
- Determine if fish condition is similar in reconnected versus existing habitat (i.e., what is the quality of reconnected tributary habitat relative to existing habitat?). Pre- and post-reconnection data on fish attributes (e.g., size, weight, or condition factor) collected at rotary screw traps and during electrofishing surveys enables a test of the effects of reconnections on these attributes. If pre-treatment data for fish condition are unavailable, the effects of differing levels of stream connectivity on fish condition can be evaluated in a treatment versus control framework.

Study site locations in the Salmon River subbasin

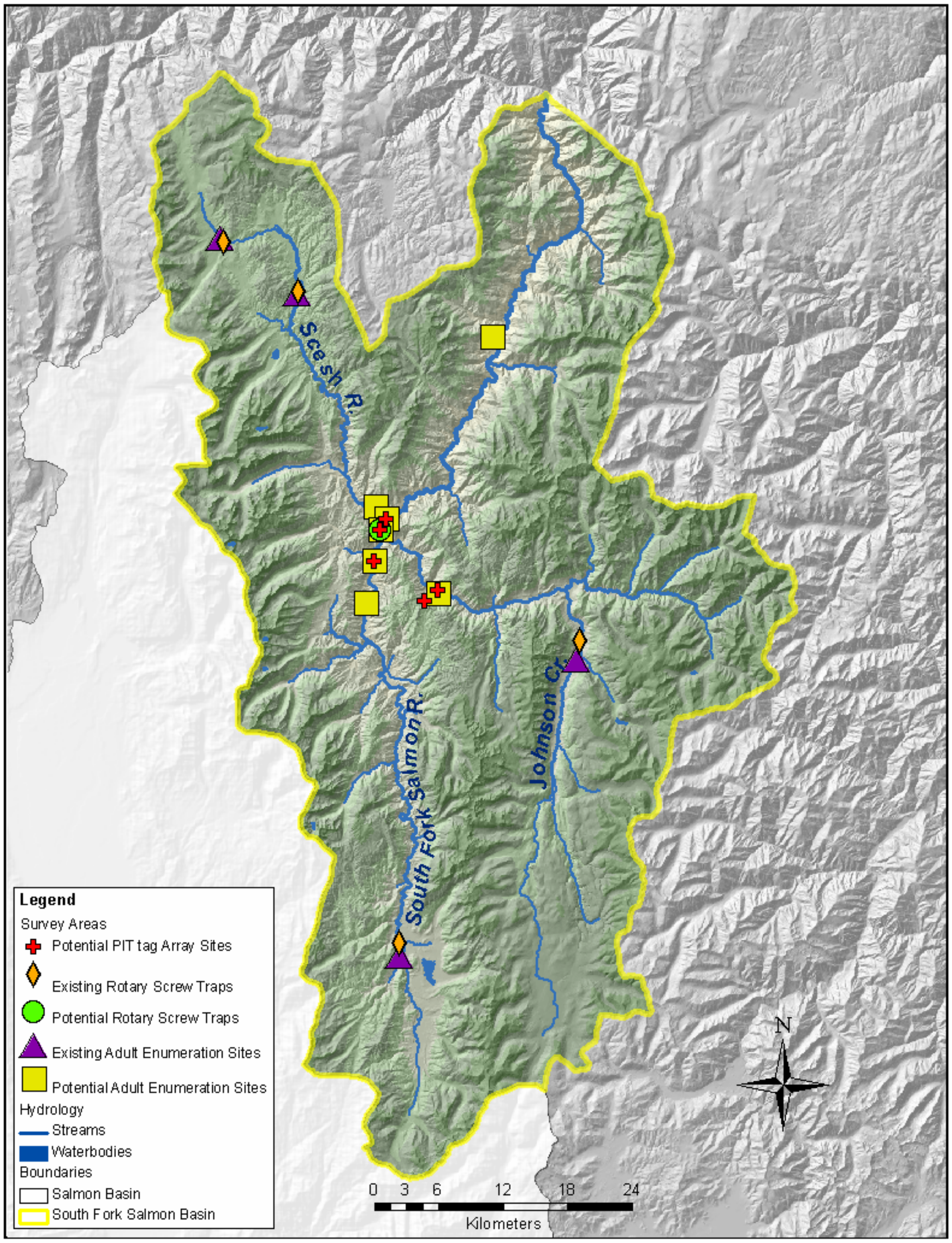


Figure 27. Location of existing sampling infrastructure and potential locations for additional infrastructure proposed by the ISEMP in the South Fork Salmon Basin, Idaho.

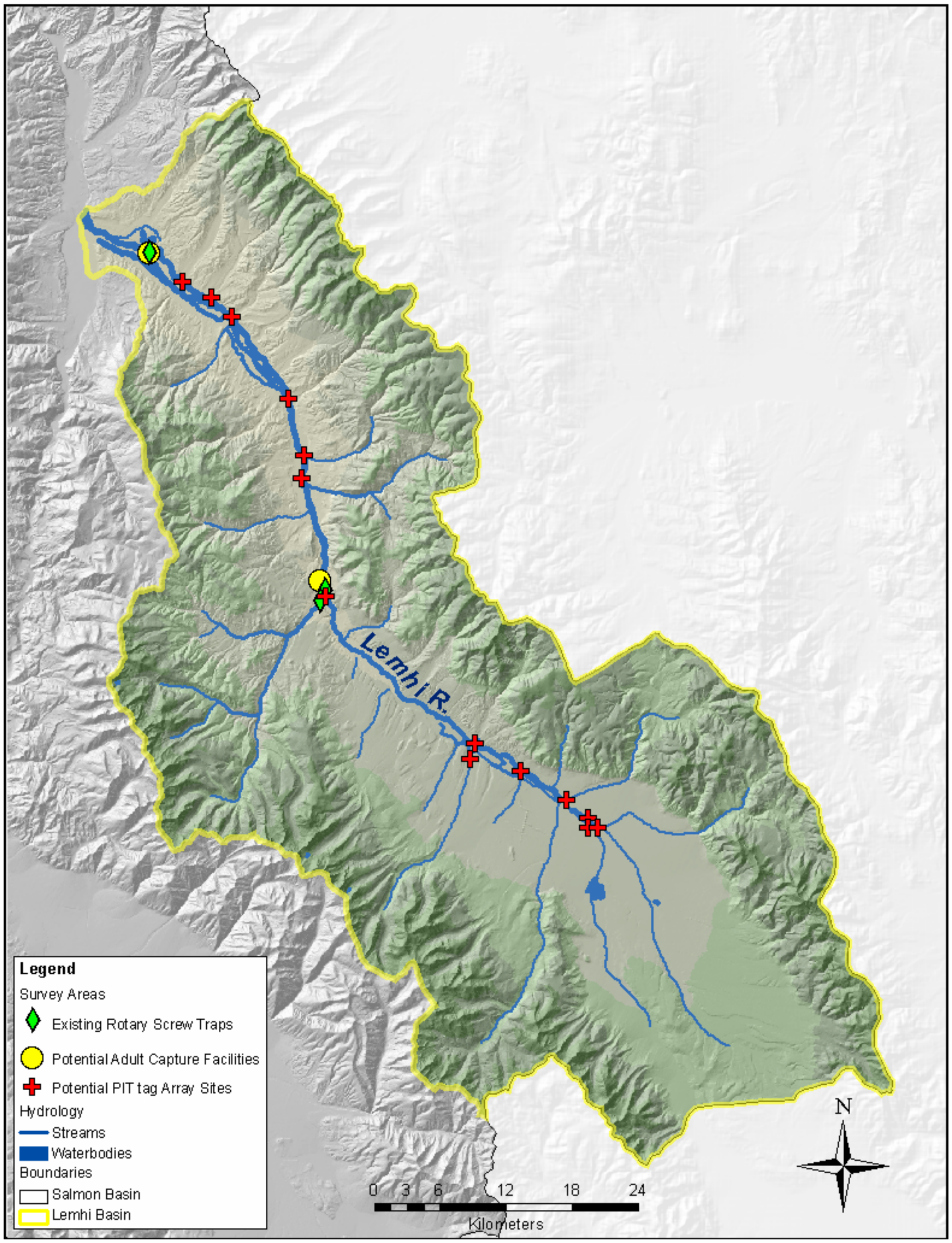


Figure 28. Location of existing sampling infrastructure and potential locations for additional infrastructure proposed by the ISEMP in the Lemhi Basin, Idaho.

What's ahead

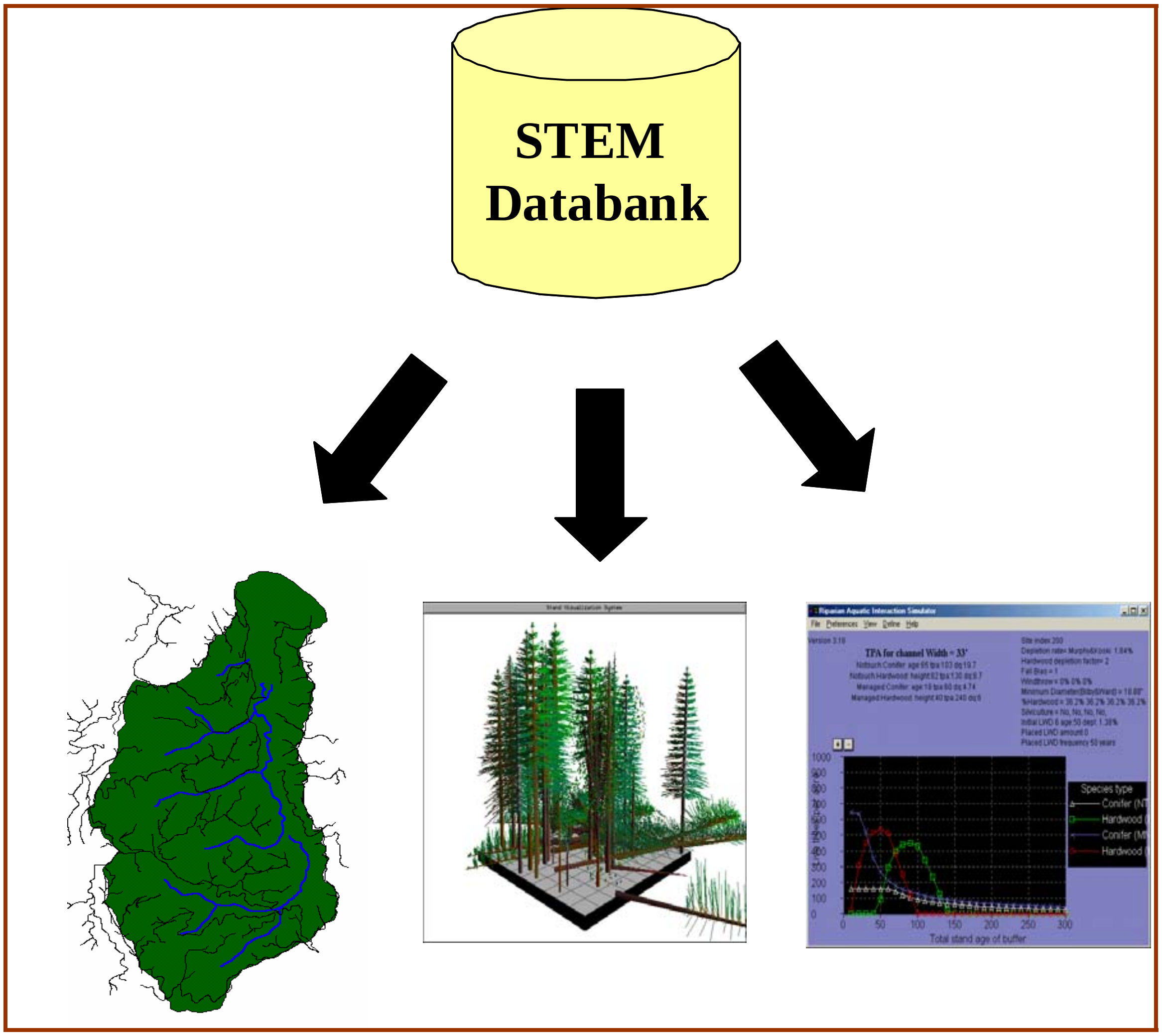
South Fork Salmon River

Install and operate rotary screw trap in mainstem SFSR.	2007 - 2015
Install and operate an acoustic imaging camera in the mainstem SFSR, Secesh River, and East Fork SFSR.	2007 - 2015
Install and operate DIDSON in Secesh River.	2007 - 2015
Install PIT tag detection arrays in mainstem SFSR, Secesh and East Fork SFSR.	2007 - 2015
Purchase PIT tags for deployment during electrofishing surveys and at juvenile and adult traps.	2007 - 2015
Coordinate sampling activities, data collection, data analysis, and reporting with local researchers.	2007 - 2015
Administer project funds and subcontracts.	2007 - 2015
Calculate estimates of population metrics (e.g., escapement) generated using proposed methods, and develop methods to retrospectively apply variance to time series data (e.g., redd counts).	2007 - 2015
Develop methods to enable continuation of existing time series data should existing sampling be replaced with ISEMP infrastructure or methods.	2007 - 2015
Continue development and adaptive refinement of statistical design and analytical methods.	2007 - 2015
Increase temporal span of operations of the lower Secesh River rotary screw trap.	2007 - 2015
Operate PIT tag detection arrays in mainstem SFSR, Secesh River, and East Fork SFSR.	2007 - 2015
Conduct probabilistic and fixed site seining surveys throughout the SFSR.	2007 - 2015
Conduct probabilistic and fixed site habitat surveys throughout the SFSR.	2007 - 2015
PIT tag juveniles collected at rotary screw traps and during seining surveys.	2007 - 2015
PIT tag and visually mark adults collected at the mainstem fish trap.	2007 - 2015

Design and implement a database to capture metadata and data from project activities.	2007 - 2015
Develop, maintain, and adapt STEM database to house project metadata and data.	2007 - 2015
Compare estimates derived from proposed methods to estimates derived from existing methods (e.g., tributary specific juvenile abundance generated from rotary screw traps versus proportional estimation from SFSR aggregate).	2007 - 2015
Apply retrospective variance estimators to time series data.	2007 - 2015
Apply methods to maintain continuity of current time series data.	2007 - 2015
Evaluate whether proposed infrastructure can reliably meet information needs without relying on existing infrastructure.	2007-2015
Analyze project data annually to adaptively manage collection and evaluate methods.	2007 - 2015
Complete permit applications for handling listed species.	2007 - 2015
Update study design document and model annually.	2007 - 2015
Lemhi River	
Install and operate rotary screw trap in the mainstem Lemhi and Hayden Creek.	2007 - 2015
Install and operate adult trap in the mainstem Lemhi.	2007 - 2015
Install and operate PIT tag detection arrays in the Lemhi mainstem and reconnected tributaries.	2007 - 2015
Purchase PIT tags for deployment during electrofishing surveys and at juvenile and adult traps.	2007 - 2015
Coordinate sampling, and data collection, analysis, and reporting.	2007 - 2015
Administer project funds and subcontracts.	2007 - 2015
Continue development and adaptive modification of watershed model.	2007 - 2015

Continue development and adaptive refinement of methods.	2007 - 2015
Conduct probabilistic and fixed site electrofishing surveys throughout the Lemhi watershed.	2007 - 2015
Conduct probabilistic and fixed site habitat surveys throughout the Lemhi watershed.	2007 - 2015
PIT tag juveniles at rotary screw traps and during electrofishing surveys.	2007 - 2015
PIT tag and visually mark adults collected at the mainstem fish trap.	2007 - 2015
Develop and maintain a database to house project metadata and data.	2007 - 2015
Update model annually with empirical data.	2007 - 2015
Analyze recapture data for PIT tagged juveniles generated by PIT tag detection arrays, repeat electrofishing, and at rotary screw traps.	2007 - 2015
Analyze project data to adaptively manage the project.	2007 - 2015
Complete permit applications for handling listed species.	2007 - 2015
Determine adequacy of sampling, annually update sampling design and model.	2007 - 2015
Update study design document and model annually.	2007 - 2015

CHAPTER 6: DATA MANAGEMENT



Data Management System

For a monitoring program at the scale of the Columbia River Basin to be truly successful, a strategy utilizing strong yet flexible lines of communication needs to exist between project coordinators and local collaborators and should be mirrored within the data management tools developed for the program. A large volume of data is being generated in the Columbia River Basin from many agencies and projects. The ISEMP is creating a system of data processing, storage, analysis, reporting, and distribution to meet the crucial needs of managers and analysts. These needs include: (a) summarizing how, when, and where the monitoring data was collected, (b) supporting a range of analytical methods, such as hypothesis testing, time series analysis, structural equations, and mapping, and (c) adapting to changing requirements in the future.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

U.S. Bureau of Reclamation

Contractors

Environmental Data Services

NOAA-Scientific Data Management Team

U.S. Bureau of Reclamation

Volk Consulting

Time Line

The ISEMP has developed and implemented a range of data management tools over the past three years and will continue to create innovative ways to solve data management problems for the life of the ISEMP program.

Budget

Contractor	Scope of Work	FY06
Environmental Data Services	Develop pilot data management system. Design standardized data structures, forms, and output for data entry tool.	$56,000
NOAA – SDM Team	Develop pilot data management system. Develop central data repository and web-based interface.	$200,000
U.S. Bureau of Reclamation	Develop pilot data management system. Develop tool to manage scientific protocols (effort was provided as an in-kind cost share).	$0
Volk Consulting	Develop pilot data management system. Define user requirements and perform beta testing and user support for data entry tool.	$28,500
	Project total for fiscal year 2006:	$284,500

Link to Report

- Summary of Status, Trend and Monitoring Data Management for the ISEMP
  - http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/stm_recap_2006_final.doc

What's been accomplished so far

In the past three years, the ISEMP has successfully implemented a data management system, including these accomplishments:

- Developed a comprehensive data management strategy;
- Piloted the use and further development of the USBR Protocol Manager (continued development in 2007);
- Integrated Protocol Manager with other data management structures (continued development in 2007);
- Developed and enforced the use of standardized data collection protocols within data entry systems;
- Established QA/QC guidelines that are integrated into the data management structures and data flow processes (continued development in 2007);
- Created Archive Template Modules (ATMs) to organize field data and assist in uploading to the central data repository;
- Created the STEM (Status Trend Effectiveness Monitoring) Databank to serve as ISEMP's central data repository;
- Created and maintained several geodatabases synchronized with the STEM Databank (continued development in 2007);
- Created and maintained a website for the flow of program information to the public and agency collaborators; and
- Conducted demonstrations, workshops, and training sessions to educate ISEMP collaborators on the use of the ISEMP data management system.

Background

In response to the inadequacies of the data management system in the Columbia River Basin, the ISRP (2000) recommended development of standardized data storage and reporting procedures. In response, the ISEMP is developing a data management approach that emphasizes an 'end-to-end' view of data as an integral component of its effort to standardize monitoring and evaluation information generation and interpretation. The ISEMP data management supports the integration and utility of monitoring data by standardizing the data flow from field generation to analytical application. The ISEMP has standardized data communication and flow, in a pilot form, through the development of a very generic STEM Databank, the Aquatic Resource Schema (ARS) to manage the crucial and broadly defined metadata, and ATMs that facilitate the field data collection, data uploading and communication between elements. The ISEMP data management elements together define a database schema that addresses the key issues raised by the ISRP by defining a standardized data structure for storing, sharing and analyzing fish, water quality, stream habitat, and landscape classification data.

Components of the ISEMP data management strategy

The ISEMP data management strategy has developed several component processes and structures that operate as step-wise functions to enter, manage, summarize, and distribute aquatic resource field data and metadata (Table 12, Figure 29).

Table 12. Functions, and component processes and structures of the ISEMP data management strategy.

Functions	Component processes and structures
Track and catalog data collection methodologies	Protocol Manager
Standardize field data collection	Standardized protocols and methodologies data dictionary?
Organize data at the local (e.g., field collector, agency) level	ATMs – archive template modules
Facilitate efficient transfer of data	Programming code between ATMs and STEM Databank
Archive data in secure, centralized repositories	STEM Databank and Geospatial Databases
Organize data within centralized repositories	ARS – Aquatic Resource Schema; other schemas
Facilitates the interaction between centralized repositories	Programming code between STEM Databank Geospatial Databases
Facilitate data manipulation (e.g., summarization, metric calculation, basic analyses) within the repositories	Programming code within STEM Databank and Geospatial Databases
Facilitate efficient output of data to data analysts and other users	ISEMP website and other media (e.g., DVDs)
Train system users in the use of each component of the data management system	Demonstrations, workshops and training sessions

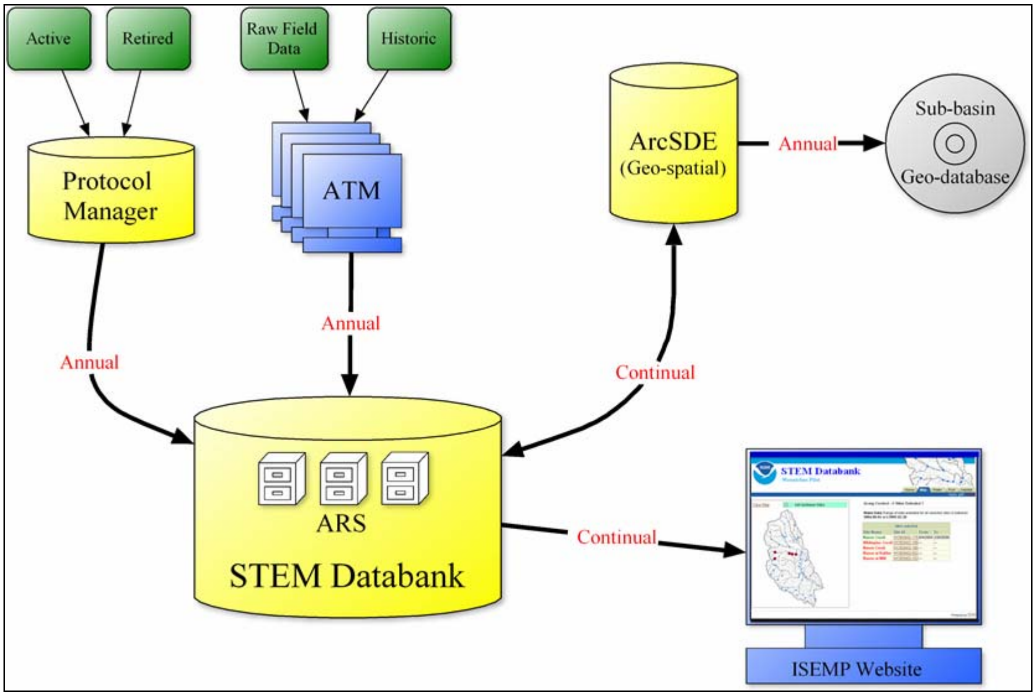


Figure 29. An illustration of data flow and data structures under the ISEMP data management strategy.

Protocol Manager

The first step in the ISEMP data management system is the management of the scientific protocols used in monitoring. Protocols refer to suites of methodologies used by researchers to collect information about an ecosystem. Protocols can be sub-divided into methods, attributes, domains, and ranges, and each subdivision must be tracked in an efficient large-scale monitoring program (see text box below).

Tracking protocols in a large-scale monitoring program is important because the quality of observational data can vary by protocol and, often, data from one protocol is not compatible with data from alternative protocols. Researchers and agencies within the Columbia Basin have consciously (or unconsciously) adopted a range of protocols and methods in order to achieve specific research or monitoring objectives. These objectives have also varied over the last 50 to 60 years, resulting in a plethora of protocols and methods in use throughout the basin.

In an integrated large-scale monitoring program, standardizing the use of protocols may be ideal but may not be practical. For example, determining the best protocol for a given objective may require testing (see Chapter 7). In the absence of standardized protocols, the next best situation is a clear understanding of which protocols have been used in monitoring, how they relate to each other, and how data management structures, such as field forms and databases, need to be modified. Finally, the minimum requirement for the management of monitoring program data from various protocols is clear documentation of the methods, attributes, and domains used during data collection.

No standardized protocols have been agreed upon in the Columbia Basin. As a result, the ISEMP has adopted the Protocol Manager tool, developed by the USBR and National Park

Parts of a Protocol

Protocols are a collection of methods used to efficiently capture accurate data. The ISEMP habitat surveys in the Wenatchee/Entiat largely follow the EMAP protocols developed by EPA (Peck et al. 2001). This single protocol contains many **methods**. For example it describes the methods for measuring channel morphology, classify habitat types, characterize substrate, assess riparian conditions, etc.

Data collection **methods** describe how data are to be collected in the field (which tools to use, how the tools are applied) and describe the set of **attributes**. For example, the method for measuring width/depth ratios in the EMAP protocol requires measuring attributes such as bankfull height, thalweg depths, bankfull width at a several locations in the stream.

Attributes are the data elements that are collected by a method. Characteristics of attributes include the unit of measure, number of decimals recorded, and default value. Data entered for a given attribute must conform to acceptable values as defined by the method and protocol. For example, bankfull height is measured in centimeters and is rarely greater than 100 cm in the habitats we study. Similarly, a given method may state the only three acceptable values for the attribute "habitat type" are pool, riffle, or glide.

Domains are the list of acceptable values for a categorical attribute and **ranges** are the expected upper and lower values for a continuous attribute. Tracking this level of detail about protocols and methods allows values to be validated at the time of data entry and is used to describe the data itself.

Service, to perform the necessary protocol management functions. The Protocol Manager tool is also being adopted by PNAMP in an attempt to prescribe standardized methods for field data collection across a regional scale. To date, Protocol Manager has been populated with data collection methods from the Upper Columbia Monitoring Strategy, EMAP, and PIBO. Protocol Manager increases the ease, accuracy, and efficiency of documenting protocols by allowing users to select from existing protocols, modify existing protocols, or create new protocol documentation. All data values stored within the ISEMP's ATMs and the STEM Databank are associated with a method catalogued in Protocol Manager, which allows automated access to full metadata descriptions of every value within the databases. The synchronization of Protocol Manager with the STEM Databank supports efficient protocol comparisons, site comparisons, or analysis of functional relationships.

Standardized protocols and methodologies

As stated above, it is preferable to use standardized protocols in a large-scale monitoring program. The ISEMP has adopted existing standards when available or developed pilot standards when necessary. For example, all the ISEMP habitat surveys in the Wenatchee and Entiat have been standardized to conform to protocols found within the Upper Columbia Monitoring Strategy (Hillman 2006). In the case of fish capture and PIT tagging, where standards have not been set, the ISEMP worked with several participating agencies to develop a pilot PIT tagging protocol that has been standardized by these agencies throughout the Upper Columbia ESU. The ISEMP's ultimate recommendations for standardized protocols for the entire Columbia Basin will be shaped by the lessons learned through using these standardized protocols.

ATMs

ATMs are small databases functioning at the agency or desktop scale operated by field data collectors that facilitate data entry and quality control and can perform database functions specific to local agency or the ISEMP's reporting needs. ATMs ensure data integrity by requiring metadata to be documented before observation values can be entered, and by forcing entered values to conform to the specifications of the protocol. Most importantly, ATMs provide a standard procedure to deposit data into the STEM Databank; simple output queries operated within the ATMs produce tables that are directly loaded into the STEM Databank without the need for additional formatting or filtering.

ATMs for water quality, stream habitat, and fish abundance currently exist and consist of a set of data entry forms, data tables, and summary queries built according to the ARS (Figure 30 and Figure 31). Additional ATMs will be created to handle other types of data (e.g. macroinvertebrate). The ATMs were developed with Microsoft Access, although other database programs can be used, and they expand upon Protocol Manager by not only tracking protocol and method information but also managing attribute, domain, and range information for each data element.

Initial beta testing has shown the ATMs to be remarkably flexible and popular among data collectors. The ISEMP contractors who learned about the ATMs at ISEMP workshops have enthusiastically adopted ATMs for use within their agencies.

The STEM Databank

The STEM Databank is the central data repository for the ISEMP project and was developed by the Science Data Management (SDM) Team at NOAA-Fisheries to provide core data management functionality. The STEM Databank provides data validation, long-term storage and back-up, and supports multiple users and a web-based user interface.

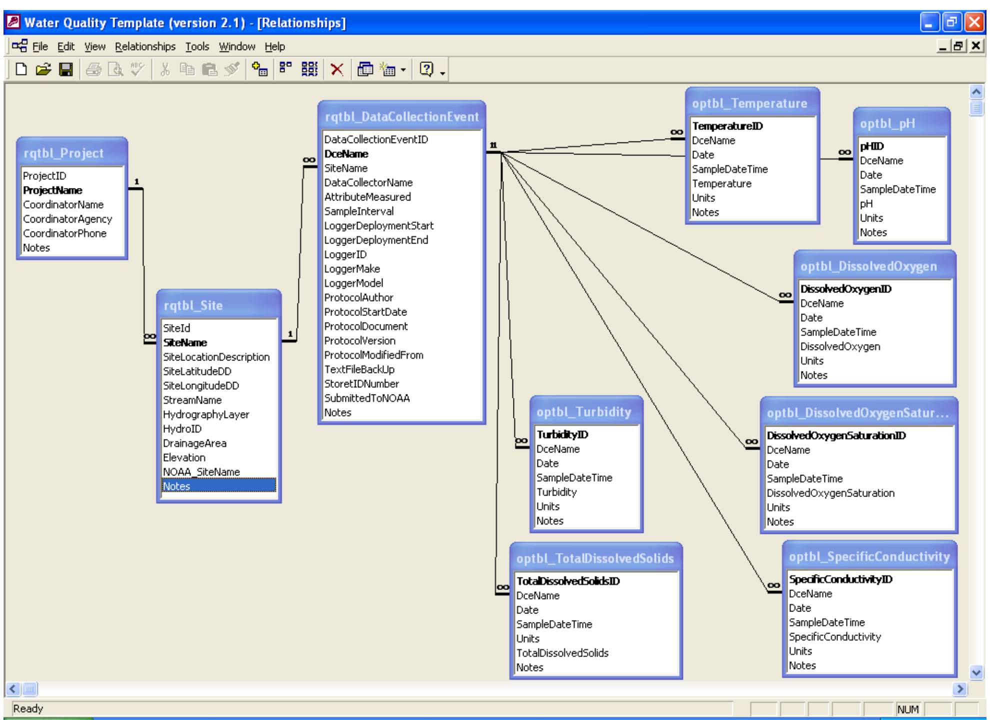


Figure 30. An example schematic of an Archive Template Module (ATM) developed by the ISEMP data management team.

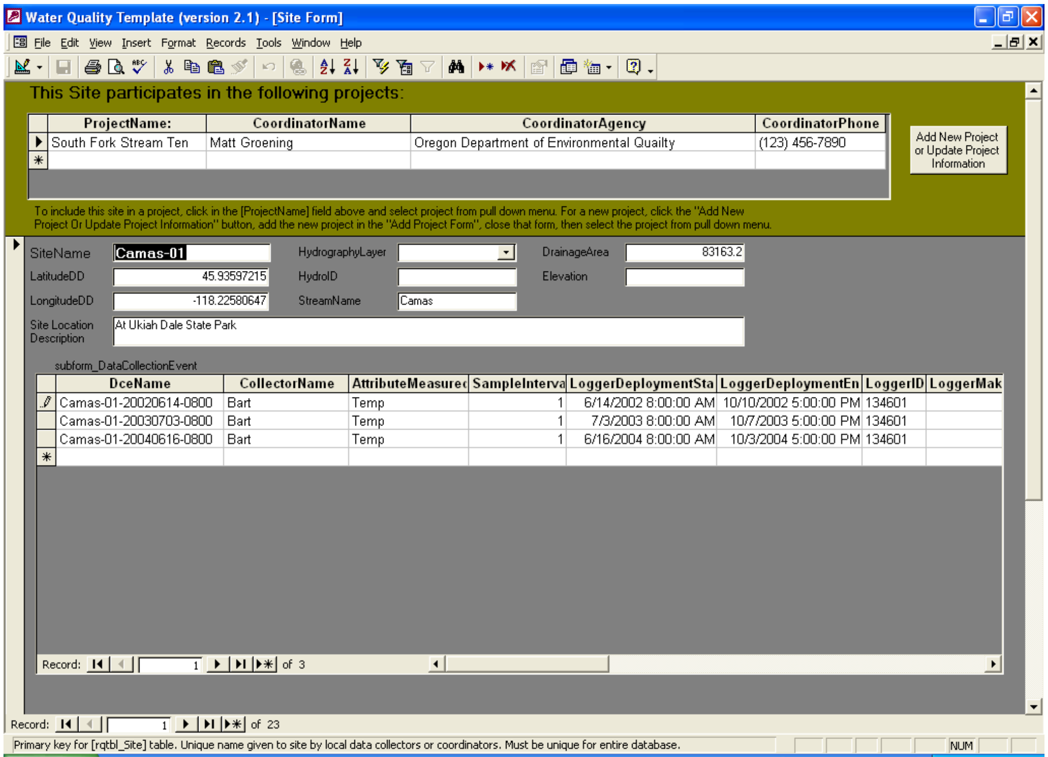


Figure 31. An example of a data entry form designed by the ISEMP data management team that allows for easy data entry for field staff and provides data validation.

The STEM Databank was developed to:

- Accommodate large volumes of status, trend and effectiveness monitoring data from multiple agencies and projects;
- Track protocols and methods for all stored data;
- Support a range of analytical methods;
- Develop a web-based data query and retrieval system; and
- Adapt to changing requirements.

The Databank's architecture was designed to be very flexible, allowing the addition or removal of attributes without modifying the underlying structure of the repository. The Databank flexibility also allows the integration of data from external electronic sources that are needed by the ISEMP to meet analysis needs (e.g., National Resource Information System, Streamnet, or EPA's Water Quality Data Exchange). These features have been accomplished by normalizing the STEM Databank architecture and the use of the ARS (see below). A normalized relational database architecture means that data is organized and stored with the minimal redundancy of attributes possible that retains all metadata associated with a unique value. For example, the ISEMP data stored within the STEM Databank are organized according to the ISEMP's ARS (see section below). Note that it is possible for the STEM Databank to store data according to other schemas, as long as they are consistent with the ISEMP ARS.

The STEM Databank has several key characteristics, including:

- Data summary in a variety of formats to meet most reporting and analytical requirements (continued development in 2007);
- Built-in functions calculate standard metrics and generate standard summary statistics (continued development in 2007);
- Synchronized with Protocol Manager to enhance data analysis by having protocols attached to individual data values;
- Synchronized with the ISEMP's ATMs for automated upload of field data (continued development in 2007);
- Synchronized with the ISEMP's geospatial databases in the ArcSDE software environment (see section below on geospatial databases) (continued development in 2007).

The Databank was developed and populated with field data from the Wenatchee sub-basin in close coordination with the John Day ISEMP by NOAA-Fisheries SDM and the USBR data management team. However, its design is not geographically restrictive and is intended to accommodate aquatic resources data from the entire Columbia River Basin.

The STEM Databank is currently functional, storing data from the Wenatchee 2004 and 2005 field seasons, but is still being developed and improved. Limited summary queries and a prototype web interface currently function to export data from the STEM Databank, and further development of the STEM Databank is projected to include increased tabular and spatial query power. These data are internally accessible by the ISEMP staff for testing and further query development.

ARS and other schemas

The ISEMP ARS is a database structure that was developed to organize the ISEMP data within the STEM Databank and to serve as a template to support non-ISEMP agencies within the Columbia River Basin in managing, documenting, and analyzing aquatic resources data. The ARS resulted from a design process that focused on development of small-scale, data type specific prototypes, employing ecologist to test the prototypes, gathering input from other database designers, and then integrating the lessons learned. The ARS improves upon previous efforts by imposing a structure on the data that is robust against protocol variation, by supporting the development of cross-walks between protocols (cross-walks define the process for transforming an attribute measured under one methodology to a roughly equivalent value if the attribute had been measured under an alternate methodology), and by defining relationships inherent to the data.

The primary characteristics of the ARS include:

- It is a data model that is robust against variations in data collection protocols. In fact, the ARS assumes that data collection protocols will vary depending on the resource management questions being addressed and that protocols will continue to evolve over time as both scientific understand and measurement methodologies evolve;
- It supports procedures for ensuring increased data integrity at the time of data entry;
- It supports proper analysis and summarization of aquatic resources data.

The ARS includes tables for documenting projects, sites, statistical designs, data collection events, sampling units, observations, and measurement methodology (for a figure illustrating how the ARS is built see http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/BPA_ARS_figure_20061129.jpg). The database schema requires that appropriate metadata about field observations be recorded prior to entering field data into the database. The schema requires that a statistical design, a site, and a protocol exist before data collection events can be created, and that a data collection event exist before observations of water quality, fish abundance, or stream habitat can be created. This referential integrity helps to ensure data integrity at the time of data entry. Additionally, metadata about the data collection protocol and measurement methodologies are used to place restrictions on data entry forms, thereby providing data validation at the time of data entry and ensuring consistency between a protocol and data entered under that protocol.

Geospatial Databases

Geodatabases are databases designed to store geospatial data (i.e., "GIS data layers") in a standardized format. This format maintains the integrity of metadata and the geographic projections that define the spatial coordinate system. The unique ability of geodatabases to define spatially explicit relationships between data elements allows geodatabases to support advanced spatial analyses.

The ISEMP uses two types of geodatabases: an enterprise geodatabase and personal geodatabases. The enterprise geodatabase is an Oracle database managed through the ESRI ArcSDE software that is maintained on a central server by the SDM team at NOAA Fisheries. The enterprise geodatabase acts as the primary archive of geospatial data for the ISEMP project, stores geospatial data for regional scale analyses, and provides the spatial context for data stored in the STEM Databank. The STEM Databank maintains links to the enterprise geodatabase through the use of unique identifiers, which allow monitoring data in the STEM Databank to be represented and analyzed in a spatial context.

Personal geodatabases are desktop-scale databases (Microsoft Access database managed through the ESRI ArcCatalog software) designed to facilitate the distribution of geospatial data (the small size of personal geodatabases means they can be distributed via DVDs) and to support subbasin specific analyses. The ISEMP maintains personal geodatabases for each pilot basin and IMW that contain the regional-scale data from the enterprise geodatabase, plus additional geospatial data that hold local relevance within each pilot basin or IMW. For example, the 1:100,000 National Hydrography Dataset is the stream layer used to support regional-scale analyses, while the 1:24,000 stream layers are typically maintained by local GIS coordinators, where the additional detail is often required when implementing projects within the pilot basin or IMW. Personal geodatabases are also used to develop and troubleshoot spatial analysis procedures, which can later be implemented on the enterprise geodatabase. For example, the Wenatchee geodatabase was used to define the process of characterizing monitoring sites and upstream catchments; now that the process has been defined, it can be replicated on the central server using the enterprise geodatabase and performed for other sites throughout the region.

Website and other media

The ISEMP facilitates data distribution through the ISEMP website, STEM Databank website linkages, geodatabases, the ATMs and by other media. The ISEMP website (http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/?CFID=31055621&CFTOKEN=73780522&jsessionid=643090c2f7705e3e7334) is accessible by the public and contains documents, such as annual reports and presentations, map products, and data management tools. The website is updated quarterly and is managed by NWFSC. This website will eventually contain links to the STEM Databank interface when that tool is ready for public use. Upon request data are also distributed using other media (e.g., DVD), particularly when data volume is too high for the Internet (e.g., when shipping geodatabases). ATMs are also available upon request or via the website and are updated as needed.

Education: demonstrations, workshops and training sessions

The final element of the ISEMP data management strategy is education. In addition to developing novel data management tools, the ISEMP has recognized that it must train people to facilitate tool use. For this reason, the ISEMP has conducted demonstrations of its data management tools and has sponsored training workshops for the widespread use of ATMs. Individual training sessions have also been conducted one-on-one between the ISEMP staff and agency contractors. These one-on-one sessions assist the ISEMP staff in assessing ATM and data management needs within pilot basins and the region. These educational functions, as well as some of the more manual aspects of the data flow process, will eventually be integrated into a Data Steward staff position piloted in 2007 that will hopefully be cooperatively funded by the ISEMP and participating agencies. The Data Steward will serve at the regional level assisting with on-the-ground implementation of the ISEMP data management strategy.

Lessons Learned

The development of the ISEMP data management strategy has provided valuable insights into:

1) Understanding data collector needs and limitations;
2) The need to standardizing data format and content, and
3) The existence of political issues that inhibit consistent data management across agencies.

During the development of the STEM Databank, ARS, and ATMs, it was critical to understand the needs and limitations of data collectors in order to create a useable tool that efficiently helped the ISEMP meet data analysis needs. Data collector limitations were primarily outdated software, limited time to commit to data management, and data stored inefficiently on computers, such as using multiple Excel files for data storage rather than a database. These problems are often the result of the limited time data collectors have to invest in data management training.

Data is most efficiently summarized and stored when in a standardized format. This allows large quantities of data to be processed using the same technique. Data collection efforts in the ISEMP pilot basins highlighted how agencies, and even individuals within agencies, often use different standards for data storage. As a result, any agency requiring data from multiple sources must first spend significant time reformatting data. This time investment has resulted in the ISEMP Data Dictionary and ARS.

The ISEMP also learned that the development of a flexible data management system helped develop ‘buy in’ from agencies. The time that data collectors can commit to data management is often limited. However, many data collectors became interested when a ready-made, user-friendly data management system was available. Collectors found the educational time investment worthwhile if it would allow them to handle data more efficiently. The ISEMP acknowledges that this political 'buy in' across agencies is necessary to effectively implement a data management strategy across a large spatial scale. The proactive method of initiating data management strategies with the onset of a project also reduces the time investment of 'backtracking' and 'backfilling' that often occurs at the time of data analysis.

What's ahead

Develop data management tools appropriate for programmatic needs.	2007 - 2015
Update the USBR's Protocol Manager to accommodate future ISEMP protocols and to include details of protocol and method attributes.	2007
Further develop the existing ATMs for water chemistry, stream habitat, and fish abundance data and develop additional ATMs as needed. Develop the ISEMP ARS and revision of existing ATMs to match ARS.	2007
Complete ARS review process and conduct pilot testing in Wenatchee basin. Expand schema to include additional data types (e.g., macroinvertebrates).	2007-2009
Continue to maintain the STEM Databank and load 2006-2008 ISEMP data. Automate import/updates from both Protocol Manager and the Database Templates. The SDM team will further its development of the web-based user interface and data access applications for the STEM Databank. The data access application will include metric and summary calculations for water quality, habitat, and fish abundance data. Historical water quality and fish abundance data from the John Day subbasin will also be loaded to the STEM Databank.	2007 - 2011
The ISEMP has been working to deploy a web-based communication and information-sharing tool that will allow users to post documents and data to a central repository and provide collaborators with access to this information. The Oracle Collaboration Suite also provides several secure web-based communication tools that allow users to chat and share desktop environments through a secure Internet channel. The SDM team plans to make this collaboration suite available to the Wenatchee RTT in first quarter of fiscal year 2007.	2007 - 2008
The ISEMP will also develop specific geodatabases for GIS layers and stand-alone geodatabases for the three pilot basins and the IMWs to store GIS layers for the specific basin and support advance geo-processing. Layers will be stored in a single consistent projection and extent. Geodatabases will be delivered through the ISEMP website or via DVDs and the ISEMP will provide user training to regional GIS analysts.	2007 - 2015
Site Manager: the ISEMP will create and populate a Site Manager to uniquely identify all sites of monitoring activity within pilot basins.	2007-2009
Data Steward: a cooperatively-funded staff position will be developed in 2007 to assist at the regional level with the on-the-ground implementation of the ISEMP data management strategy.	2007-2009

Compilation and Inventory of Historical and Current Data

An inventory of existing data sources and an analysis of the spatial distribution of historical and current monitoring efforts allow the identification of both spatial and content gaps that can be filled through the proper design of status/trend and effectiveness monitoring programs. Understanding existing data provides a framework for determining future data management and monitoring needs.

The ISEMP has begun an effort to compile and inventory historical and current data within the three pilot subbasins. Agencies participating in the historic data collection include local, state, and federal agencies, such as ODEQ, BLM, USFS, ODFW, U. S. Geological Survey, Soil and Water Conservation Districts, the Confederated Tribes of the Warm Springs, Oregon Water Resources Division, University of Washington, OSU, and the USBR. Relevant water quality and fish abundance data were inventoried by phone interviews with participating agency staff and were compiled electronically.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration

Contractors
Environmental Data Services
Northwest Fisheries Science Center-Scientific Data Management Team
Volk Consulting

Time Line

Since 2004, the ISEMP has compiled a comprehensive inventory of historical monitoring data collected in the past 20 years in the John Day subbasin in an effort to establish a working foundation for status and trend monitoring sites. Similar work has begun for the Wenatchee/Entiat and Salmon subbasins and is expected to continue during the course of the next few years.

Budget

Contractor	Scope of Work	FY06
Environmental Data Services	Compile and standardize GIS data layers.	$4,600
Volk Consulting	Generate standardized data layers from historical data and GIS data. Build data migration templates. Build database output forms.	$38,000
	Project total for fiscal year 2006:	$42,600

What's been accomplished so far

An inventory of historical and recent GIS and tabular datasets from 1985 to the present has been performed for the John Day, Salmon, and Wenatchee subbasins. We have completed the compilation of this data for the John Day subbasin and are still working on this compilation for the remaining two pilot subbasins. The remainder of this section primarily describes the work done to compile and inventory data from the John Day.

The data inventory process included finding and contacting agencies, conducting interviews, and compiling data lists. This process had the added benefit of facilitating the coordination of local agencies, their monitoring designs, and their current data storage methods.

Tabular data inventory

The principal data types of interest for data compilation efforts in the John Day subbasin were tabular records of water temperature and fish abundance. The compilation of this data was complicated by several factors. For example, multiple agencies were responsible for the collection of these data types and limited communication between and within agencies had resulted in non-standardized data storage methods and limited data sharing capacities. Compilation efforts were further complicated by the large quantity of data (e.g., more than 3,000 water collection events over 20 years in the John Day), the variety of data types (water quality data, fish abundance data, habitat data), and the variety of data formats used to store data (e.g., text files, spreadsheet files, and database files). These complications were time consuming[5] and prompted the ISEMP to develop a process to efficiently identify, locate, prioritize, process, and store historical datasets. Another offshoot of this process was the creation of ATMs that are discussed in more detail in the Data Management System subchapter.

Existing data collected so far has been stored in ATMs and will eventually be incorporated into the STEM Databank to facilitate dissemination and to manage its use. Records compiled so far for the John Day subbasin include:

- Water temperature data from more than 800 unique sites and 3,200 monitoring events provided by 10 agencies;
- Fish data collected by the ODFW since 2000 (continued data entry in 2007), and
- Over 60 cross-section and macroinvertebrate monitoring sites (continued in 2007).

Additional fish data from OSU and ODFW (Corvallis, OR) have been identified but are not currently housed in NOAA databases. Data collection and the inventory process is ongoing but has been simplified with the establishment of working databases for each data type.

To demonstrate the usefulness of historical data, John Day subbasin-wide maps of water temperature were developed by plotting average monthly values of daily 7-day running-average data and displaying these using GIS (Figure 32 and Figure 33). These maps show an overall picture of water temperature within the basin and reflect general patterns of warm and cool streams.

[5] Data was acquired over 80 hours in a 3-month period and required 1,300 hours over 12 months to process.

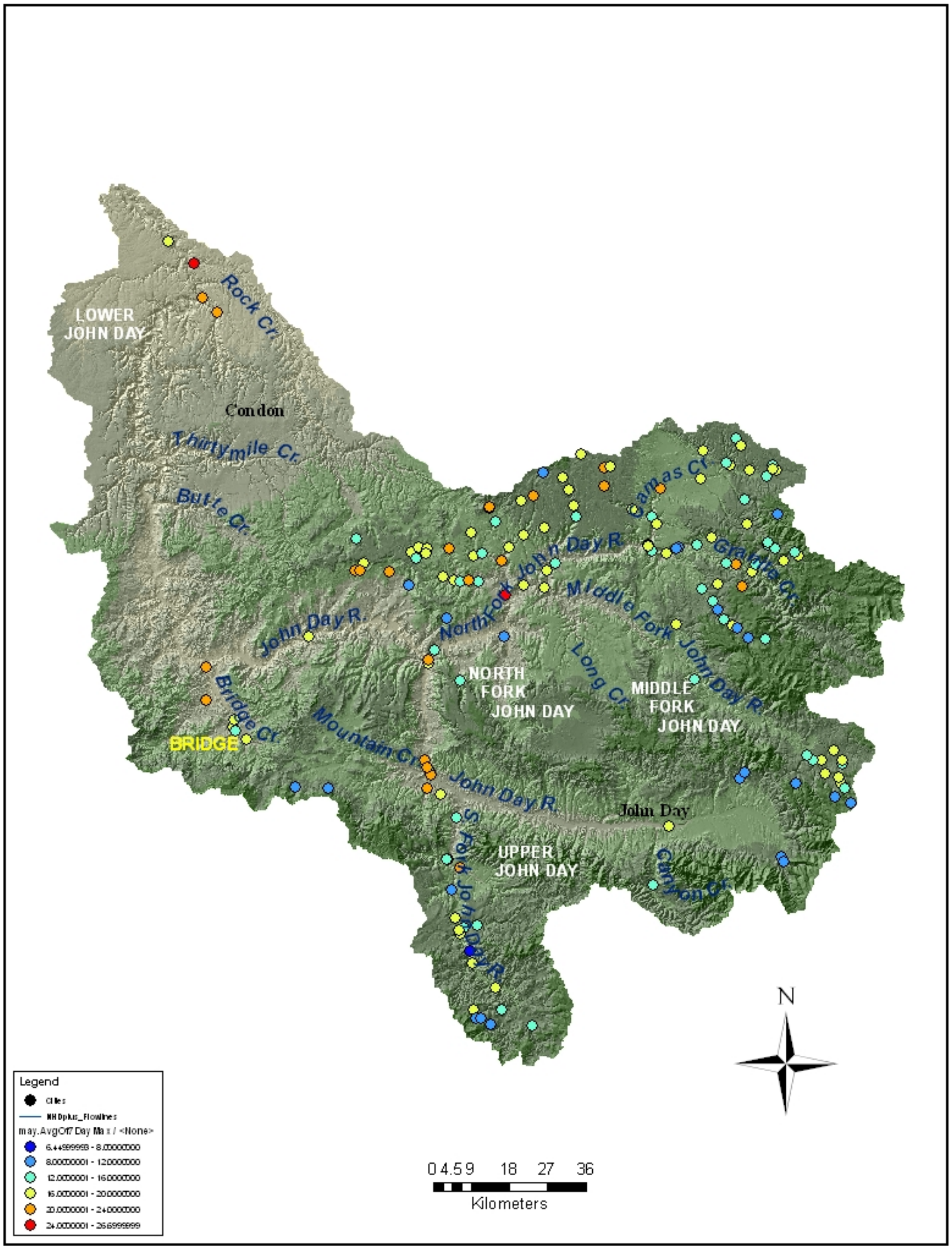


Figure 32. Monthly average of 7-day-running-averages of daily maximum temperatures for May (1985-2004) in the John Day subbasin, OR.

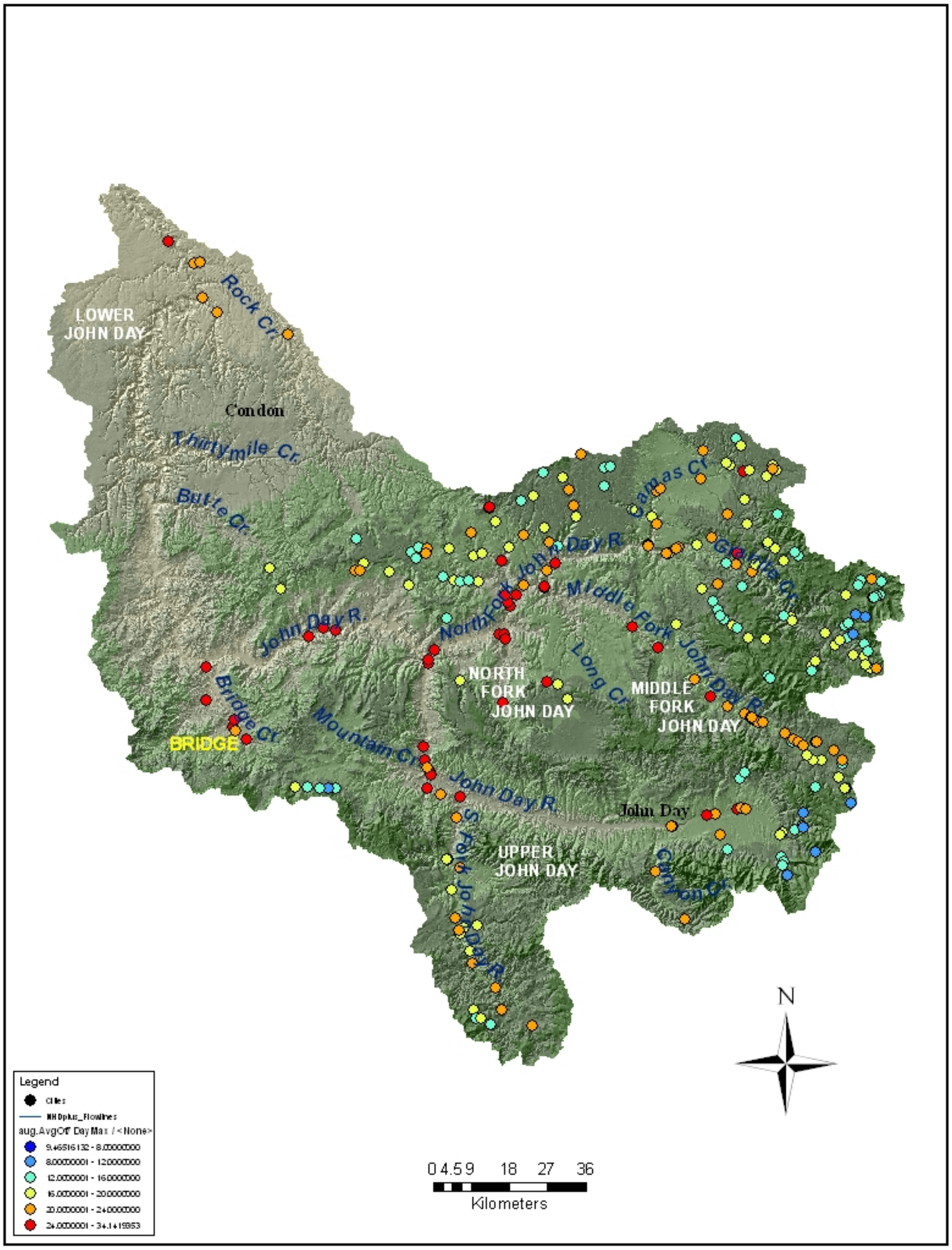


Figure 33. Monthly average of 7-day-running-averages of daily maximum temperatures for August (1985-2004) in the John Day subbasin, OR.

GIS data inventory

GIS layers necessary for site selection and site characterization have been compiled for the three pilot subbasins, as well as for the region as a whole. The layers describe topography, hydrography, watershed boundaries, geology and soils, climate, fish distribution, aquatic habitat, and human influences (http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/docs/BPA_GISInventory20061129.jpg). This information has been used to support the selection of monitoring sites in the Wenatchee and Salmon subbasins, to derive metrics that characterize the 8,431 sub-watersheds in region 17, to describe site-level and upstream catchment-level characteristics of monitoring sites in the Wenatchee and John Day subbasins, and for general cartographic purposes. The GIS layers held at NOAA are stored in an ArcSDE, which stores geospatial information in a standard relational database architecture and supports efficient geo-processing and data distribution. All GIS layers on the ArcSDE have been converted to a single projection (NAD83 datum using an Albers conical equal area projection) appropriate for spatial analyses in the Columbia River Basin. Federal Geographic Data Committee metadata has been maintained for all layers on the ArcSDE.

Lessons learned

The three subbasins differed in the number of agencies, collaborative efforts, projects, and data organization. The level of detail collected about monitoring projects varied among subbasins.

The most common problems encountered during the inventory process were:

- Agency personnel were initially challenged by the question "What monitoring projects are you familiar with in the basin?"
- Understanding agency structure, goals, and projects was necessary but difficult to accomplish during a short phone interview.
- There was often limited data organization or management within agencies, making it difficult for agencies to easily send organized data to the ISEMP.
- Data provided to the ISEMP was in multiple formats.
- Data quality varied among datasets.
- Managing, formatting, and summarizing large quantities of data was time consuming.

A set of guidelines for the interview process was developed to overcome these issues and to ensure that a standard set of information about projects was collected, including:

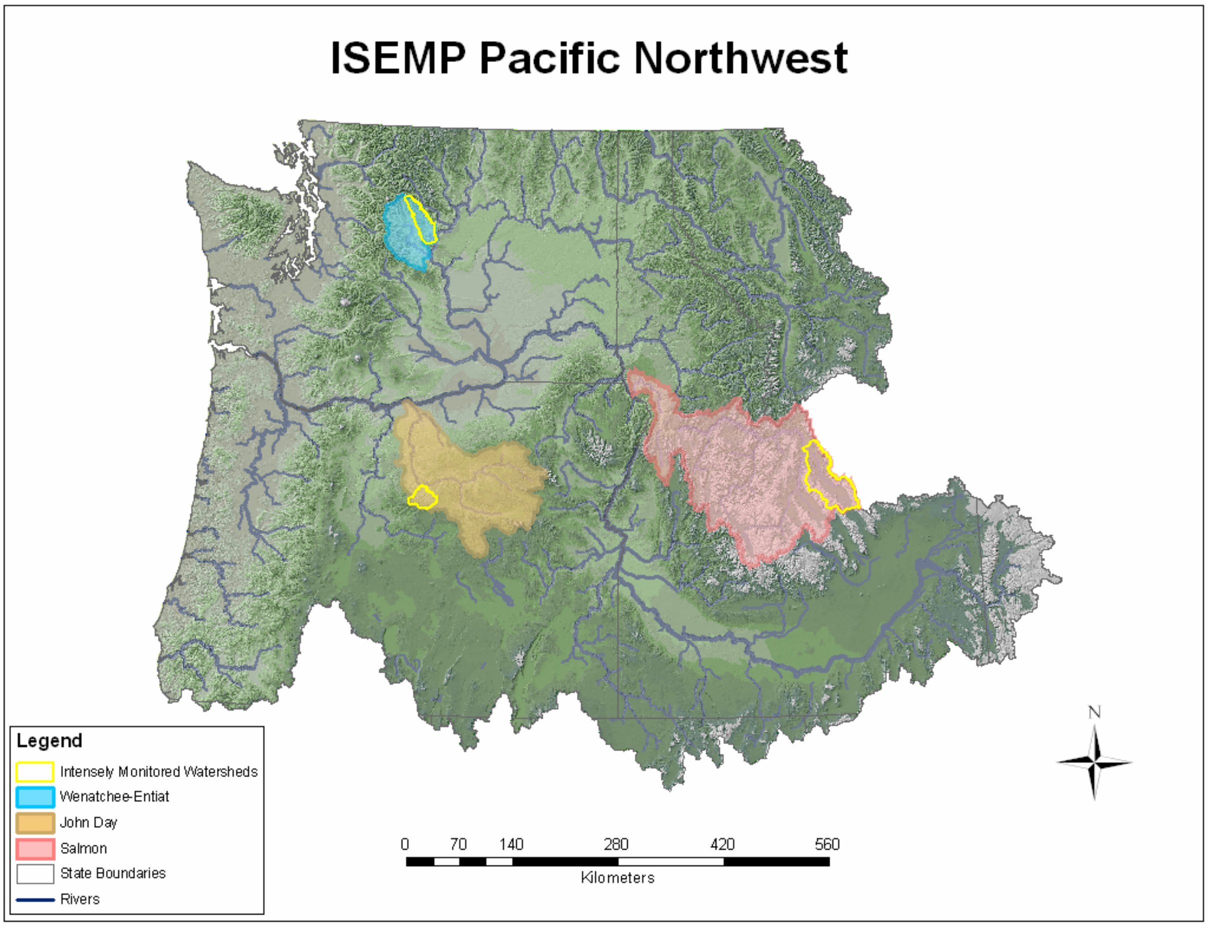
- Determine *a priori* goals for the inventory process. Agencies hold copious amounts of data and it is important to quickly steer an interview to the information that is desired for the inventory. To determine these goals, understand how the inventory will be used in the future.
- Create a spreadsheet of desired attributes/information to collect from agencies. It is critical to track the personnel and project information in a spreadsheet format. Not only does this facilitate 'backtracking' and 'linking' information sources together, but it also allows an interviewer to ask specific questions about a project to get the appropriate amount of detail for the inventory.

- Be aware of the data collector's knowledge base. The knowledge of the interviewer will determine the amount, type, and accuracy of the data that is collected during the inventory. The inventory and interview process is time consuming and decisions about time investment for personnel with different prior knowledge of the agencies, projects, and data types will determine the resolution of the collected data. For example:
    - Are interviewees familiar with data collection methods?
    - Are interviewees familiar with how the inventory will be used?
    - Are interviewees familiar with the structure of the agencies that will be interviewed?
- Use multiple methods to inventory data. This maximizes the amount and type of data that can be collected for the inventory. Phone interviews gain the trust of agencies/individuals, facilitates communication among providers, and a non-partisan approach can be used to avoid conflict among agencies and coordinators. Internet research allows a data collector to gain familiarity with existing groups, agencies, and projects, allowing more useful information to be extracted during phone interviews. Report reading is the most time consuming method, but is sometime the only way detailed information about project attributes can be extracted for monitoring projects.

What's Ahead

Complete the compilation of historical data within the Wenatchee/Entiat and Salmon subbasins.	2007
Evaluate the effort needed to coordinate inventory databases, such as the historical data and Pacific NW Salmon Habitat Project Tracking Database (NOAAF, NWFSC) databases, with ISEMP monitoring plans. Develop recommendations for use at the regional-scale regarding the need, efficacy, and procedures for compiling and creating inventories of historical datasets.	2007-2009

CHAPTER 7: DATA ANALYSIS



ISEMP Data Analysis

The ISEMP is a primarily a data analysis project. A key role of the ISEMP is developing tools to evaluate monitoring programs and approaches, and analyzing monitoring data. Quantitative tools are needed for data analysis and to aid in RME evaluations that improve local agency data manipulation and feedback to the RME pilot programs. To meet this need, the ISEMP is developing data analysis tools focused on the creation of a standard process to reduce status and trend monitoring data, calculate standard habitat and statistical summary metrics, develop indicators of habitat metrics relevant to biological populations of interest, and develop model approaches for assessing the population level biological effect of watershed-scale restoration actions.

The ISEMP is beginning to explore datasets produced from the monitoring programs in the pilot project basins. Data collected from status and trend monitoring programs is being used to characterize the condition of fish populations and their habitat and whether this condition is improving or degrading. These data are also being used to identify limiting factors and restoration actions to improve conditions for fish populations. The ISEMP is developing analytical methods that can be used throughout the region to evaluate theses questions. Since the ISEMP also has a responsibility for developing standardized monitoring designs and protocols that allow for status and effectiveness characterizations across multiple scales, much of the immediate analyses is to evaluate the efficacy of alternative monitoring designs and protocols in producing the most precise, accurate, relevant, and cost effective monitoring programs.

The full suite of ISEMP analytical tasks is by no means complete or even initiated since many of these tasks will arise as assessments of data for which the collection process is only just being designed and implemented; however, the general framework of the analytical tools and the overall quantitative approach should be clear from the initial tasks summarized below. Future project reports will document overall progress in data analysis while individual final products will be released as stand-alone documents or publications. The analytical tasks presented below provide a general overview of the range of the ISEMP's capabilities and capacity, but also provide specific technical tools and ultimately guidance useful for natural resource managers.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

US Bureau of Reclamation

Contractors

BioAnalysts, Inc.

Eco Logical Research

Environmental Data Services

National Oceanic and Atmospheric Administration –Northwest Fisheries Science Center

Quantitative Consultants, Inc.

Terraqua, Inc.

Volk Consulting

Budget

Contractor	Scope of Work	FY06
BioAnalysts, Inc.	Analyze data	$15,000
Eco Logical, Inc.	Analyze data	$40,000
Environmental Data Services	Analyze data	$26,000
Volk Consulting	Analyze data	$2,000
NOAA/NMFS/NWFSC	Analyze data	$5,000
Quantitative Consultants, Inc.	Analyze data	$10,000
Terraqua, Inc.	Analyze data	$5,000
	Project total through fiscal year 2006:	$103,000

What's been accomplished so far

Below we present an outline of the analyses completed so far with a complete discussion of each analysis following in subchapters.

A Comparison of Habitat Project and Monitoring Locations

Status/trend and effectiveness monitoring projects often must assume that information collected at monitoring sites is somehow representative of typical habitat and biological conditions within a watershed or subbasin. However, monitoring sites may be affected by the legacy effects of pre-existing habitat restoration projects. Therefore, knowledge of pre-existing habitat restoration projects will assist the proper the design of status/trend and effectiveness monitoring programs. The ISEMP has begun an effort to investigate the benefits and limitations of overlaying independently assembled inventories of habitat restoration projects and monitoring sites.

A Comparison of the Precision of Convex and Concave Densiometers

The ISEMP is comparing different monitoring protocols at various levels ranging from broad-scale differences in statistical designs to fine-scale differences in measurement methodology. In this case, the relatively simple difference between two similar instruments was tested to determine the relative precision and instrument calibration of concave and convex densiometers, hand-held instruments for quantifying riparian canopy cover.

Analysis of sampling schemes

Precise, unbiased estimates of population size are an essential tool for fisheries management. Redd counts are commonly used to monitor annual trends in abundance for a wide variety of native salmonid fishes. In most situations population estimates are developed by inference from a sample of the population. Using a dataset that consisted of a census of redds, we evaluated six common sampling strategies for estimating the total abundance of redds. In addition, we developed an additional assessment metric to scale the sampling strategy performance to the effort of data collection in order to compare the cost effectiveness of each sampling strategy.

Sampling site selection tool

For habitat and fish population status and trends monitoring in the Wenatchee and Entiat subbasins, the ISEMP has employed the U.S. EPA's EMAP sampling design. The EMAP sampling design is an application of Generalized Random Tessellation Stratified Design (GRTS) that emphasizes spatial-balance of the sample in the sense that every sample reflects the spatial balance of the population. Critical to an efficient application of this approach is the distribution of sampling effort across relevant strata. In order to manage the information necessary to develop a GRTS sample, the ISEMP has developed a tool that interfaces with the site selection process underlying a GRTS sample.

Classifying the Columbia River Basin

The ISEMP is developing a multi-dimensional classification system for watersheds of the Pacific Northwest based on immutable landscape characteristics and human impacts and land use. The classification process will result in eco-regionalization of watersheds across the Pacific Northwest and will form the basis of much of the ISEMP's landscape-scale analysis relating status and trends data collected at points and reaches to the larger watershed or subbasin scale necessary for interpretation and application.

Probing a sample design to optimize coverage on continuous variables

A primary objective of the ISEMP is identifying methods to increase the efficiency of monitoring programs without sacrificing information quality (e.g., statistical power of evaluations). Thus, it is of interest to determine whether sampling effort can be decreased without sacrificing the quality of the estimators. The tradeoff between efficiency and information quality is perhaps best illustrated by the frequency with which temporally continuous variables must be measured to enable robust statistical analyses.

Recommendations on fish survey protocols for the ISEMP pilot projects based on an analysis of Wenatchee subbasin fish surveys

Fish species distribution and relative abundance have been intensively monitored through either electrofishing or snorkel surveys in the Wenatchee subbasin as part of the ISEMP pilot project since 2004. The sampling design of these surveys has been two-fold: 1) to establish status and trends of fish populations throughout the Wenatchee subbasin, and 2) to evaluate how different protocols vary in precision, accuracy, and characterization of metrics of interest in order to identify the most cost effective approach for monitoring programs. The first of these goals is addressed via the sampling design, which employs an EMAP spatially randomized site selection process implemented in a split (rotating and fixed) panel design described in Chapter 1. The second goal is addressed by comparing multiple protocols with repeated visits to several sites.

Decomposing Site Specific Variability on Fish count data: A Primer using the Wenatchee Subbasin Data

IMW data have been collected in the Wenatchee River watershed at various locations. This analysis organizes the variation in fish count data by site and species, and then addresses the variability in fish count data for one species, juvenile Chinook salmon (*Oncorhynchus tshawytscha*). In this manner, we demonstrate how some of the information collected over the past few years can be used to explain variability in fish counts. However, some caveats are identified as the sites are not collected using a balanced design, thus the data are essentially observational in nature.

Evaluating Mark-Recapture Approaches to Survival Estimates for Migratory Salmonids

Mark-recapture techniques have been used extensively in fisheries research in the Columbia River Basin. PIT tags, in particular, have been utilized to evaluate survival across a variety of life stages for anadromous fishes in the Columbia River and its major tributaries. More recently, there has been an increase in the use of PIT tags in small stream applications to investigate factors (i.e., abiotic parameters) affecting the survival of resident and anadromous fishes within small tributaries. However, the life-history strategies of resident fish and species that do not have obligate migratory life-history expressions (i.e., steelhead, bull trout, etc.) present a number of challenges in the data organization of individual-specific mark-recapture data. These challenges warrant evaluation of alternative approaches to mark- recapture analyses.

Invertebrate Productivity Monitoring Project

A study has been initiated as part of the John Day Pilot Project to develop an indicator of food resource availability for juvenile salmonids. Juvenile salmonids depend on aquatic and terrestrial macroinvertebrate drift as their primary food resource, and numerous studies suggest that macroinvertebrate abundance may explain variation in salmonid growth and survival in freshwater rearing environment. While macroinvertebrate sampling is common among habitat monitoring programs throughout the Columbia River Basin, the metrics obtained from this sampling have been developed to describe water quality rather than food availability. The ISEMP is addressing the question can invertebrate food abundance serve as a surrogate to secondary production, providing a means to estimate production potential of juvenile rearing habitat?

Growth potential models

The ISEMP John Day Pilot Project is developing a model to map potential fish growth across stream reaches of the John Day. Models that estimate heat budgets based on physical inputs will be combined with bioenergetics models that use these heat budgets and invertebrate abundance information to estimate fish growth.

Comparison of protocols

Monitoring programs throughout the Pacific Northwest use a variety of protocols to describe the same general metric and often data collected under different protocols are not comparable, preventing an aggregation of data to address larger scale management questions. The ISEMP is testing multiple protocols and sampling designs in a coordinated fashion within the Wenatchee/Entiat subbasins to identify feasible and effective alternatives to legacy monitoring approaches. In the summer of 2005, Upper Columbia Monitoring Strategy protocols for sampling fish habitat were compared with other protocols in use in the Pacific Northwest as part of a “Side-by-Side” protocol comparison experiment organized by the PNAMP.

A Comparison of Habitat Project and Monitoring Locations

Status/trend and effectiveness monitoring projects must often assume that information collected at monitoring sites is somehow representative of typical habitat and biological conditions within a watershed or subbasin. However, monitoring sites may be affected by the legacy effects of pre-existing habitat restoration projects. Therefore, knowledge of pre-existing habitat restoration projects will assist the proper the design of status/trend and effectiveness monitoring programs. Fortunately, there are ongoing initiatives to develop inventories of habitat restoration projects and monitoring efforts in the Pacific Northwest.

The ISEMP has begun an effort to investigate the benefits and limitations of overlaying independently assembled inventories of habitat restoration projects and monitoring sites. A test-case scenario has been completed using a compilation of habitat projects from the Pacific Northwest Salmon Habitat Project Tracking (PNWSHP) database with location data for the ISEMP's monitoring efforts in the Wenatchee/Entiat subbasins.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

National Oceanic and Atmospheric Administration /Northwest Fisheries Science Center Staff

Volk Consulting

Time Line

Since 2004, the ISEMP has completed a mapping exercise that overlays habitat projects' location information with location data for the ISEMP monitoring efforts in the Wenatchee/Entiat subbasins. Similar work has begun for the John Day and Salmon subbasins and is expected to continue during the course of the next few years.

What's been accomplished so far

The benefits and limitations of overlaying independently assembled inventories of habitat restoration projects and monitoring sites was tested by comparing an inventory of restoration projects with the ISEMP monitoring sites in the Wenatchee/Entiat subbasins. The inventory of restoration projects was based on local agency knowledge combined with restoration project data in the PNWSHP, maintained by NOAA. The PNWSHP documents an extensive survey of freshwater restoration actions in the states of Washington, Oregon, Idaho and Montana funded by all federal and state agencies, tribes, local (e.g. county), and NGO groups that have been implemented over the last 10 years.

Data was solicited on all projects occurring in and around freshwater systems as many projects not specifically labeled as 'salmon habitat restoration' do affect salmon habitat. The minimum requirement of project data for the inventory included:

- Who is doing the work and has contact information?

- What *exactly* was the project designed to do (e.g., type of project, size, or number of installations)?
- Where *exactly*, in a standard coordinate system, did the project occur (e.g. Lat./Long., LLID & Stream Mile)?
- When was the project going to be completed?

The inventory was organized by project types and subtypes. For example, project types included actions like barrier removals, stream channel complexity modifications, sediment reduction, etc. Project sub-types provided more specifics, such as whether the barrier removal was a culvert removal, dam removal, or fish ladder improvement. Project-level data included taxonomic identifier, dates, contact information, cost and other attributes that were project or contract specific.

Location data for the ISEMP-funded steelhead redd surveys and habitat surveys conducted in 2004 and 2005 were displayed in coordination with PNWSHP sites using GIS for the Chiwawa and Nason subbasins (Figure 34 and Figure 35). For each monitoring site within the Chiwawa and Nason subbasins we counted the number, distance, and type of restoration projects that could affect these monitoring points. Barrier restoration projects were listed as influential factors to monitoring points if they were downstream of a monitoring point while all other factors were considered a possible influential factor if located upstream of a monitoring site. No maximum distance of a restoration site from a monitoring site was set for this exercise. Restoration sites on tributaries to fish abundance monitoring reaches (sites) were differentiated from restoration sites located within the monitored reach.

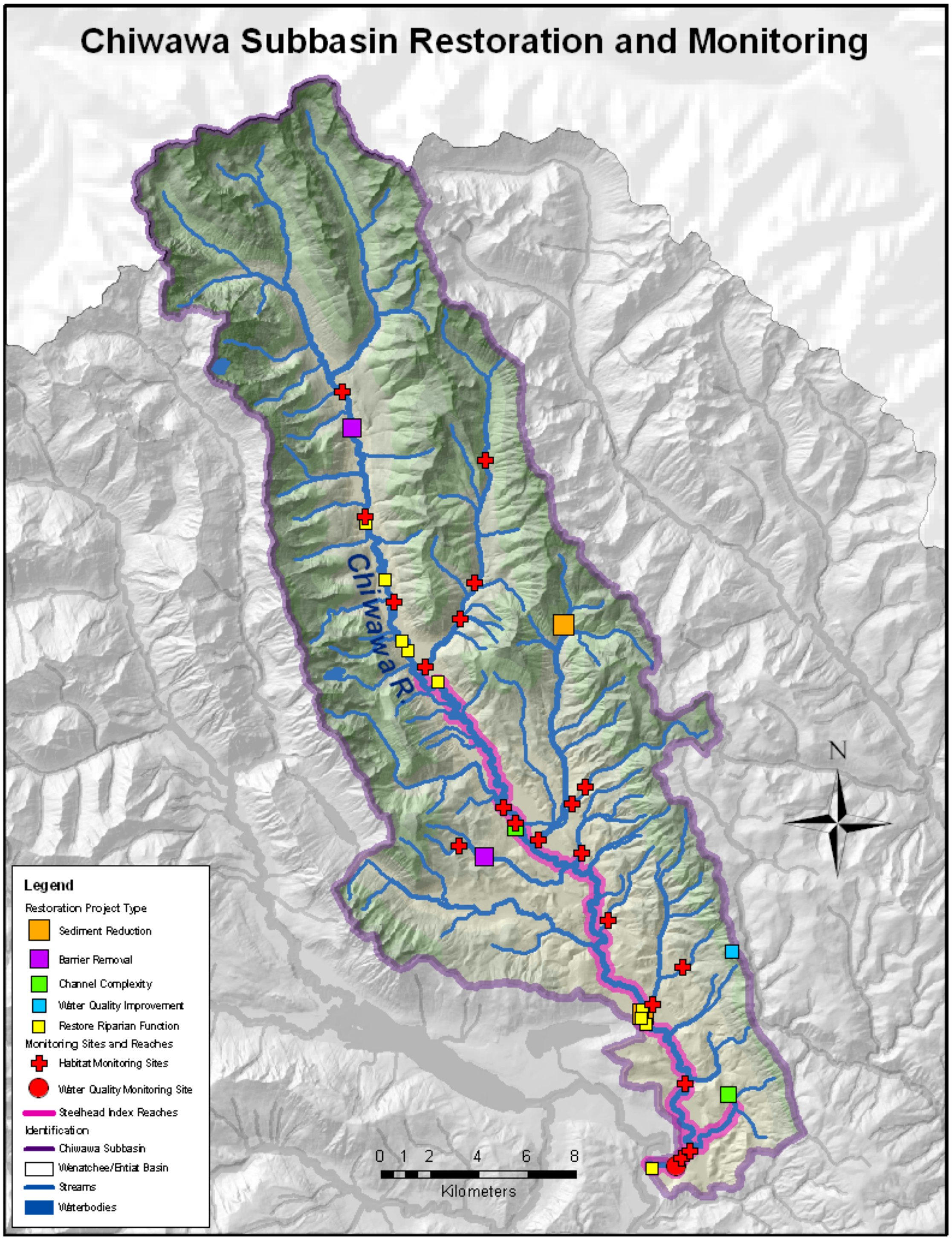


Figure 34. Location of restoration projects and the ISEMP Wenatchee Pilot Project monitoring sites within the Chiwawa subbasin, WA.

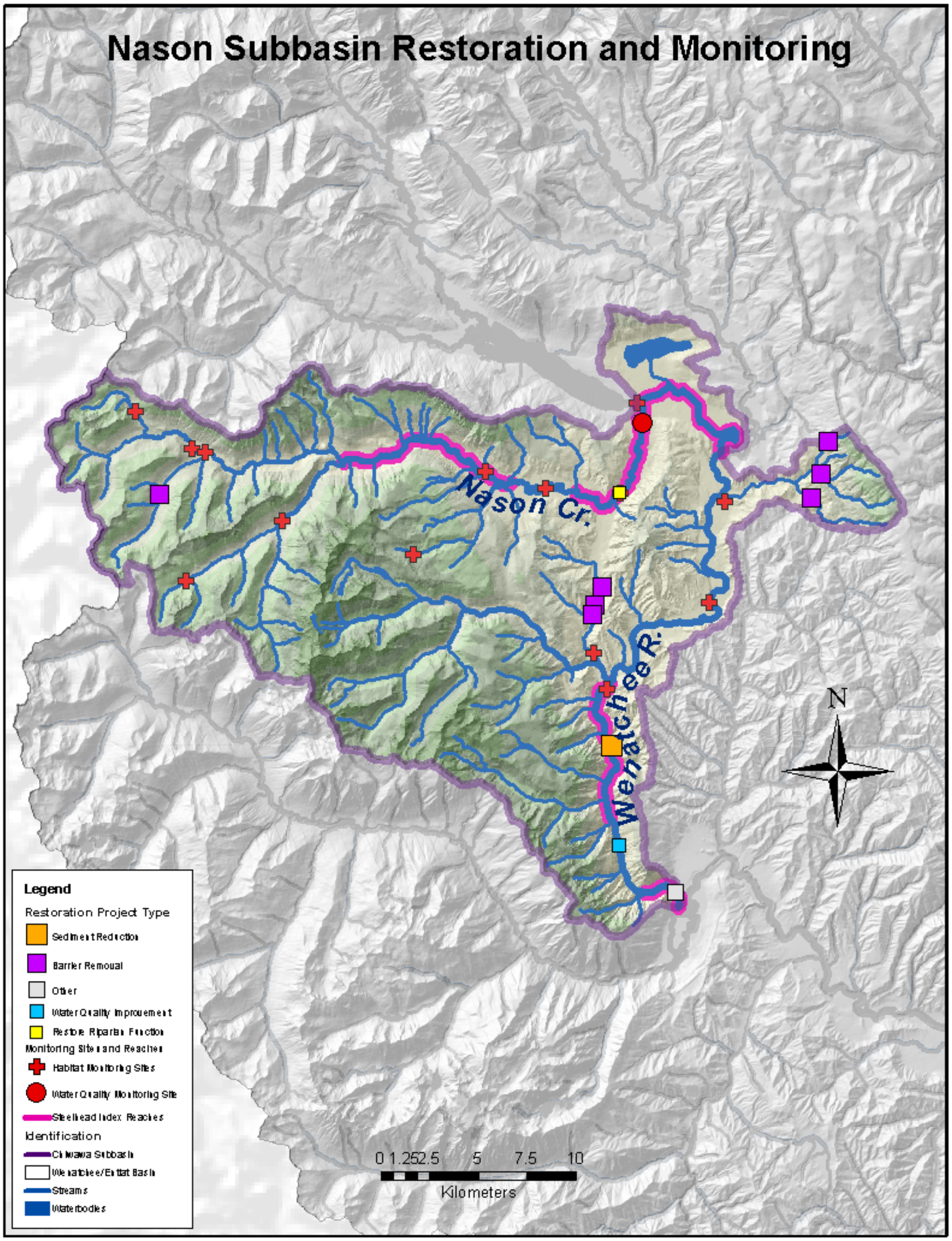


Figure 35. Location of restoration project and ISEMP Wenatchee pilot project monitoring sites within the Nason subbasin.

Results

The Chiwawa and Nason subbasins had 21 and 12 restoration projects, respectively (Table 13) and 20 habitat monitoring sites each (Table 14 and Table 15). Within the Chiwawa, only 6 habitat monitoring sites were within the area of influence of restoration projects (distance range of 1,117 to 17,989 m; Table 14). Project types included riparian function (11), channel complexity (1), sediment reduction (2), and barriers (2). In the Nason subbasin, 3 habitat monitoring sites were within the area of influence of restoration projects (Table 15). Two of the three monitoring points were within the range of multiple restoration sites, and project types included riparian function and barrier removals. Project distances from monitoring sites ranged from 2,401 to 7,202 m. Out of 22 steelhead redd survey reaches, only 4 contained restoration projects and 2 had restoration projects on tributaries draining into survey reaches (Table 16). Reach 3699819 had 5 riparian function projects and one sediment retention project take place between 1998 and 2000. In the Nason subbasin, 2 of 26 steelhead redd survey reaches were within the area of influence of restoration projects (Table 17). Two steelhead redd survey reaches had barrier removal projects on adjacent tributaries.

Table 13. Restoration project types within the Wenatchee subbasin.

Project Type	Limiting factor	Little Wenatchee*	Chiwawa	White*	Icicle-Chumstick*	Nason-Tumwater	TOTAL
Barrier removal	Fish passage	7	2	3	17	8	37
Diversion screen	Fish passage	1	0	0	0	0	1
Riparian function	Water temperature, sedimentation	0	12	0	8	1	13
Channel complexity	Water temperature, sedimentation, habitat complexity	3	2	0	0	0	5
Instream structure	Habitat complexity, sedimentation	1	0	3	0	0	4
Nutrient enrichment	nutrients	0	0	0	0	0	0
Instream flow	flow	1	0	0	0	0	1
Other		0	0	0	0	1	1
Sediment reduction	Sedimentation, water quality, nutrients	9	2	3	9	1	24
Upland management	Sedimentation, flow	2	0	0	0	0	2
Water quality	Water temperature,	3	3	0	1	1	8

nutrients						
TOTAL	27	21	9	35	12	96

* 7 projects in the Wenatchee, 4 projects in Icicle/Chumstick, and 3 projects in White have multiple project types (not included in count).

Table 14. Inventory of restoration projects associated with habitat monitoring sites in the Chiwawa Basin.

Monitoring site	# restoration projects associated with a monitoring site	Type of project	Year of project completion	Project distance from monitoring site
WC503432-007	1	Barrier downstream	1998	1283
WC503432-015	0			
WC503432-017	0			
WC503432-019	0			
WC503432-038	0			
WC503432-164	0			
WENMASTER-0010	0			
WENMASTER-0011	1	Barrier downstream	1998	1797
WENMASTER-0054	0			
WENMASTER-0055	2	Riparian function	1999 2000	1117 (RF) 4725 (RF)
WENMASTER-0067	0			
WENMASTER-0071	0			
WENMASTER-0099	0			
WENMASTER-0119	0			
WENMASTER-0131	0			
WENMASTER-0179	4	Riparian function	2000 2000 1998 1998	10992 (RF) 9339 (RF) 9339 (RF) 673 (RF)
WENMASTER-0195	1	Sediment reduction	1998	9679 (SR)
WENMASTER-0231	0			
WENMASTER-	7	5 riparian	2000	4000 (RF)

0246		function 1 sediment reduction 1 channel complexity	2000 2000 1998 1998 1999 1998	4428 (RF) 4627 (RF) 4653 (RF) 4780 (RF) 4558 (SR) 17989 (CC)
WENMASTER-0266	0			

Table 15. Inventory of restoration projects associated with habitat monitoring sites in the Nason Basin.

Monitoring site	# of restoration projects associated with a monitoring site	Type of project	Year of project completion	Project distance from monitoring site
WC503432-001	0			
WC503432-021	0			
WC503432-032	0			
WC503432-048	3	barrier removal (upstream of point)	1998, 2000, 2000	5506, 6170, 7202
WC503432-153	0			
WC503432-158	0			
WC503432-166	0			
WENMASTER-0008	0			
WENMASTER-0030	1	Riparian	1999	5870
WENMASTER-0042	0			
WENMASTER-0052	0			
WENMASTER-0060	0			
WENMASTER-0106	4	barrier removal (upstream of point)	no dates	2471, 2527, 3075, 4117
WENMASTER-0152	0			

Table 16. Restoration projects associated with steelhead survey reaches in the Chiwawa Basin.

Steelhead survey reach ID	Reach length, m	# of projects within reach	Type of project within reach	# of projects on upstream tributaries to reach	Type of project on upstream tributaries	# of projects on mainstem (upstream of reach)	Distance of tributary projects from reach (m)
3699613	3216	0		0			
3699622	3046	1	Riparian (no date)	0			
3699806	2721	2	Riparian (2000, 1998)	0			
3699807	899	0		0			
3699808	1003	0					
3699809	898	0		0			
3699810	439	0		0			
3699811	2015	1	Channel complexity (1998)	0			
3699812	1157	0		0			
3699813	1930	0		1	Sediment reduction		10147
3699814	405	0		0			
3699815	1003	0		0			
3699816	1253	0		0			
3699817	867	0		0			
3699818	3803	0		0			
3699819	2219	6	5 riparian function, 1 sediment (2000,2000,2000, 1998, 1998)	0			
3699820	2530	0		0			
3699821	434	0		0			
3699876	3542	0		0			
3699877	2093	0		0			
3700374**	2508	0		1	Channel complexity		611
3700379**	307	0		0			

**On Clear Creek Tributary from Chiwawa segment #3699622 (farthest downstream segment of Chiwawa. Projects associated with steelhead survey reaches in the Nason Basin.

Table 17. Restoration projects associated with fish abundance monitoring sites in Nason.

Steelhead survey reach ID	Reach Length, m	# of projects within a reach	Type of project within reach	# of projects on upstream tributaries to reach	Type of project on upstream tributaries	# of projects on mainstem (upstream) of reach	Distance of tributary projects from reach (m)
3699617	417	0		1	Barrier (1998)		11977
3699619	1233	0		0			
3699776	2171	0		0			
3699775	1178	0		0			
3699608	185	0		0			
3699623	3792	0		0			
3699624	320	0		0			
3699627	1093	0		0			
3699628	447	0		0			
3699854	2950						
3699634	5765	1	Riparian (1999)	0			
3699620	2325	0		0			
3700427	228	0		0			
3699609	225	0		0			
3699610	4206	0		0			
3699607	1836	0		0			
3699836	1269	0		4	Barrier (no dates)		4198, 4237, 4805, 5903
3699837	423	0		0			
3699838	1580	0		0			
3699839	1362	1	Sediment (1999)				
3699840	150	0		0			
3700432	169	0		0			
3699841	1397	0		0			
3699842	300	0		0			
3699906	604	0		0			
3699904	987	0		0			

Conclusion

There are a series of limitations to the coordinated use of restoration project and monitoring site data. For example, there are limitations about the data quality within the PNWSHP (and, presumably, other similar inventories) that should be considered. For example, the assignment of project types may be arbitrary, the assumed sphere of influence (upstream or downstream influences) associated with project types may not be appropriate for the type or location of a particular project, projects may not be effectively maintained or implemented, and the project locations may not be accurate.

With these limitations in mind, this exercise has demonstrated that inventories can be used to ‘alert’ monitoring project personnel of areas with legacy conditions, can help identify those agencies responsible for habitat restoration actions, and can distinguish areas within a basin that have prior information available that might be useful for future monitoring projects.

Additional examples of questions that can be asked of inventories that may benefit monitoring projects include:

1) Questions dealing with spatial or temporal-based differences between observations and expectations, such as: How is the distribution, abundance etc., of the inventory collection different from the expected condition?
2) Questions dealing with spatial or temporal-based comparisons, such as: If multiple inventories collected information within the same spatial domain, then what is the correlative relationship between ‘inventory 1’ and ‘inventory 2’- i.e., do we monitor conditions in the same places as restoration projects?
3) Questions dealing with inventory content, such as: How does the density of restoration projects within a specified spatial domain correlate with resource conditions within the same spatial domain?
4) Questions dealing with causal mechanisms, such as: Do restoration projects cause responses in some resource condition?

The work presented in this section represents a very preliminary effort to link specific habitat restoration projects to the population and habitat monitoring landscape. This work will be continued in the Wenatchee/Entiat, and expanded to the other project subbasins as needed to provide sufficient contrast in project type and landscape setting to support quantitative modeling.

A Comparison of the Precision of Convex and Concave Densiometers

The ISEMP is comparing different monitoring protocols at various levels ranging from broad-scale differences in statistical designs to fine-scale differences in measurement methodology. In this case, the relatively simple difference between two similar instruments was tested to determine the relative precision and instrument calibration of concave and convex densiometers, hand-held instruments for quantifying riparian canopy cover.

The ISEMP habitat monitoring in the Wenatchee/Entiat follows the Upper Columbia Monitoring Strategy (Hillman 2006, based on Peck et al. 2001) which calls for the use of Convex Spherical Densiometers (Model B) for assessing canopy cover, despite the fact that existing monitoring programs in the Upper Columbia region conducted by the Colville Confederated Tribes have historically used Concave Spherical Densiometers (Model C). When the discrepancy between these two programs was realized in 2005, the ISEMP undertook the present analysis to determine whether the different approaches would lead to the same (or different) conclusions, and if a calibration of the two instruments could be developed.

Funding Agencies
Bonneville Power Administration

Contractors
Solutions Statistical Consulting
Terraqua, Inc.

Time Line

The ISEMP completed field data collection for this comparison of two different densiometers in 2005. Preliminary analysis has been completed. Additional analysis may be forthcoming pending additional internal review by the ISEMP. Specifically, this protocol comparison is only one of many that are underway. A standardized approach to the ISEMP protocol comparisons is being developed and may lead to refinements in this analysis.

What's been accomplished so far

Both concave and convex densiometers were employed to measure riparian canopy cover at each of ten sampled sites during 2005 fieldwork in the Entiat River subbasin. The paired measurements support comparisons of both densiometer relative precision (coefficient of variation, CV) and densiometer agreement, or calibration, at the transect scale, the site scale, and the watershed scale. The relative precision analyses and preliminary investigations of the functional form of calibration between densiometers are presented here.

Methods

Study Region/Sample Frame

All measurements were conducted at 10 sample sites in the Entiat River subbasin. These sites were randomly selected from a sample frame consisting of all fish-bearing stream reaches within the subbasin following a GRTS (Stevens and Olsen 2004).

Eleven cross-channel transects were systematically located along the length of the reach at each site following Section 2 of Moberg (2006). Six densiometer measurements were taken at each transect following Section 4.III of Moberg (2006): one each at the left and right bank, four at the center of the channel (looking upstream, downstream, to the left bank, to the right bank).

Measurement Devices

The convex spherical densiometer was model B (Lemmon 1957) taped or marked as detailed in Section 4.III of Moberg (2006). The model C concave densiometer was taped or marked in similar fashion as detailed in Moberg (2006).

Response measures at each scale

The response measure of interest depended on the scale under consideration: the individual measurement, the mean measurement across all six directions at a transect, the mean across all transect means at a site, and the mean across all sites in the watershed.

Mean estimators at each scale

Transect-specific means were estimated using the arithmetic mean of the direction-specific observations, i.e., by treating them as a simple random sample (or, actually, as a cluster sample) (Cochran 1977). Site-specific means were estimated using the arithmetic mean of the transect means as the transects were an unreplicated systematic sample (Cochran 1977). Watershed-scale means were estimated using the Horvitz-Thompson estimator and the final GRTS weights (Stevens and Olsen 2004).

Standard error estimators at each scale

Transect-specific standard errors were estimated using the sample variance of the direction-specific observations, i.e., by treating them as a simple random sample (Cochran 1977). Site-specific standard errors were estimated using the sample variance of the transect means, implicitly treating the unreplicated systematic sample as a simple random sample (Cochran 1977), i.e., ignoring any potential spatial correlation (Wolter 1984; Reynolds et al. in press). Watershed-scale standard errors were estimated using the Horvitz-Thompson estimator and the final GRTS weights (Stevens and Olsen 2004).

Agreement or calibration exploration

True riparian cover is not known at any of the measurement locations, thus bias cannot be calculated for either densiometer method using the available data. Agreement among the methods was visually explored at the measurement scale, transect scale, and site scale in order to gain insight into differences between methods and necessary functional forms for any crosswalk or calibration relationship developed in the future.

Precision Comparison

The data collection design only supports comparing precision of the densiometer methods in terms of either the scale-specific standard errors or CV. Ratio estimators were used for estimating the mean CV at the site scale (Cochran 1977).

Software

All analyses were conducted in the freeware R language and environment, version 2.3.1. (R Foundation 2006). Command scripts are available from the author upon request.

<u>Results</u>

Agreement or Calibration Explorations

Measurement level agreement: Convex measurements tended to be larger than concave densiometer measurements, with greater agreement at the extreme values (no canopy cover, canopy full cover) and greater differences in the mid-range measurements, peaking when one or the other device measured 50% cover (Figure 36). The form of the differences varied with the location of the measurement within the stream channel: up or down stream center measurements versus left or right center measurements versus left or right bank measurements (Figure 36).

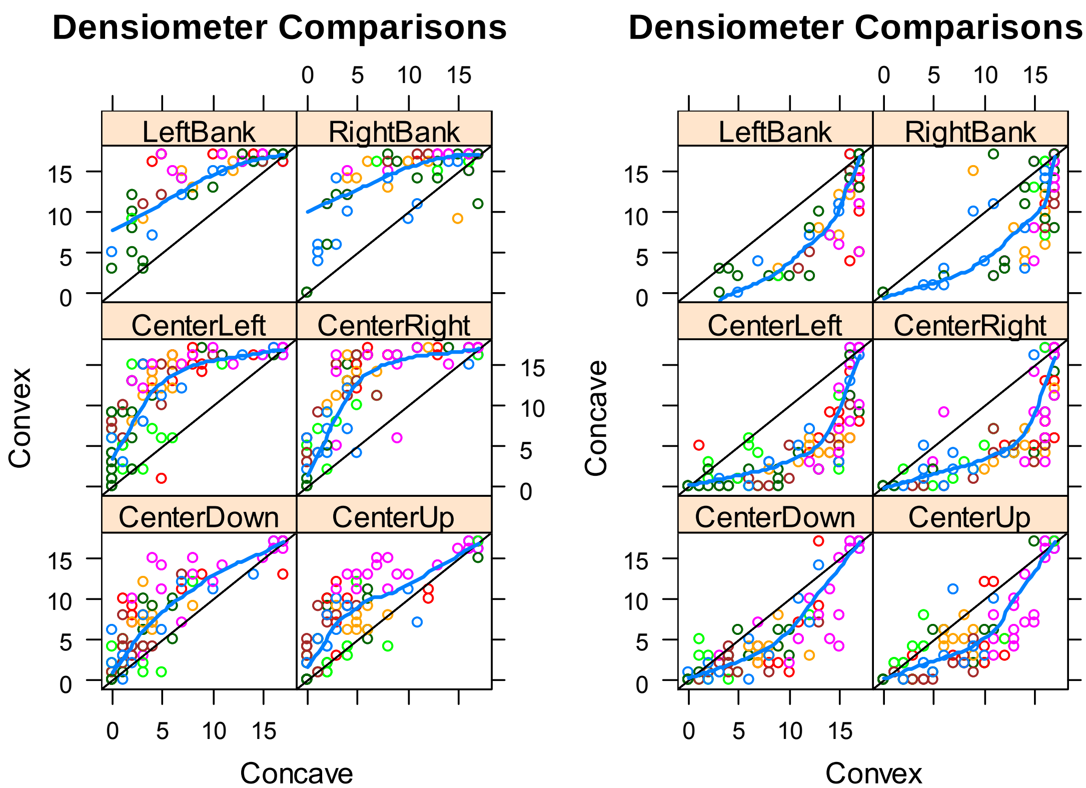


Figure 36. Relationship between concave and convex densiometer readings, by reading location (panel). The left figure shows a nonparametric smooth (blue) curve for predicting convex from concave; the right figure shows a nonparametric smooth curve for predicting concave from convex. Transects from the same site have a common color. The 1-1 line that points would fall along if the two measurements were identical is given as a reference (the black diagonal).

Transect scale: Comparing mean densiometer measurements at the transect scale (mean across the six directions at each transect), the larger values from the convex densiometer were still apparent, especially at those sites were the concave densiometer value was near 0 (Figure

37). The bankfull width of the stream channel appeared to have little influence on the magnitude of the difference between the measurement devices (Figure 37).

Site scale: At the site scale (mean across the eleven transects at a site), the increase from using convex rather than concave measurements appeared almost constant in the mid range values (Figure 38), the finer scale differences (Figure 37) being masked by the spatial averaging.

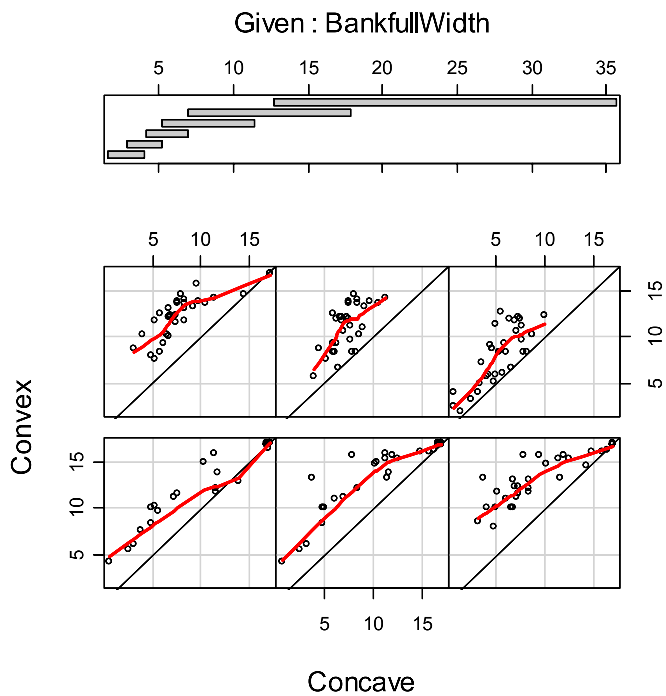


Figure 37. Agreement between concave and convex mean densiometer measurements at each transect, by bankfull width. The top strip plot identifies the range of bankfull widths displayed in each panel, where the panels are ordered from left to right, from bottom to top (the bottom left panel shows measurements from channels with bankfull width < 4 m, the upper right panel shows measurements from channels with bankfull width ranging from 12.5 m to 35 m). The red curve is a nonparametric smooth suggesting the form of the calibration function for predicting convex from concave transect mean measurements; the solid black line is the 1-1 reference line showing complete agreement. The data suggest that bankfull width has little effect on the difference between convex and concave measurements and that convex measures are consistently larger than concave measures.

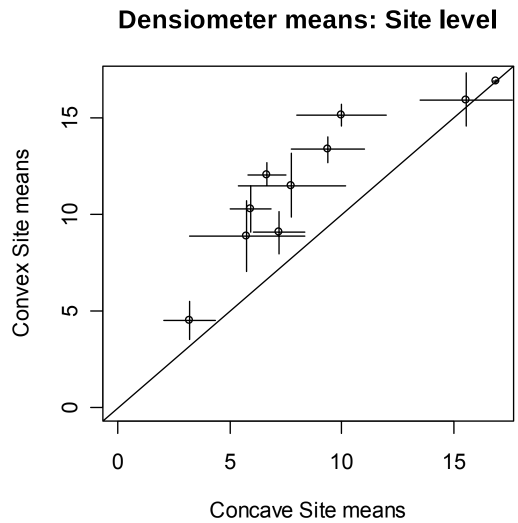


Figure 38. Agreement between convex and concave densiometer mean measurements at the site level (mean of transect values), with approximate 95% confidence intervals. The 1-1 line is shown for reference.

Precision Comparison

Convex densiometer measurements were more precise than concave measures at the site scale (variance columns, Table 18; Figure 39). Combined with the tendency for convex measures to have higher densiometer readings resulted in the convex method having consistently smaller CVs (Table 18, CV column and ratio of CV column).

Table 18. Site-scale relative precision of convex and concave densiometer measurements (CV=(SD/Mean) x 100%). Note that CVs were calculated using four significant digits for mean and variance estimates, though only two are reported here. The last column gives the ratio of the convex CV / concave CV for relative comparison (Figure 41).

Site	Convex			Concave			Convex/ Concave
	Mean	Var	CV	Mean	Var	CV	CV / CV
WAWO5541-000277	16.91	0.02	0.9	16.91	0.02	0.8	1.13
WAWO5541-000589	15.96	4.21	12.9	15.56	9.51	19.8	0.65
WAWO5541-000853	11.52	6.22	21.7	7.76	12.86	46.2	0.47
WAWO5541-003861	13.39	0.96	7.3	9.36	5.91	26.0	0.28
WAWO5541-006037	12.08	0.78	7.3	6.65	1.69	19.6	0.37
WAWO5541-006677	9.08	2.63	17.9	7.21	3.00	24.0	0.75
WAWO5541-013077	10.30	3.08	17.0	5.92	1.85	23.0	0.74
WAWO5541-015253	8.89	7.67	31.1	5.76	14.90	67.0	0.46
WAWO5541-016469	15.15	0.73	5.6	9.97	8.91	29.9	0.19
WAWO5541-028237	4.53	2.14	32.3	3.18	3.01	54.6	0.59

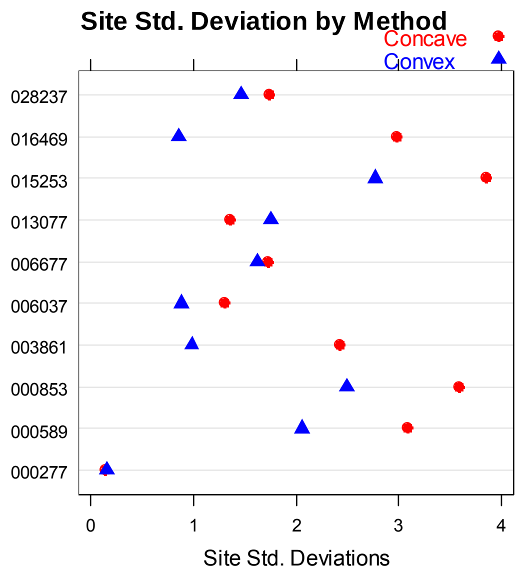


Figure 39. Standard deviation of site-level mean densiometer readings, by site (row) and densiometer method (symbol/color). The convex readings tended to have smaller standard deviations (see Table 18).

Watershed scale: Means, variances, and standard errors could not be calculated as the relevant sampling design weights were unavailable at the time of this analysis. Note that regardless of the ultimate weights, the larger site-specific means and smaller site-specific variances from the convex measurements guarantees that the convex mean estimate at the watershed scale will exceed the concave mean, and the convex variance will be smaller than the concave variance.

Discussion

Measures of riparian cover from convex densiometers tended to be consistently larger than those from concave densiometers (Table 18, Figures 36 – 39) and tended to have smaller associated standard errors (presented as variances and standard deviations in Table 18, Figure 39, respectively). Thus convex densiometer measures appeared to be *relatively more precise*.

The precision reported here is spatial variation: variation among direction measurements at a transect, variation among transects at a site, variation among sites at a watershed. There was no data available to estimate variation from repeated measurements (measurement error) or variation among field crews.

There was no agreed upon gold-standard benchmark measurement of true riparian cover. Thus it is impossible to distinguish between the convex measures being relatively more precise because (i) they accurately represent the spatial variation in riparian cover while the concave measurements do not, or because (ii) they fail to detect small-scale differences (variation) in riparian cover that the concave measurements do capture. Fundamentally, the final decision among densiometer measures, and hence the final interpretation of the differences in relative precision reported here, should be made in consideration of the sensitivity required to satisfy the ISEMP objectives.

Analysis of sampling schemes

Precise, unbiased estimates of population size are an essential tool for fisheries management. Redd counts are commonly used to monitor annual trends in abundance for a wide variety of native salmonid fishes. In most situations population estimates are developed by inference from a sample of the population. Using a dataset that consisted of a census of redds, we evaluated six common sampling strategies for estimating the total abundance of redds. In addition, we developed an additional assessment metric to scale the sampling strategy performance to the effort of data collection in order to compare the cost effectiveness of each sampling strategy.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration

Contractors
National Oceanic and Atmospheric Administration –Northwest Fisheries Science Center staff

Time Line

Initiated in 2003, this work is complete and a manuscript is in peer review (Courbois et al. 2006). Future work will include using the approaches developed to compare sampling methods for other species (e.g., steelhead) and potentially for habitat metrics as well.

What's been accomplished so far

The goal of this work was to compare several probability-sampling strategies for estimating the total abundance of redds in a large river basin and to demonstrate a process of selecting a sampling strategy. A sampling strategy is a sampling design along with an estimator for the parameter of interest. Censused populations of Chinook salmon redds were used as the "truth" for comparison of estimators derived from each strategy. We describe the statistical performance of the different sampling strategies and estimate the economic costs for each design. We conclude with a discussion of the trade-offs associated with sample strategy selection.

Using a dataset that consisted of geo-referenced censuses of Chinook salmon redds from a large wilderness basin in central Idaho, we evaluated six common sampling strategies for estimating the total abundance of redds. The dataset was a 9-year time series of redd population data with a range of 20 to 2,271 redds per year. We evaluated two sampling-unit sizes (200-, and 1000-meter reaches), three sample proportions (0.05, 0.10, and 0.29), and six sampling strategies (index sampling, simple random sampling, systematic sampling, stratified sampling, adaptive cluster sampling, and a spatially balanced design). We evaluated the strategies based on their accuracy (confidence interval coverage), precision (relative standard error), and cost (cost function based on travel time). Results included:

- Model-based methods for estimating the number of redds from the non-probability index strategy are biased, and although none of the other strategies were always accurate, accuracy increased with increasing number of redds, increasing sample size, and smaller sampling units.

- The total number of redds in the watershed and budgetary constraints will influence which strategies are most precise and effective. For years with very few redds (0.15 redds/km) a stratified sampling strategy was most precise, whereas for years with more redds (0.15 to 2.9 redds/km) either of two systematic strategies were most precise. Using a simple cost function we found that inexpensive strategies were best for years with very few redds, and the expensive but precise strategies were best for years with medium to many redds in the watershed.

Sampling location selection tool

The ISEMP has employed the U.S. EPA's EMAP sampling design for habitat and fish population status and trend monitoring in the Wenatchee and Entiat subbasins. Critical to an efficient application of this approach is the distribution of sampling effort across relevant strata. In order to manage the information necessary to develop a GRTS sample, the ISEMP has developed a tool that interfaces with the site selection process underlying a GRTS sample.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

Environmental Data Services

Terraqua, Inc.

Time Line

The sample selection tool has been refined each year new EMAP samples are drawn (2004 – 2006), and will continue to be used and improved through one rotating panel cycle (5 years).

What's been accomplished so far

The EPA's methodology was used to select a spatially balanced sample of stream resources for the Wenatchee and Entiat subbasins. Sampling efforts were stratified according to Strahler stream order and fish usage (anadromous streams versus resident streams). GIS layers representing EPA sample points, fish distribution, Strahler stream order, and stream gradient were assembled for the two subbasins. A statistical model developed under the Forest Practice Water Typing project at the Washington State Department of Natural Resources predicted the extent of resident fish distribution (last upstream point where resident fish were expected to be observed) in the Wenatchee subbasin. Those points were transferred to the 1:100, 000 NHD stream network and all downstream sections of stream were designated as having resident fish usage. Anadromous distribution was determined by interviewing USFS and local biologists in the Wenatchee subbasin and local biologists in the Entiat subbasin. Strahler stream order and stream gradient were calculated in ArcView 3.2. The length of the stream network in each Strahler order and fish usage category was summed, and sample sites were partitioned to strata relative to the proportion of the network in each strata.

To test the spatial balance of the sample sites, NOAA-Fisheries compared the cumulative frequency distribution (cdf) of pairwise distances between points within our sample sites relative to that of the master list (developed as a spatially balanced sample by EPA) of all possible sample sites. Pairwise distances of all points were calculated in the master sample, ranked according to distance and plotted as a cdf. Fifty sites were iteratively randomly selected according to code and conforming to the set stratification rules. Pairwise distances of sites within the random samples were rank and plot for comparison against the CDF for the master sample. Sites within 500 meters of one another along the stream network were removed from the sample site location set.

Classifying the Columbia River Basin

The ISEMP is developing a multi-dimensional classification system for watersheds of the Pacific Northwest based on immutable landscape characteristics, and human impacts and land use. The classification process will result in eco-regionalization of watersheds across the Pacific Northwest and will form the basis of much of the ISEMP's landscape-scale analysis relating status and trend data collected at points and reaches to the larger watershed or subbasin scale necessary for interpretation and application.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration
U.S. Bureau of Reclamation

Contractors
D'Iorio Consulting
Environmental Data Services
National Oceanic and Atmospheric Administration –Northwest Fisheries Science Center staff
Volk Consulting

Time Line

Started in 2003, this work is ongoing with preliminary products delivered in 2006. The next stage of the project will be initiated in 2007, with final products expected in one to two years.

What's been accomplished so far

The ISEMP has begun a multi-dimensional classification of the Columbia River Basin and the coastal range of Oregon and Washington to classify and group watersheds with similar physical, biological and anthropogenic impact characteristics in relation to the watersheds where IMWs will be conducted. Ultimately, the classification process will support the extrapolation of expected results from restoration projects between monitored and non-monitored watersheds, inform the design and distribution of future restoration and monitoring projects, and support the interpolation or imputation of data across regions not monitored as intensively as the IMWs. To generate landscape classification schemes for this purpose requires choosing biophysical variables that capture most of the information pertinent to salmonid productivity. The choice of these variables is therefore critical to the success of this exercise. Variables are chosen based on the current understanding of fish-habitat relationships available in the literature. The two main assumptions underlying this exercise are that the variables used are:

(1) Some of the most important determinants of the overall characteristic of a watershed, and

(2) Important determinants of salmonid population processes.

The basic list of variables currently thought to correlate to fish productivity includes:

- Climate
- Geology
- Watershed topology
- Vegetation

- Channel confinement and gradient
- Land-use/cover
- Ownership
- Wetlands.

In addition, recent work shows that channel size (e.g., drainage area or some regionally calibrated estimate of discharge) and elevation are also important. A variety of studies have shown empirical correlations between fish numbers and these variables. It is certainly feasible to simply seek correlations between the distribution (histograms, cumulative distributions) of these attributes and fish species and population sizes, which would allow extrapolation to other basins that lack monitoring data. However, it may also be useful to look at how these attributes affect fish directly, which may provide a more powerful means of extrapolation.

Ultimately each attribute included in the extrapolation process somehow affects aquatic habitat and these effects occur point by point through the channel network. Thus, it is the combined suite of variables at each point that is important. For example, the relationship of channel gradient and valley width for a reach is lost when the distribution for each variable is viewed independently. A measure of basin productivity requires a method of assessing the effects and interaction of all variables point by point and then aggregating that information over the basin. A number of recent examples of constructing similar geomorphically based watershed intrinsic potential metrics have been very useful for the management and recovery planning of listed anadromous salmonids.

However, existing approaches to classifying landscapes for the purpose of managing and recovering listed anadromous salmonid populations have not included parallel assessments of immutable characteristics of watersheds and human land-use impacts on the watersheds. Therefore, to extend our current understanding of, and approaches towards, landscape classification specific to aquatic resources, similar methods must be applied to both the geomorphic and anthropogenic determinants of watershed intrinsic potential. Human activity over the past 100 years in the Pacific Northwest has dramatically altered the region's land- and waterscapes. As such, human activity has impacted the productive potential of most of the region's aquatic systems. In fact, some of the immutable factors used above to describe the inherent potential of aquatic systems have been changed by human activities (e.g., channel confinement, local climate). However, the primary mode by which human activities impact aquatic ecosystems is indirectly through land use practices (e.g., agriculture and urbanization). Therefore, it would be naïve to ignore the impacts of these activities in any exercise to characterize broad scale patterns of aquatic productivity. Thus, the effect of human activity on the landscape will be assessed through a parallel effort to develop a regional classification of watershed condition as a function solely of human activity. The potential list of human land use practices and activities that have the potential to alter relevant physical and biological processes will include:

- Agricultural activities,
- Forest practices,
- Livestock activities,
- Transportation,
- Channel alteration,
- Mining, and
- Urbanization.

Methods

Eight data layers of immutable landscape characteristics included climatic (temperature range, precipitation, and growing degree day) and influential physical-biological features (geology, elevation, slope, percent response reach, and tributary junction density) (Table 19). These layers were picked because of their importance in shaping catchments, hydrologic features, and fish habitat. Data layers were projected into a common coordinate system, complied in GIS, and summarized in both raster (200m pixel) and vector polygon (HUC6 watershed) space. Raster datasets were summarized to HUC6 watersheds by zonal summaries. The two metrics describing channel characteristics, response area density and tributary junction density, were calculated at the HUC6 subwatershed scale and then converted to rasters (200m pixels) using ArcView 9.1 Spatial Analyst. All data were transformed for normality and normalized (0-1 scale) in raster space prior to summarizing to HUC6 watersheds. Raster grids were combined into a multilayer stack for classification in Arc/Info GIS software and HUC6 summarized data were classified using MCLUST software.

Table 19. Spatial data layers constructed for immutable landscape characteristics.

Layer name	Layer relevance	Source	Source pixel size	HUC summary of 200m raster
Growing Degree day	ecosystem productivity	PRISM	2000m 1.25 arc-minute	mean
Mean annual precipitation	stream power terrestrial vegetation	PRISM	4000m 2.5 arc-minute	mean
Temperature range	Longitude temperature extremes	PRISM	4000m 2.5 arc-minute	mean
Elevation	hydrologic regime terrestrial vegetation	DEM	30m	median
Slope (degrees)	hydrologic complexity	DEM	30m	median
Percent response reach density	sediment delivery hydrologic complexity	NHD	HUC6	
Tributary junction density	hydrologic complexity ecosystem productivity	NHD	HUC6	
Geologic erodibililty	sediment source erodibililty	ICBEMP		mean

Data layers

Climate layers. Temperature range, precipitation and growing degree day (base 50) were derived from 2 km grid PRISM data (http://www.ocs.orst.edu/prism/ for temperature range and precipitation; http://www.climatesource.com/products.html for growing degree day) and resampled to 200 m using bilinear interpolation. The median pixel value was used to summarize all datasets to the HUC6 watershed (Figure 40).

Elevation was derived from the U.S. Geological Survey 30 m raster DEM and resampled to 200 m using bilinear interpolation. The median pixel value was used to summarize data to HUC6 watersheds (Figure 40).

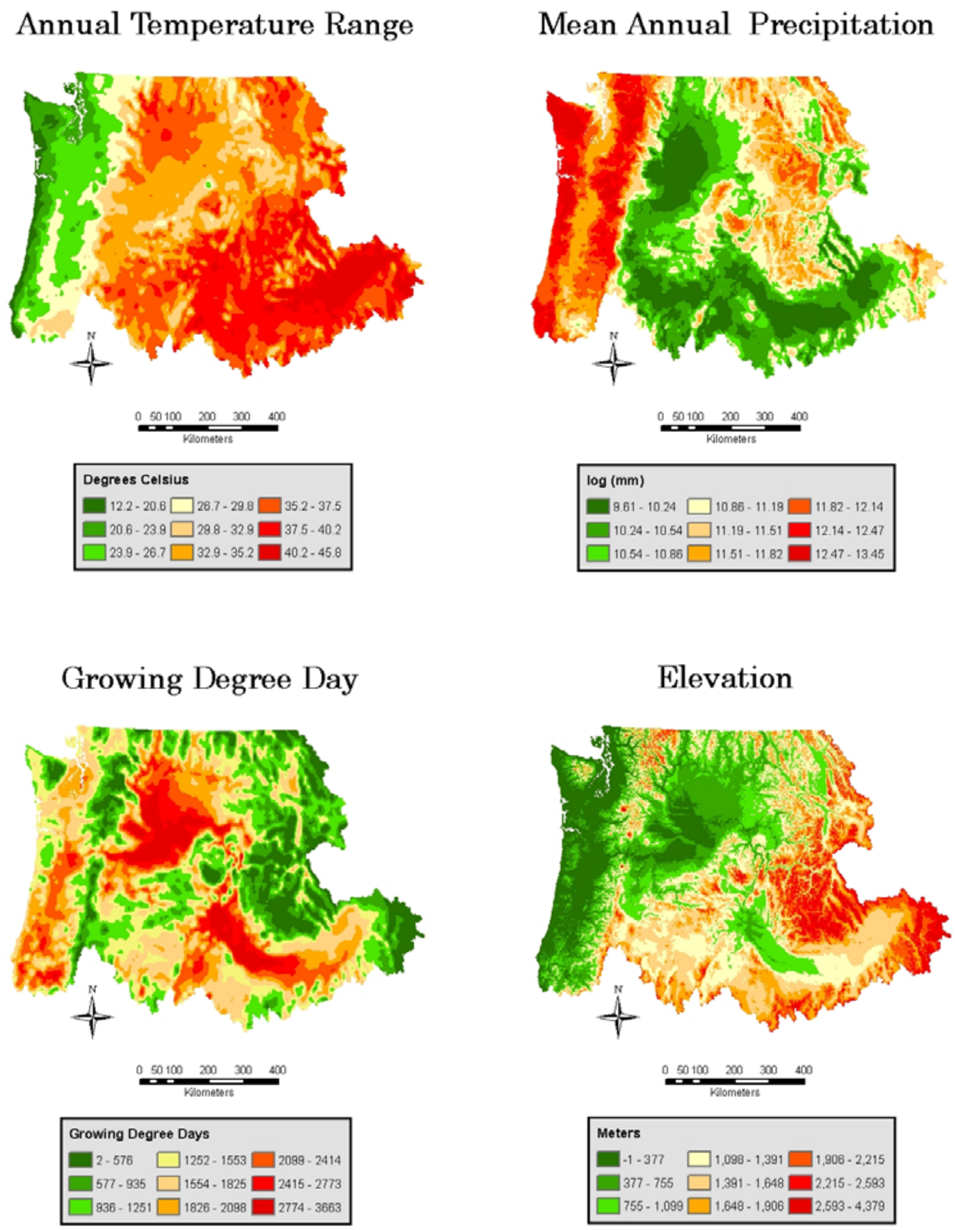


Figure 40. Climate data layers as input to the ordination scheme.

Physical-biological layers. Slope was derived from the U.S. Geological Survey 30 m raster DEM and resampled to 200 m using bilinear interpolation. The median pixel value was used to summarize data to HUC6 watersheds (Figure 41).

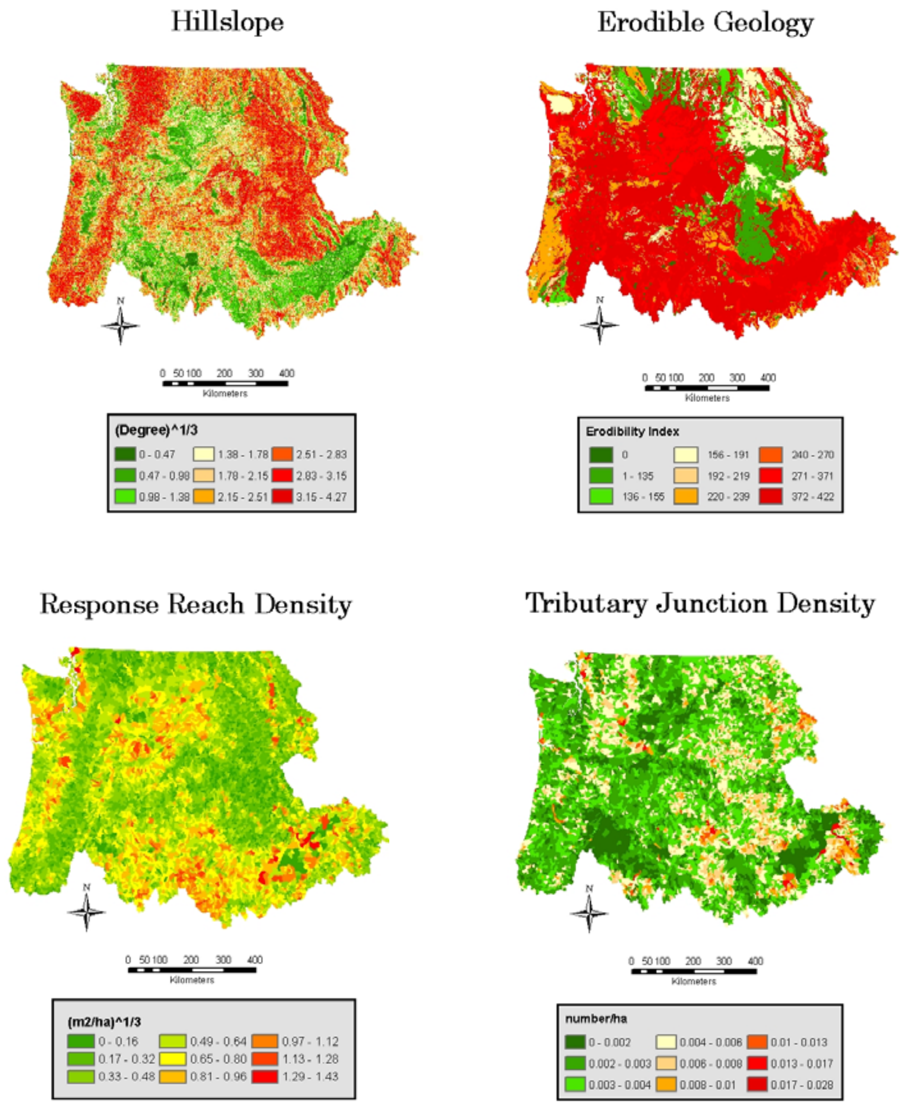


Figure 41. Physical-biological data layers as input to the ordination scheme.

Erodible geology was derived from the Interior Columbia Basin Ecosystem Management Project (ICBEMP 1999) major lithology data layer, a digital compilation of state geology maps (1:500,000) that has been reclassified into generalized rock categories (http://www.icbemp.gov/). This reclassified vector compilation was attributed using a hardness classification adapted from Dolan et al. (1975) which assigns an ordinal scale value to each rock type based on the relative hardness of minerals comprising the rock (Table 20).

Table 20. Geology erodibility based on a hardness classification adapted from Dolan et al. (1975) which assigns an ordinal scale value to each rock type based on the relative hardness of minerals comprising the rock.

Lithology	Erodibility
open water	0

alkalic intrusive	130
calc-alkaline intrusive	130
granite	130
mafic intrusive	130
ultramafic	130
mafic meta-volcanic	135
granitic gneiss	140
argillite and slate	150
mafic gneiss	150
mafic schist and greenstone	150
calc-alkaline meta-volcanic	155
meta-sed phyllite & schist	165
mixed meta-sedimentary	170
meta-siltstone	175
meta-sandstone	180
meta-conglomerate	185
meta carbonate & shale	190
shale and mudstone	210
siltstone	220
sandstone	230
conglomerate	240
carbonate	250
Quartzite	260
mixed carbonate & shale	270
dune sand	330
glacial drift	350
lake sediment & playa	350
Loess	355
Alluvium	370
Landslide	370
mixed eugeosynclinal	370
mixed miogeosynclinal	370
mafic volcanic flow	410
felsic volcanic flow	420
Tuff	420
calc-alkaline volcanoclastic	430
felsic pyroclastic	430
mafic pyroclastic	430

Individual classes were discriminated by the relative resistance of each rock type to physical and chemical weathering. The ranking scheme is generalized as erodibility and depends upon the specific mineral content, cementation (especially for sedimentary rocks), grain size (for unconsolidated sediments), and presence of planar elements (i.e., bedding, schistosity, cleavage, and fractures) within the rock. Attributed vector polygons were rasterized (200m pixel) and the majority pixel value was used to summarize rasterized geology to HUC6 watersheds (Figure 41).

Response area density and tributary junction density were calculated from the 1:100,000 National Hydrology Dataset Plus (Dewald, *in press*). Response area density was calculated by squaring the length of channel with gradient less than or equal to 4 percent and then dividing by the area of the subwatershed. Tributary junction density was determined by counting the number of tributary junctions within each subwatershed and dividing by the area of the subwatershed. When response area density and tributary junction datasets were converted to raster (200 m pixels), all pixels within the same HUC6 watershed were assigned the same value (Figure 41).

Data preparation

Classification input data should have a roughly Gaussian distribution in order to accurately characterize classes using mean vectors and covariance matrices. Raw data for elevation, growing degree day, temperature range and geologic erodibility exhibited relatively normal distributions (Figure 42 and Figure 43). Precipitation, response area density and tributary junction density data histograms were slightly skewed and were therefore log transformed to improve their distributions (Figure 42 and Figure 43). The slope data was strongly left skewed and was transformed by taking the cube root of degree-slope – the resulting distribution is unimodal, but lacks strong tails. Further transformation may be necessary (using a Uniform to Gaussian transformation), but was not done at this point.

Classification clustering is maximized when input data layers have similar data ranges. As a result, our transformed data layers were normalized using the following equation to a range between 0 and 1 prior to running the ISOCLUSTER classification:

$$Z = X - Xmin/Xmax\text{-}Xmin \qquad (1)$$

Where: Z = output grid with new data range(0-1);

X = input grid with original data range;

xmin = minimum value X;

xmax = maximum value X;

Data Classification/Clustering

200m pixel classification: ISODATA. The main objective of an unsupervised classification is to identify naturally occurring clusters in the data. For this analysis, we applied the ISODATA (Iterative Self-Organizing Data Analysis Technique) unsupervised clustering algorithm (Tou and Gonzalez 1974) accessed via the ISOCLUSTER function in Arc/Info GIS software. The ISOCLUSTER function uses a modified iterative optimization procedure, also known as the migrating means technique. The process starts with arbitrary means being assigned by the software, one for each cluster (the number of clusters is dictated as a user input). Every cell is then assigned to the closest of these means, all in the multidimensional-attribute space. New means are then recalculated for each cluster based on the attribute distances of the cells that belong to the cluster after the first iteration. The process is repeated enough times to ensure that the migration of cells from one cluster to another is minimal and all the clusters become stable.

The user specifies the number of classes, number of iterations, minimum number of cells in a class, and sampling interval. The ISOCLUSTER function returns a signature file, containing class means and covariance matrices, which are then used as input for the maximum likelihood classifier (MLCLASSIFY function in Arc/Info). The classifier uses the mean vector and covariance matrix of each class to compute the statistical probability that a grid cell belongs to a class. Each cell is assigned to the class for which it has the highest probability of being a member (Figure 44).

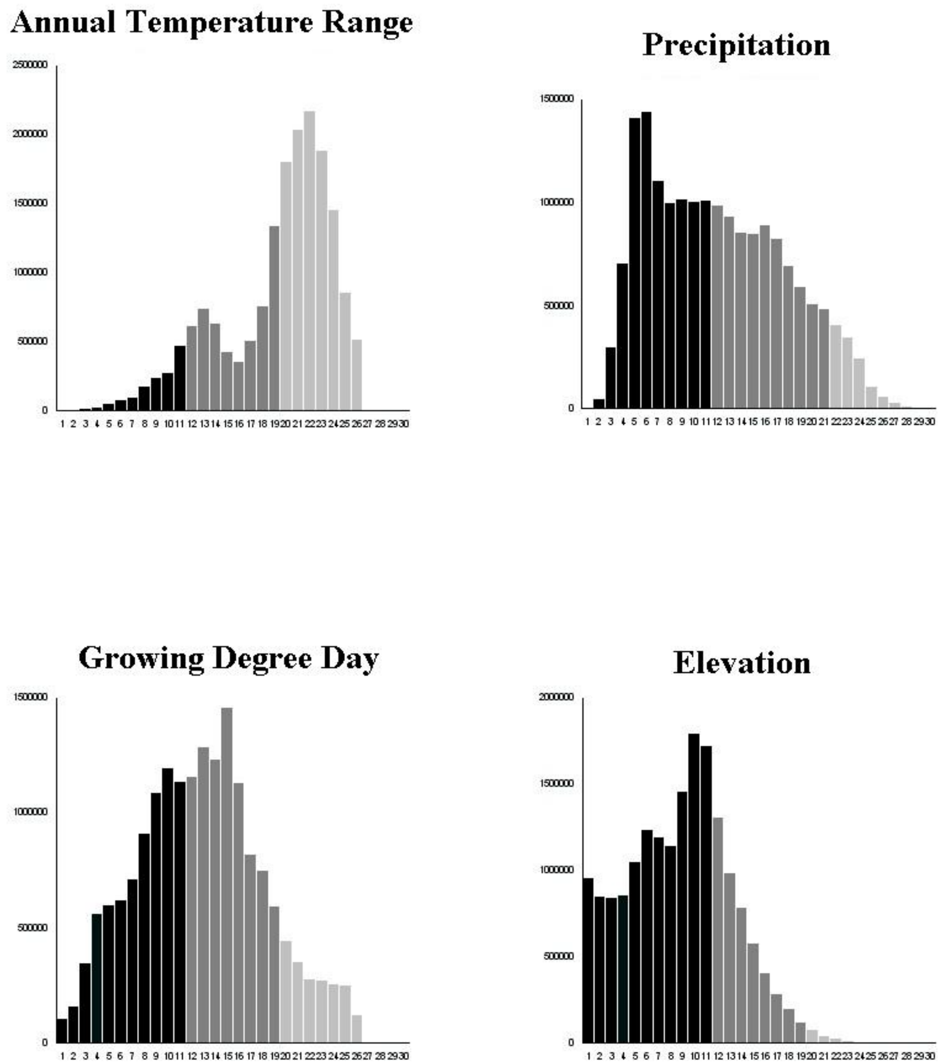


Figure 42. Distribution of climate data as used for the 6th field HUC based ordination.

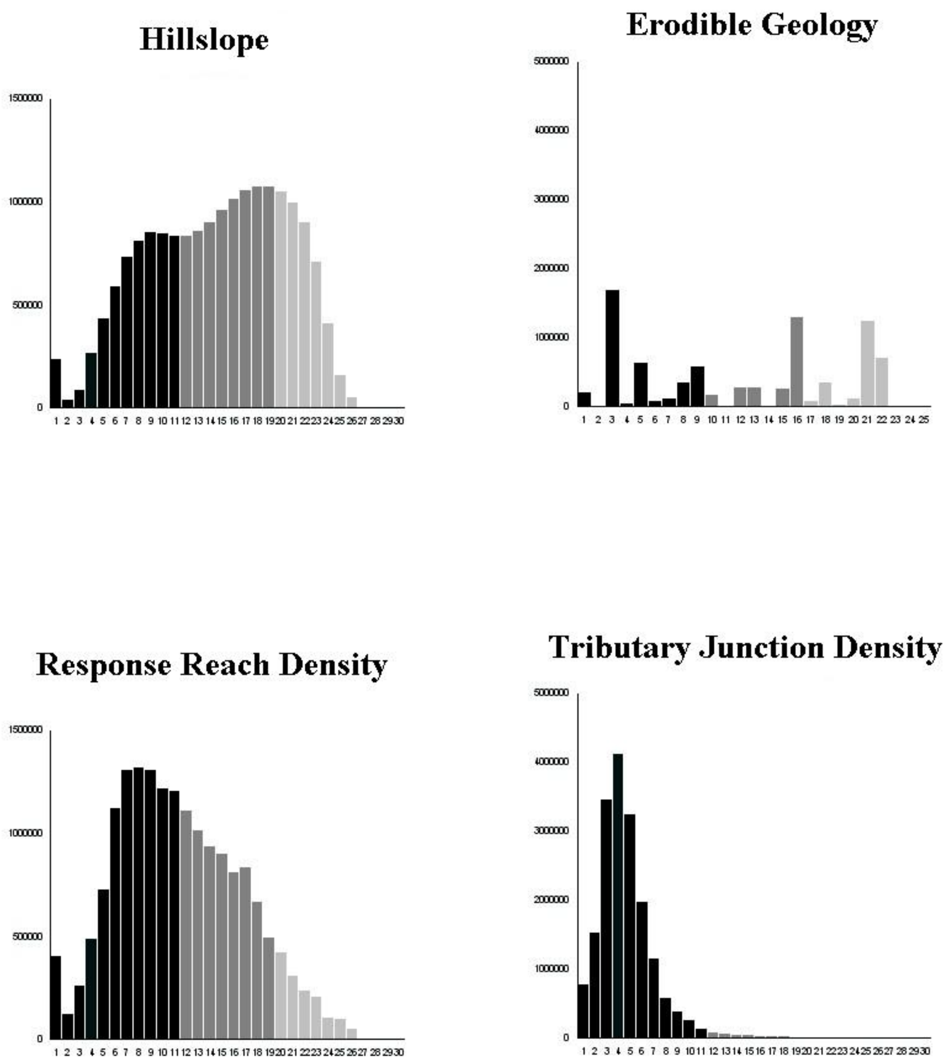


Figure 43. Distribution of physical-biological data as used for the 6th field HUC base ordination.

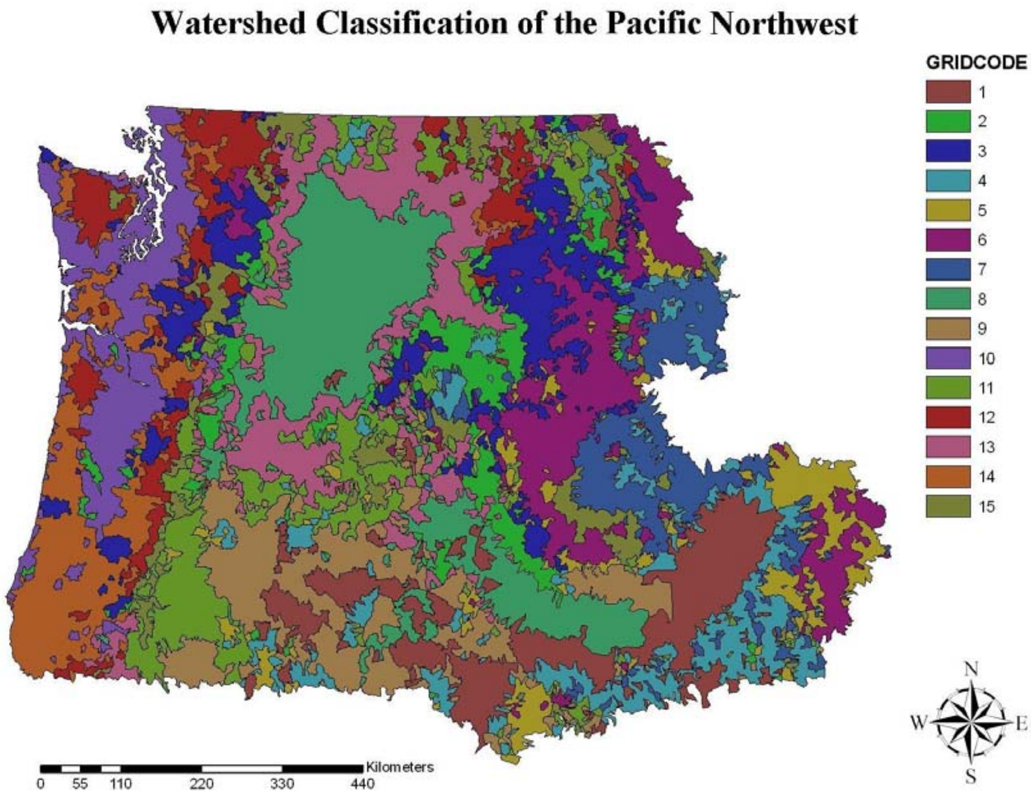


Figure 44. Preliminary ordination of data layers. In this case, the study area is classified into 15 different "types" of watersheds (groups of 6^{th} field HUCs) based on physical and climatological similarity.

HUC6 classification: MCLUST. We intend to use the MCLUST software package for watershed classification. The software implements parameterized Gaussian hierarchical clustering algorithms. In MCLUST, 10 distinct models parameterize characteristics of potential clusters. Each model describes the distribution, orientation, volume, and shape of clusters. To initiate the clustering algorithms, initial cluster centers are estimated through discrete classification. For each model, an iterative maximum likelihood procedure determines cluster centers, assigns watersheds to clusters, and reports the Bayesian Information Criterion. The procedure is iterated for a range in the number of classes. By evaluating the Bayesian Information Criterion for each model/number of classes combination, the analyst is able assess the best-fit classification. Additionally, we have programmed the software to report a log-likelihood for each iteration. The log-likelihood can be used to calculate alternate best-fit criterion.

Probing a sample design to optimize coverage on continuous variables

A primary objective of the ISEMP is identifying methods to increase the efficiency of monitoring programs without sacrificing information quality (e.g., statistical power of evaluations). For example, the operation of juvenile rotary screw traps to estimate smolt emigration timing and abundance has both a biological cost (e.g., potential handling mortality) and a monetary cost (e.g., labor). Thus, it is of interest to determine whether sampling effort can be decreased without sacrificing the quality of the estimators. The tradeoff between efficiency and information quality is perhaps best illustrated by the frequency with which continuous variables must be measured to enable robust statistical analyses. However, an analysis of this type requires finely-scaled datasets so that uncertainty introduced by decreasing sampling effort can be evaluated against the "truth" and its known variance as described by intensive monitoring.

Funding Agencies
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National Oceanic and Atmospheric Administration

Contractors
Quantitative Consultants Inc.

Time Line

Initiated in 2006, this work is preliminary and has been applied to only one monitoring data type (water quality) at this point. Now that a methodology has been established, the analysis will be expanded to additional "temporally continuous" data types such as from rotary screw traps.

What's been accomplished so far

In the Wenatchee River subbasin a number of continuous water quality variables were measured on an hourly basis in 2005. In this analysis we used temperature measurements to develop methods to test how coarser sampling rates (e.g., daily measurements) influence the ability to capture temporal variation in continuous variables.

Materials and Methods

Real-time hourly measurements of the following water quality indicators were collected at five unique sites in the Wenatchee River watershed (Figure 23) from 2004 to present:

- Temperature;
- Turbidity;
- Specific conductivity;
- Dissolved oxygen (DO);
- Dissolved oxygen percent saturation;
- PH, and
- Flow (at a subset of the sites).

We summarized the data into four temporal strata:

- Hourly;
- Daily;
- Weekly, and
- Monthly.

In order to determine the influence of sampling frequency (e.g., temporal density of sampling effort) on the information value of a given variable, one must first identify what properties of an indicator are biologically meaningful to the organism or process of interest and on what time scale. Since we elected to develop our methodology using temperature as our indicator, we focused on mean, maximum, and minimum temperature as our properties of interest. In short, mean temperature is useful for estimating emergence timing and growth rate, while minimum and maximum values are useful in identifying limiting factors (e.g., upper lethal limits). The question then becomes how infrequently can temperature be measured to enable a robust understanding of its biological influence on the species of interest?

In order to address this question, we defined the hourly measurements of temperature as our unit of measurement. The mean and variance of the sampling unit was then calculated for each stratum. Each stratum was then randomly sampled at a rate of 10, 25, and 50%. We calculated coverage probabilities to evaluate how often we would capture the true mean, maximum, and minimum temperature values as sampling effort was decreased within strata.

Coverage probabilities were computed as function of each stratum as follows. For our assessed estimators, we have:

the mean;

(1) $$\hat{\theta} = \frac{\sum_{i=1}^{n} X_i}{n}$$

maximum;

(2) $$\hat{\theta} = \max(X_i)$$

and minimum;

(3) $$\hat{\theta} = \min(X_i)$$

With the SE of each estimator given by:

(4) $$SE(\hat{\theta}) = \sqrt{1-sf}\left[\frac{Var(\hat{\theta})}{n}\right]$$

Where sf is the sampling fraction $\frac{n}{N}$ and n and N are the sampled and finite populations respectively.

We calculated 95% confidence intervals using the Law of Large Numbers and under the assumption of Normality (the Central Limit Theorem, equations 5 and 6 respectively, Cassella and Berger 1992, Cochran 1977):

(5) $$UCI(\hat{\theta}) = \hat{\theta} + 1.96 * SE(\hat{\theta})$$

and

(6) $$LCI(\hat{\theta}) = \hat{\theta} - 1.96 * SE(\hat{\theta})$$

Coverage probabilities were then computed as a function of the number of simulations where the following conditions were met:

(7) $$LCI(\hat{\theta}) \leq \hat{\theta} \leq UCI(\hat{\theta})$$

Results

Exploratory Data Analysis (EDA)

We used exploratory techniques to summarize trends in the data. Based on the available information, we observed that at each site there is an increase in temperature (Figures 45 to 49) from January through July, with a decline after that until December. We also summarized average values with variances for each site (

Table 21).

With the exception of Peshastin Creek, all sites had a complete data series for each month. We used data from 2006 to populate missing values for Peshastin Creek for January 2005, but data for March were unavailable. Across sites, June, July and August show the most variation in temperature, likely as a function of snow melt occurring in the upper watersheds, and the location of temperature monitors within the watersheds. However, some winter months also displayed a high CV, such as the Wenatchee Lake and West Monitor sites.

Simulation (Bootstrap) based Coverage

Not surprisingly, the monthly stratum exhibited the greatest variation (Figure 45, Figure 46, Figure 47, Figure 48, and Figure 49), thus we elected to evaluate the influence of subsampling within the monthly stratum since the impacts of decreased sampling effort should be most pronounced as variation within a stratum increases. We assessed the utility of applying a stratified random sample design by drawing 10, 25, and 50% of the sampling units (hourly measurements) at random from the monthly stratum. Ten thousand simulations were completed for each sampling rate, and the efficacy of the design was evaluated by the proportion of the simulations that captured the “true” mean, maximum, and minimum temperatures values as described by the compete dataset of hourly measurements for each month at each site.

Results

As displayed graphically for the Chiwawa River site, coverage probabilities for the true mean water temperature declined as the sampling rate decreased from 50% to 10% (Figure 50 and Figure 51, respectively), but are likely adequate at even the lowest sampling rate (10%). Alternatively, for the maximum and minimum water temperatures, coverage probabilities decline dramatically as the sampling rate is decreased (Figure 52, Figure 53, Figure 54, and Figure 55, respectively). Tabular results for all of the sites are presented in Table 22, Table 23, Table 24, Table 25and Table 26.

In general, the simulation results are intuitive, illustrating that sample coverage increases as a function of sample rate, and that sample rates must increase to maintain a specified desired coverage as the CV of the parameter of interest increases. Also intuitive is that this relationship is more pronounced for maximum and minimum values, as they are the “rarest” values in the time series. Less intuitive is that even in months with low variance, which we would expect to exhibit high coverage at even very low sample rates (e.g., December in Chiwawa Creek), sample coverage improves with higher sampling effort, suggesting that the sample variance and population variance change quite significantly as a function of the sample rate.

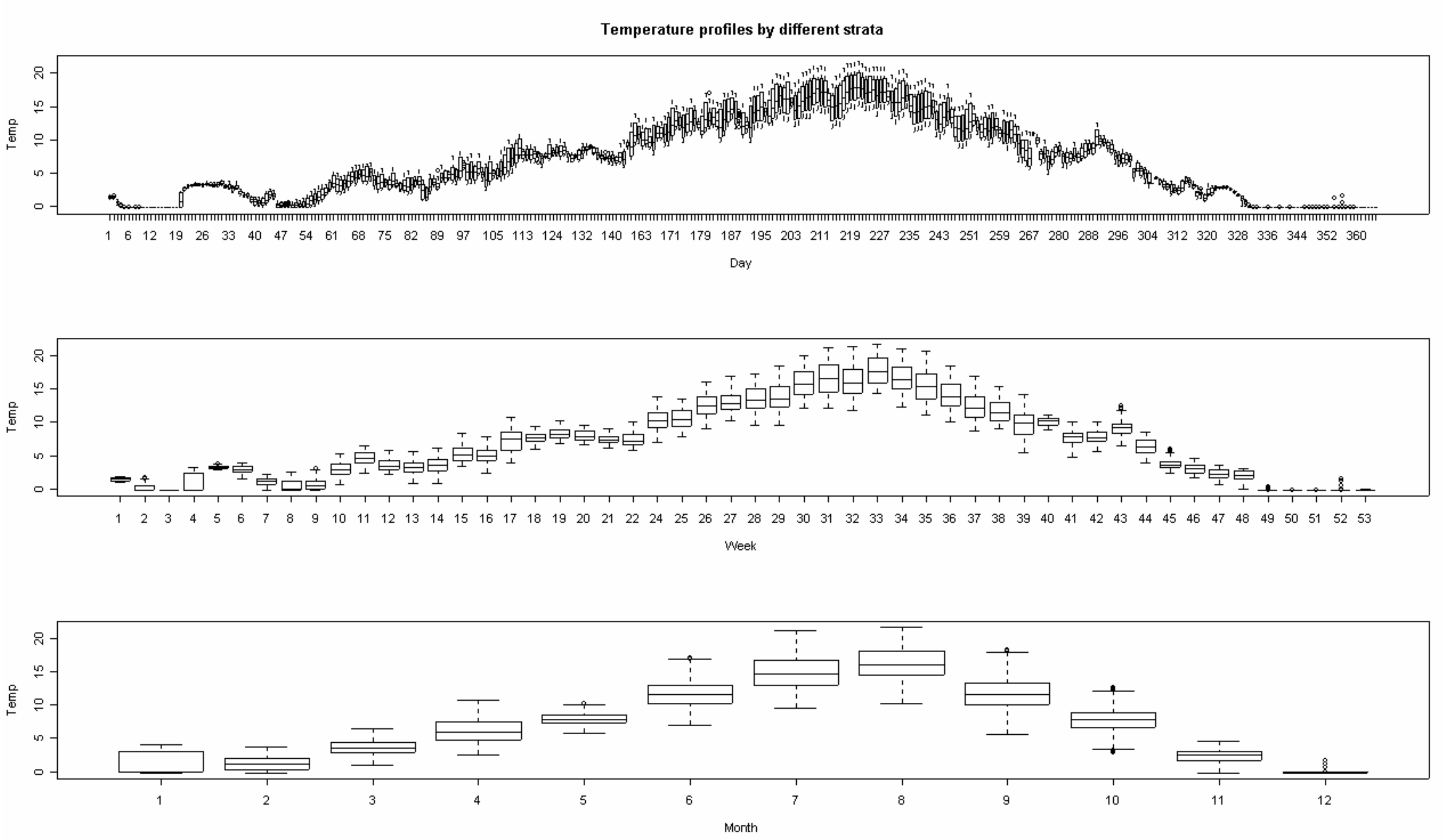

Figure 45. Water temperature at the Chiwawa Creek site, Wenatchee subbasin, WA, by day, week, and month from January 2005 to December 2005.

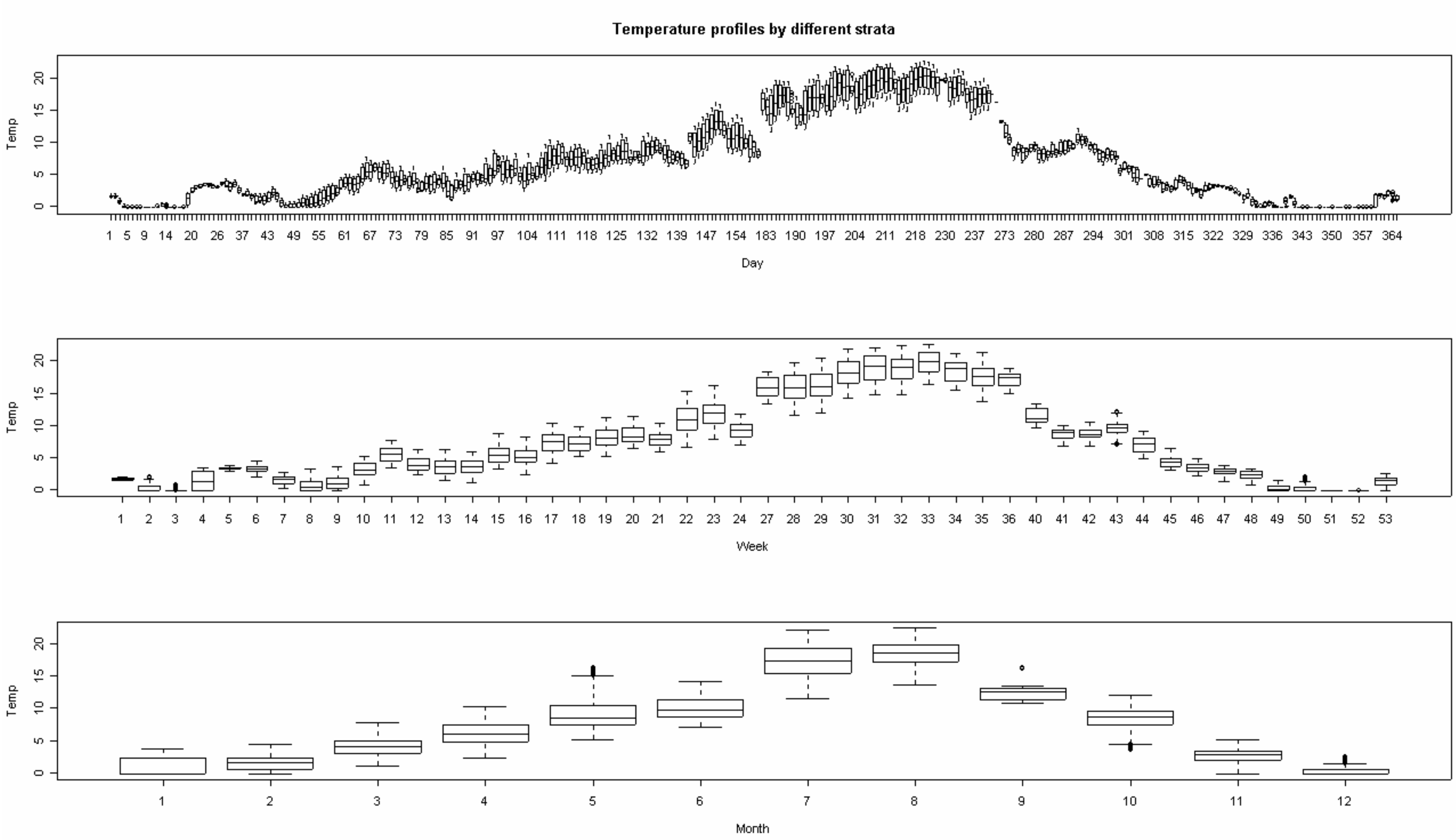

Figure 46. Water temperature at the Nason Creek site, Wenatchee subbasin, WA, by day, week, and month from January 2005 to December 2005.

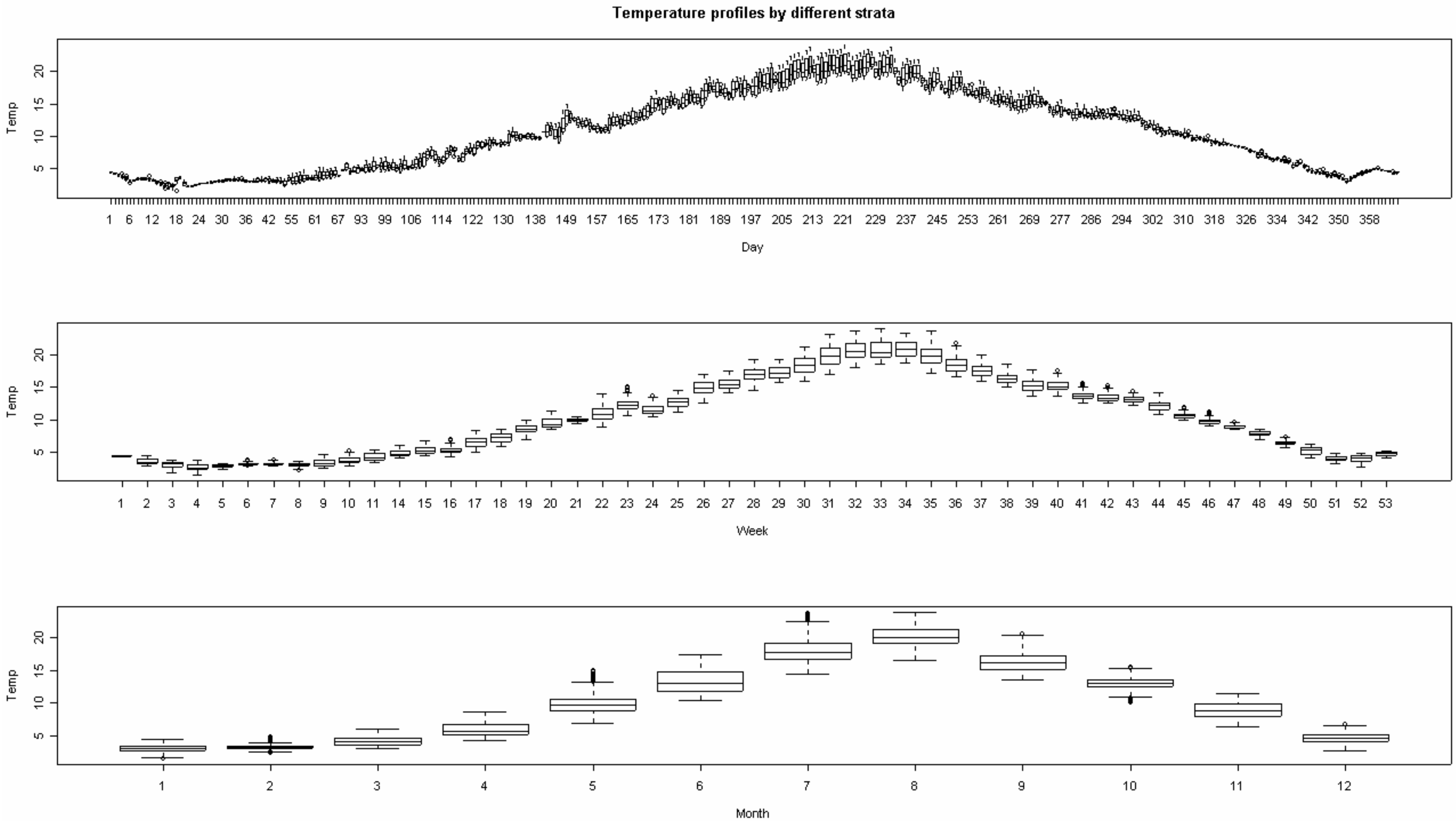

Figure 47. Water temperature at the Wenatchee Lake site, Wenatchee subbasin, WA, by day, week, and month from January 2005 to December 2005.

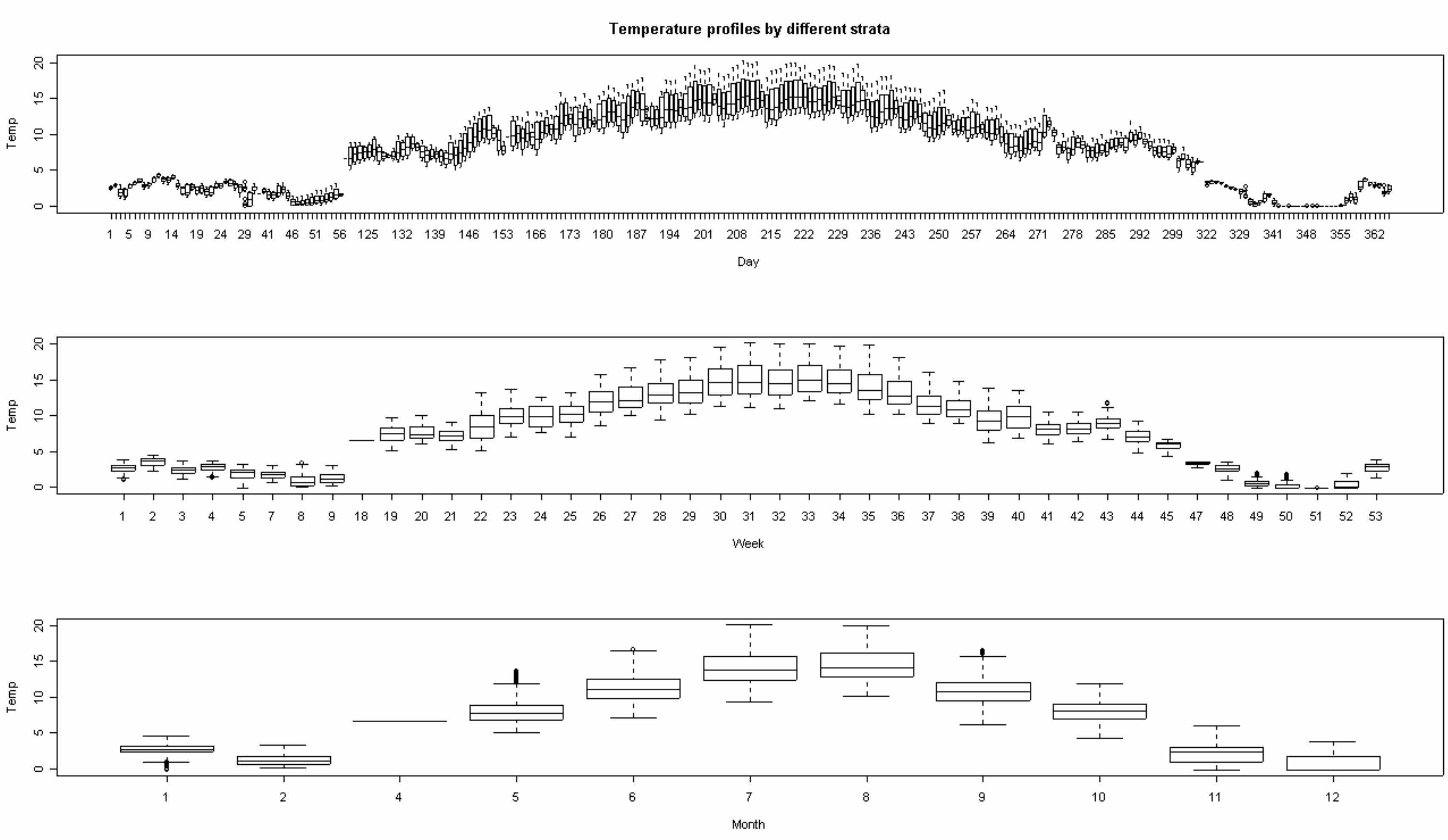

Figure 48. Water temperature at the Peshastin Creek site, Wenatchee subbasin, WA, by day, week, and month from February 2005 to January 2006 (note that data were unavailable for March and January data are from 2006).

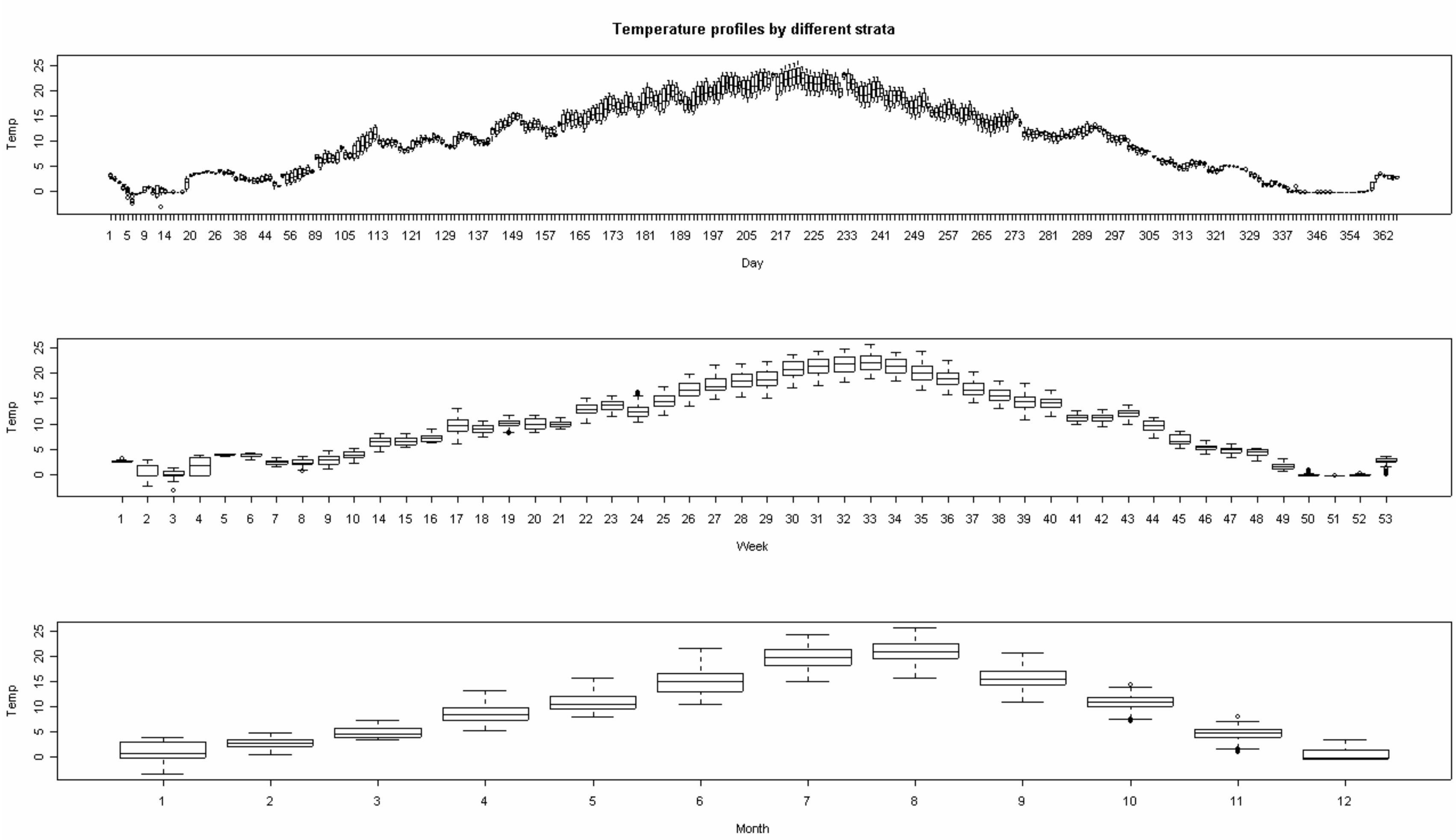

Figure 49. Water temperature at the West Monitor site, Wenatchee subbasin, WA, by day, week, and month from January 2005 to December 2006.

Table 21. Mean water temperature (Celsius) and variance by site of streams in the Wenatchee subbasin, WA.

	MEAN					Variance				
Month	Chiwawa	Nason	Wlake	Peshastin	Wmonitor	Chiwawa	Nason	Wlake	Peshastin	Wmonitor
Jan	1.19	0.94	3.11	2.71	1.23	2.43	1.97	0.33	0.68	2.82
Feb	1.17	1.50	3.24	1.22	2.85	1.02	1.37	0.14	0.64	0.73
Mar	3.64	4.03	4.11	NA	4.89	1.28	1.85	0.39	NA	1.33
Apr	6.08	6.16	5.99	6.61	8.59	3.04	3.00	1.15	NA	2.83
May	7.85	9.13	9.93	8.02	11.04	0.73	5.11	2.29	2.91	3.52
Jun	11.64	10.11	13.30	11.17	15.00	3.74	3.30	3.06	4.21	5.57
Jul	14.97	17.30	18.08	14.16	19.73	6.39	6.21	3.31	5.40	4.44
Aug	16.19	18.44	20.24	14.53	20.92	6.29	3.97	2.42	5.29	4.13
Sep	11.60	12.35	16.39	10.79	15.65	5.41	1.89	2.12	4.23	4.09
Oct	7.61	8.31	12.97	7.99	10.83	2.86	2.58	1.00	1.83	2.05
Nov	2.16	2.58	8.81	2.04	4.46	1.59	1.60	1.66	1.33	2.05
Dec	-0.15	0.28	4.64	0.83	0.65	0.01	0.53	0.70	1.60	1.60
Yearly Total	6.79	6.80	10.70	8.10	10.40	33.25	38.11	35.25	27.14	50.77

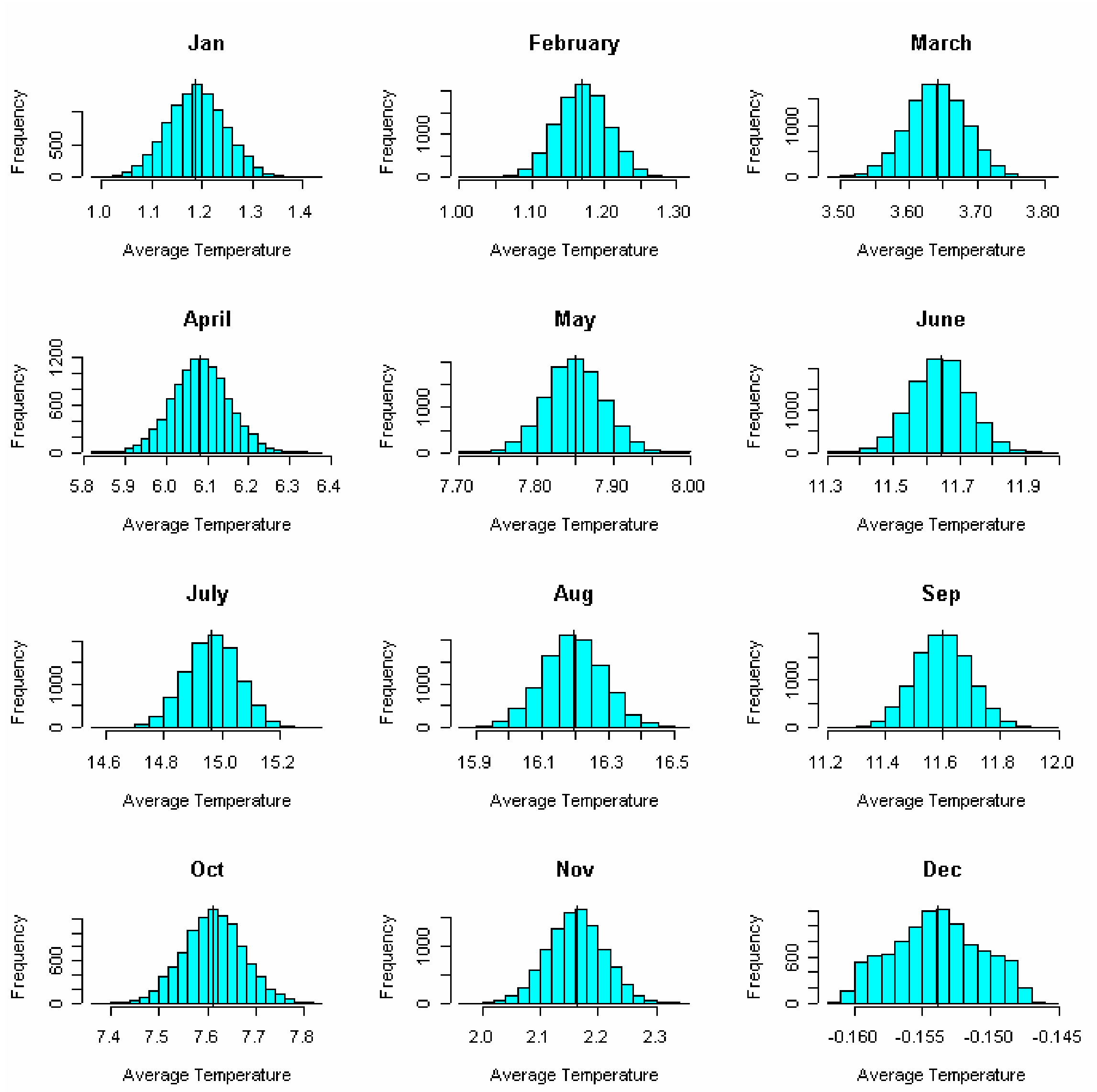

Figure 50. Coverage probabilities for monthly mean water temperature using a 50% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

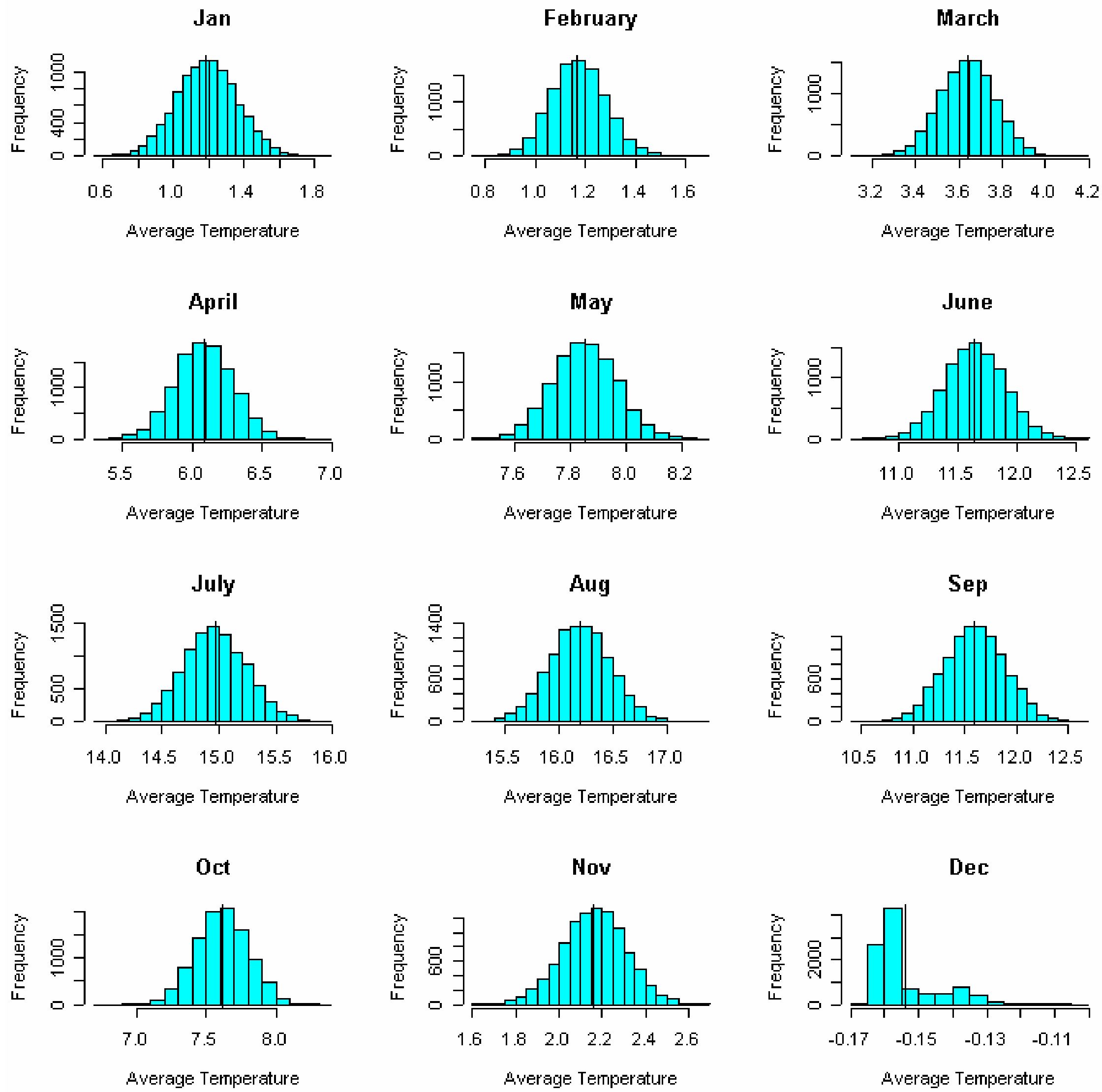

Figure 51. Coverage probabilities for monthly mean water temperature using a 10% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

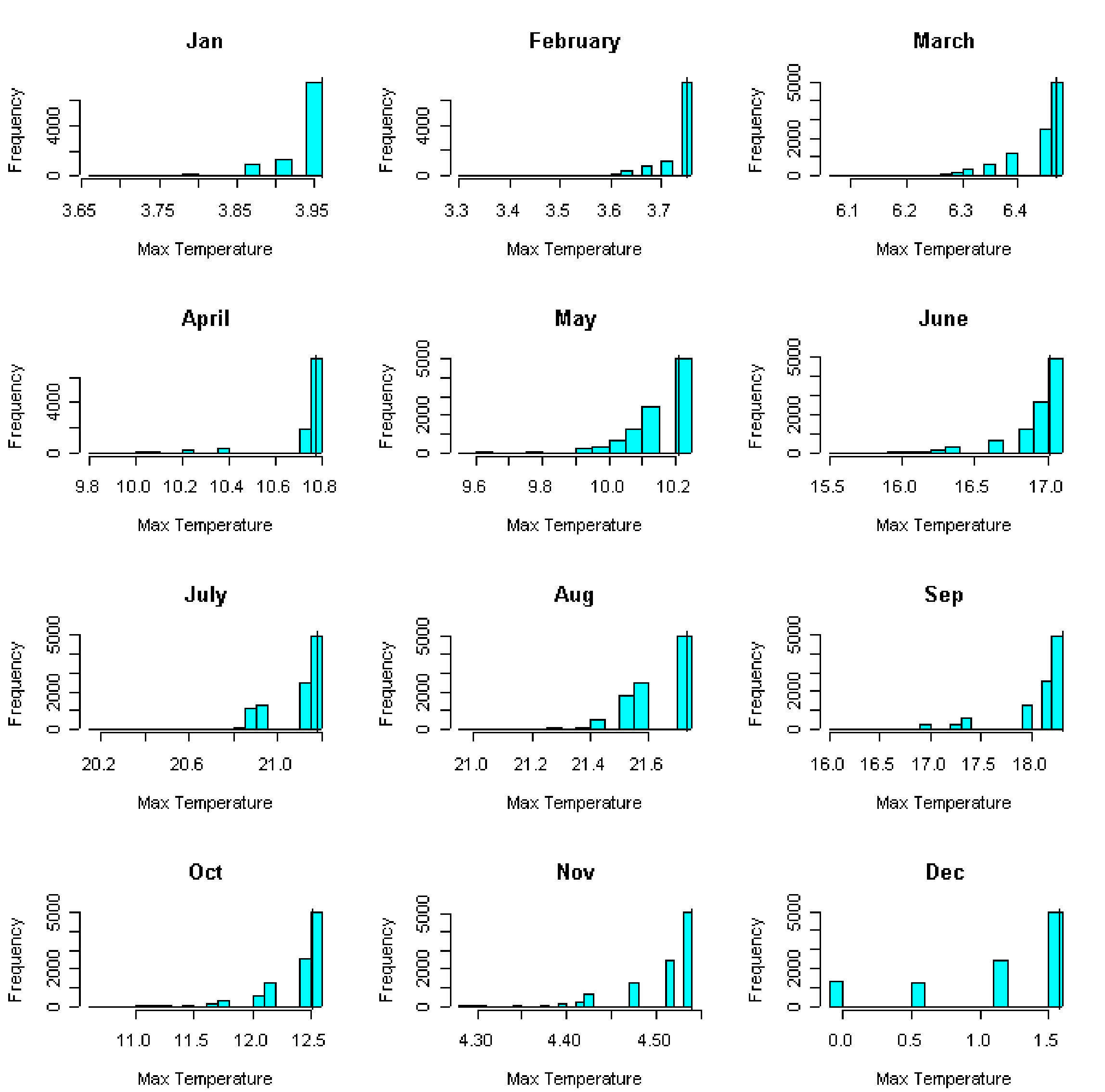

Figure 52**.** Coverage probabilities for monthly maximum water temperature using a 50% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

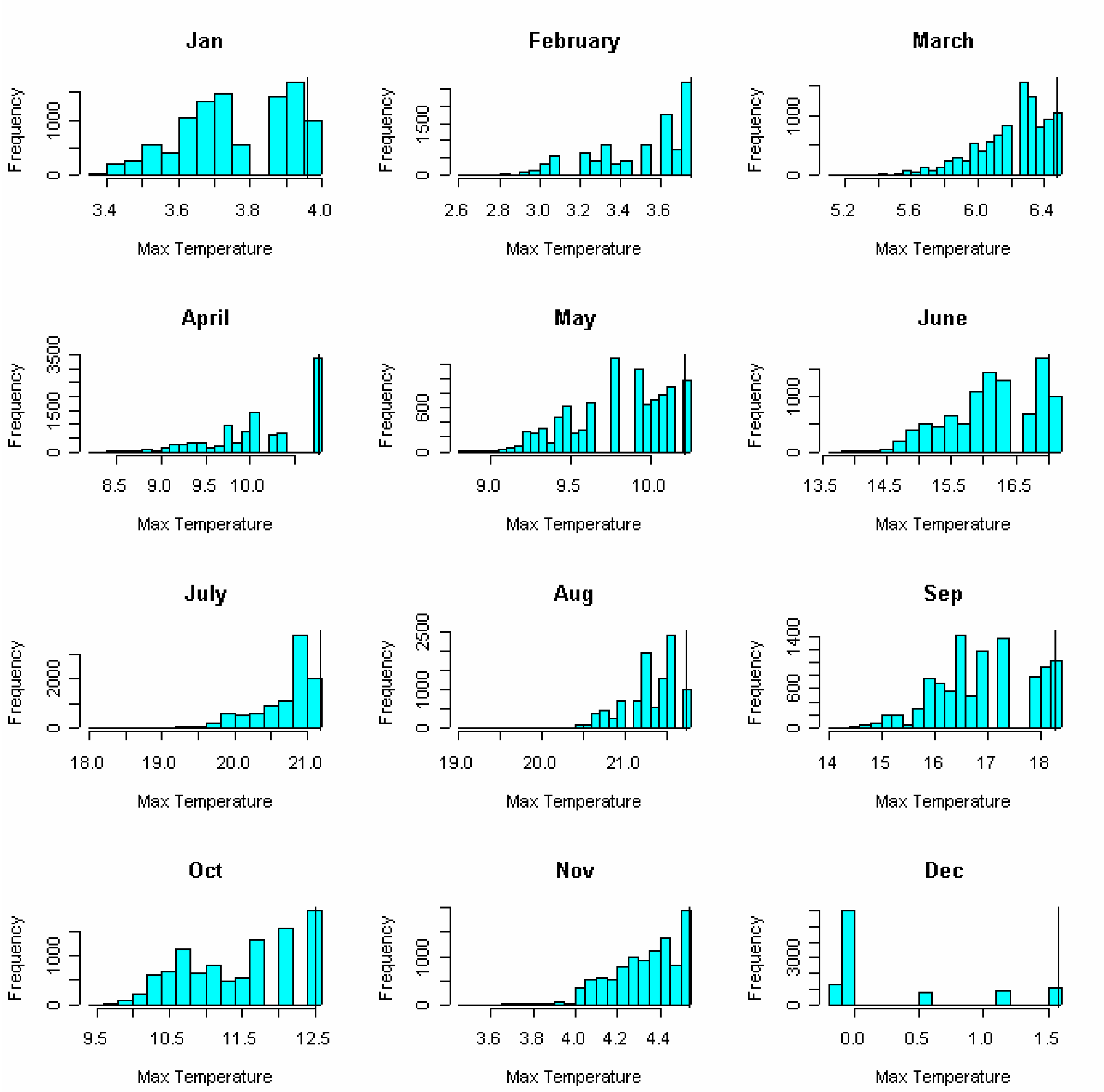

Figure 53. Coverage probabilities for monthly maximum water temperature using a 10% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

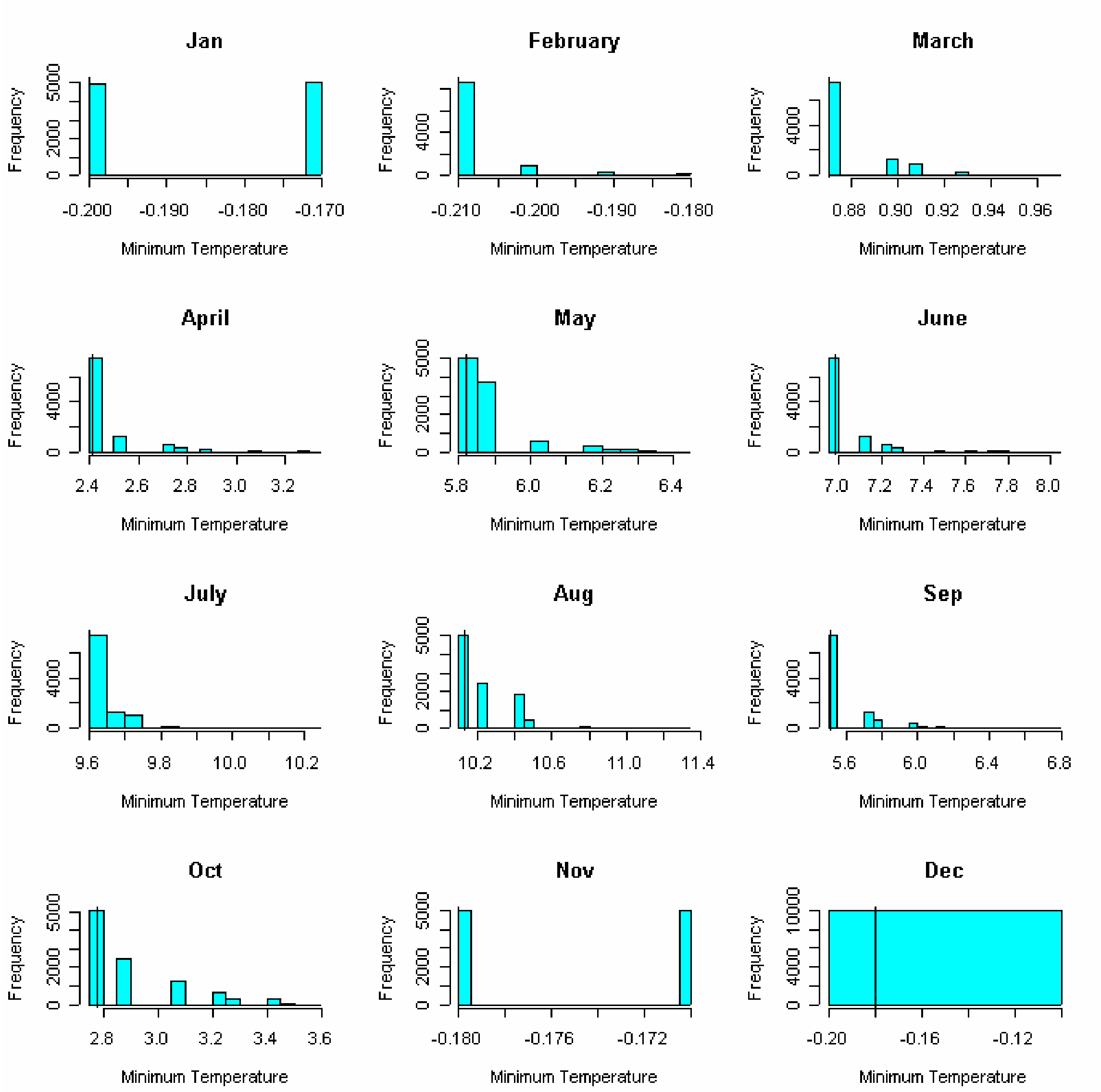

Figure 54. Coverage probabilities for monthly minimum water temperature using a 50% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

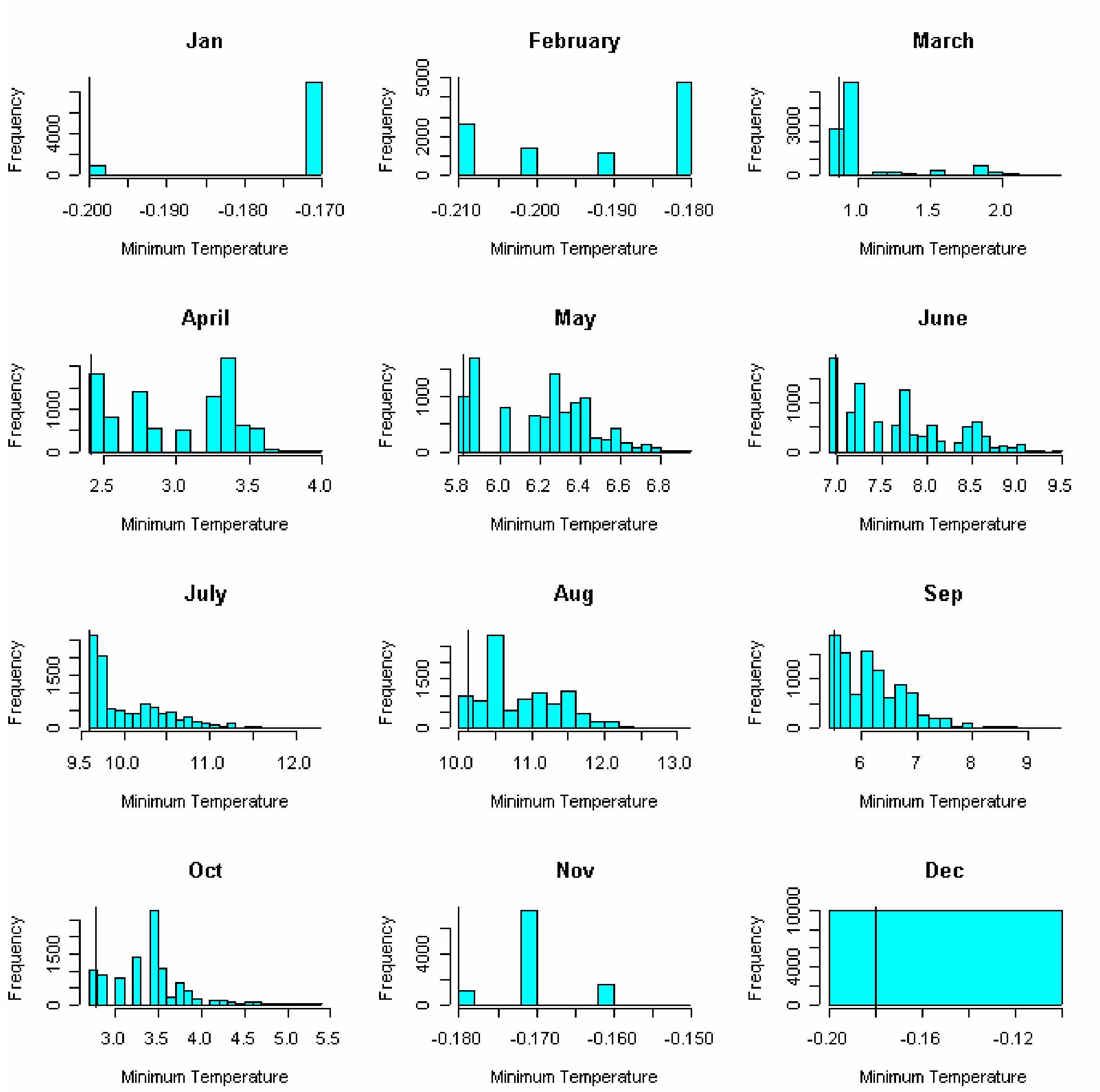

Figure 55. Coverage probabilities for monthly minimum water temperature using a 10% random stratified sample at the Chiwawa River site, Wenatchee subbasin, WA.

Table 22**.** Summary of coverage for the mean, maximum, and minimum water temperature at 10%, 25%, and 50% sample rates for the Chiwawa River, Wenatchee subbasin, WA.

	MEAN				MAXIMUM				MINIMUM		
Sample Rate	10%	25%	50%		10%	25%	50%		10%	25%	50%
Jan	0.948	0.950	0.950		0.814	0.829	0.970		1	1	1
Feb	0.948	0.949	0.949		0.547	0.785	0.913		0.836	0.991	0.999
Mar	0.946	0.950	0.951		0.573	0.698	0.864		0.567	0.567	0.567
Apr	0.949	0.948	0.948		0.406	0.694	0.940		0.393	0.578	0.878
May	0.945	0.952	0.949		0.371	0.568	0.749		0.319	0.575	0.875
Jun	0.940	0.948	0.944		0.345	0.582	0.757		0.432	0.677	0.880
Jul	0.945	0.947	0.955		0.633	0.722	0.747		0.642	0.865	0.983
Aug	0.946	0.949	0.950		0.732	0.782	0.755		0.467	0.552	0.755
Sep	0.944	0.945	0.952		0.277	0.475	0.621		0.473	0.677	0.747
Oct	0.946	0.949	0.952		0.260	0.426	0.755		0.268	0.439	0.674
Nov	0.940	0.949	0.949		0.727	0.855	0.879		1	1	1
Dec	0.584	0.596	0.815		0.101	0.251	0.496		1	1	1

Table 23**.** Summary of coverage for the mean, maximum, and minimum water temperature at 10%, 25%, and 50% sample rates for Nason Creek, Wenatchee subbasin, WA.

	MEAN				MAXIMUM				MINIMUM		
Sample Rate	10%	25%	50%		10%	25%	50%		10%	25%	50%
Jan	0.939	0.950	0.947		0.978	0.995	1		1	1	1
Feb	0.944	0.945	0.947		0.343	0.661	0.749		0.518	0.789	0.937
Mar	0.942	0.946	0.950		0.342	0.431	0.742		0.742	0.742	0.742
Apr	0.946	0.949	0.946		0.602	0.718	0.937		0.367	0.681	0.874
May	0.943	0.950	0.949		0.458	0.677	0.747		0.448	0.673	0.867
Jun	0.933	0.944	0.947		0.687	0.782	0.878		0.721	0.752	0.896
Jul	0.945	0.945	0.946		0.883	0.906	0.936		0.513	0.576	0.744
Aug	0.943	0.949	0.949		0.714	0.900	0.985		0.358	0.575	0.829
Sep	0.794	0.894	0.901		0.181	0.433	0.740		0.843	0.965	0.997
Oct	0.948	0.950	0.953		0.343	0.579	0.750		0.474	0.677	0.939
Nov	0.944	0.946	0.951		0.592	0.766	0.938		1	1	1
Dec	0.935	0.948	0.950		0.548	0.824	0.932		1	1	1

Table 24. Summary of coverage for the mean, maximum, and minimum water temperature at 10%, 25%, and 50% sample rates for Peshastin Creek, Wenatchee subbasin, WA.

	MEAN				MAXIMUM				MINIMUM		
Sample Rate	10%	25%	50%		10%	25%	50%		10%	25%	50%
Jan	0.94	0.95	0.95		0.67	0.87	0.94		1.00	1.00	1.00
Feb	0.94	0.95	0.95		0.39	0.42	0.50		1.00	1.00	1.00
Mar	NA	NA	NA		NA	NA	NA		NA	NA	NA
Apr	NA	NA	NA		NA	NA	NA		NA	NA	NA
May	0.95	0.94	0.95		0.37	0.60	0.75		0.44	0.67	0.88
Jun	0.94	0.95	0.95		0.27	0.57	0.87		0.72	0.75	0.89
Jul	0.95	0.95	0.95		0.53	0.68	0.75		0.51	0.58	0.75
Aug	0.95	0.95	0.95		0.69	0.76	0.75		0.35	0.58	0.83
Sep	0.95	0.95	0.95		0.51	0.77	0.88		0.85	0.96	1.00
Oct	0.95	0.95	0.95		0.27	0.44	0.75		0.47	0.68	0.93
Nov	0.94	0.94	0.95		0.10	0.25	0.50		1.00	1.00	1.00
Dec	0.94	0.95	0.95		0.56	0.80	0.93		1.00	1.00	1.00

Table 25. Summary of coverage for the mean, maximum, and minimum water temperature at 10%, 25%, and 50% sample rates for the West Monitor site, Wenatchee subbasin, WA.

	MEAN				MAXIMUM				MINIMUM		
Sample Rate	10%	25%	50%		10%	25%	50%		10%	25%	50%
Jan	0.95	0.95	0.95		1.00	1.00	1.00		0.10	0.25	0.50
Feb	0.94	0.95	0.95		0.41	0.62	0.88		0.91	0.99	0.99
Mar	0.85	0.92	0.94		0.63	0.46	0.64		0.64	0.64	0.64
Apr	0.94	0.95	0.95		0.46	0.69	0.94		0.89	0.93	0.99
May	0.94	0.94	0.95		0.86	0.95	1.00		0.79	0.76	0.89
Jun	0.94	0.95	0.95		0.27	0.43	0.51		0.83	0.76	0.97
Jul	0.95	0.95	0.95		0.64	0.84	0.97		0.68	0.82	0.94
Aug	0.94	0.95	0.95		0.35	0.58	0.52		0.50	0.55	0.74
Sep	0.94	0.95	0.95		0.80	0.90	1.00		0.27	0.57	0.50
Oct	0.95	0.95	0.95		0.10	0.24	0.50		0.59	0.76	0.87
Nov	0.94	0.95	0.95		0.10	0.24	0.50		0.95	1.00	1.00
Dec	0.94	0.95	0.95		0.98	0.95	0.99		1.00	1.00	1.00

Table 26. Summary of coverage for the mean, maximum, and minimum water temperature at 10%, 25%, and 50% sample rates for the West Lake site, Wenatchee subbasin, WA.

	MEAN				MAXIMUM				MINIMUM		
Sample Rate	10%	25%	50%		10%	25%	50%		10%	25%	50%
Jan	0.95	0.95	0.95		0.84	0.91	0.99		0.10	0.25	0.50
Feb	0.94	0.94	0.95		0.19	0.44	0.49		0.60	0.68	0.76
Mar	0.93	0.94	0.95		0.26	0.25	0.50		0.50	0.50	0.50
Apr	0.94	0.95	0.95		0.59	0.68	0.87		0.86	0.90	0.98
May	0.95	0.95	0.95		0.27	0.57	0.75		0.63	0.89	0.97
Jun	0.94	0.94	0.95		0.51	0.58	0.75		0.98	1.00	1.00
Jul	0.94	0.95	0.95		0.27	0.45	0.75		0.53	0.69	0.87
Aug	0.94	0.95	0.95		0.17	0.26	0.49		0.46	0.59	0.88
Sep	0.95	0.95	0.95		0.41	0.44	0.75		0.58	0.68	0.75
Oct	0.94	0.95	0.95		0.30	0.43	0.50		0.40	0.57	0.76
Nov	0.94	0.95	0.95		0.39	0.58	0.75		0.99	0.98	0.99
Dec	0.94	0.95	0.95		0.19	0.25	0.48		0.35	0.44	0.50

Discussion

We used water temperature to develop methods for evaluating the influence of sampling effort on information quality using a systematic random sampling technique coupled with bootstrapping. Although simplistic, the use of water temperature enabled an evaluation of the method that included a comparison of the derived results with the "truth" as described by a finely scaled dataset. However, we recognize that water temperature is typically monitored using data logging devices, thus there is likely very little if any biological or monetary cost to sampling on shorter temporal intervals. Nonetheless, the methods developed here can be easily modified for application to monitoring activities such as the operation of juvenile rotary screw traps, adult weirs, and habitat surveys, where very real biological and monetary cost-savings could be realized by decreasing sampling effort.

The development of these methods underscores the importance of identifying which derived measures are of greatest importance to a monitoring program. For example, in this case one might select a different level of sampling intensity if minimum water temperature were the desired metric versus mean water temperature. Aside from simple changes in sample effort, one might elect to use a systematic rather than random sample for some metrics of interest. Again, using water temperature, if one were interested in maximum water temperature, one might elect to systematically sample in the afternoon, rather than randomly across total hourly sampling units within a stratum. In either case, it is clear that well-defined study objectives can improve sampling efficiency.

Having developed methods to assess the impact of reduced sampling, we intend to apply the methods to additional monitoring activities including:

- The operation of juvenile rotary screw traps – how would operating traps at daily or weekly intervals impact the accuracy and precision of smolt emigration estimates?
- Redd counts – how would subsampling total potential spawning areas using strata such as gradient impact the total number of enumerated redds?
- The operation of adult weirs, video weirs, and sonar – how would subsampling in time (e.g., every other day) influence the accuracy and precision of adult escapement estimates?

Recommendations on fish survey protocols for the ISEMP pilot projects based on an analysis of Wenatchee fish surveys

Fish species distribution and relative abundance have been intensively monitored through either electrofishing or snorkel surveys in the Wenatchee subbasin as part of the ISEMP pilot project since 2004. The sampling design of these surveys has been two-fold: 1) to establish the status and trend of fish populations throughout the Wenatchee subbasin, and 2) to evaluate how different protocols vary in precision, accuracy, and characterization of metrics of interest in order to identify the most cost effective approach for monitoring programs. The first of these goals is addressed via the sampling design, which employs an EMAP spatially randomized site selection process implemented in a split (rotating and fixed) panel design described in Chapter 1. The second goal is addressed by comparing multiple protocols with repeated visits to several sites.

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Contractors
Quantitative Consultants Inc.

Time Line

Data collection has occurred during fiscal years 2005 and 2006, and will be suspended during fiscal year 2007 pending a full analysis of the data in hand to date. Preliminary analyses have been performed and are expected to be complete during fiscal year 2007. At that time, a more complete design for data collection will be constructed and fieldwork will continue in fiscal year 2008. A final analysis of the protocols is expected in fiscal year 2009.

What's been accomplished so far

The ISEMP is interested in determining whether day or night surveys and different survey types (snorkeling vs. electrofishing) influence fish counts, and which of these approaches is accompanied by lower observation error and bias. Here we have used the monitoring data from day and night snorkeling and electrofishing surveys as a test case to demonstrate how we plan on determining the relative precision of different juvenile fish survey methods. Techniques based on the Generalized Linear Model are used to ask if protocols differ in their characterization of fish abundance across sites, and random effects models are used to partition variance components to describe measures of precision relevant to monitoring program designs; such as confidence intervals, coefficients of variation, and signal to noise ratios. The information used in this analysis is preliminary and incomplete. Further data collected in the Wenatchee and the other pilot projects (proposed for the John Day and Salmon subbasins) will be evaluated before final recommendations will be made to the design of wide scale monitoring design. However, the methods described are a subset of those that will be used to analyze anticipated data. Since the work is on-going no recommendations or conclusions are presented at this time.

Materials and Methods

Data were collected from eight streams in the Wenatchee watershed using either electrofishing and/or snorkeling at night and/or during the day. Twenty-five different species (or hybrids) were recorded during these surveys (Table 27). In total, 329 daytime counts and 243 nighttime counts were completed, resulting in an unbalanced design. When data collection is completed, a more balanced dataset will be available for analysis.

In order to determine whether survey timing (nighttime versus daytime) produced different results, we tested different models with different error structures using fish count as the response variable. The initial model was:

$$FishCnt = \beta_0 + \sum_{i=1}^{8} \beta_i Site_i + \beta_9 Survey + \beta_{10} Q + \sum_{i=11}^{43} \beta_i (Species)_i + \sum_{i=44}^{76} \beta_i (Species)_i (Q) + \varepsilon \quad (1)$$

Where Q=0 and Q=1 for nighttime and daytime counts, respectively. Similarly, snorkel surveys were coded as 0 and electrofishing surveys were coded as 1. The following hypotheses were evaluated:

H_0: $\beta_{10} = 0$ and/or $\beta_{44,}\ \beta_{45,\ldots\ldots}\ \beta_{76}=0$

H_A: $\beta_{10} \neq 0$ and/or $\beta_{44,}\ \beta_{45,\ldots\ldots}\ \beta_{76} \neq 0$

In addition to evaluating whether different protocols yield different counts we were interested in describing how they differ. Thus, we correlated daytime versus nighttime snorkeling surveys to evaluate how these protocols differ from each other over sites with different observed densities. For this analysis, daytime and nighttime snorkel surveys were paired by site and date and correlated to each other.

Although the previous hypothesis is relevant, it is equally important to assess how differences in protocols inform the selection of a sampling design. Because snorkelers will only see a fraction of the fish in an area, both daytime and nighttime snorkel surveys will not provide actual densities, rather they are indicators with an associated bias. From a sampling design perspective, the usefulness of each protocol as an indicator can be evaluated by assessing their relative precision, because bias can be corrected with proper calibration.

As discussed in Kaufman et al. (1999) and Roper et al. (2002) multiple metrics are useful in evaluating precision: 1) the width of the confidence interval, 2) the CV, and 3) and the signal to noise ratio, which is the variability due to sites divided by measurement variability (e.g. repeat visits or multiple crews plus residual). The CI or %CI of the mean gives a measure of precision relative to the mean and, for variables where one has a good understanding of the variability that is acceptable this metric can be used to inform protocol selection. However, small sample sizes may produce an inaccurate depiction of the true distribution, and therefore the estimated standard deviation and the width of the CI may also be exaggerated. In addition, it is often difficult to define an "acceptable" width for a CI. As general guidance, Platts et al. (1983) suggests that protocols returning a CI < 5% of the mean for a given habitat metric are excellent, ± 5-10% are good, ±11-20% fair, and >20% poor.

Table 27**.** Species enumerated during Wenatchee day and night snorkel surveys.

Code	Species Name	Common Name
1	Catostomus catostomus	longnose sucker
2	Catostomus columbianus	bridgelip sucker
3	Catostomus machrocheilus	largescale sucker
4	Catostomus playtrhynchus	mountain sucker
5	Catostomus/Rhinichthys sp.	unknown sucker/dace
6	Catostomus sp.	unknown sucker
7	Catostomus/Cyprinid sp.	unknown catostomid or cyprinid
8	Cottus bairdi	mottled sculpin
9	Cottus beldingi	Pauite sculpin
10	Cottus cognatus	slimy sculpin
11	Cottus confusus	shorthead sculpin
12	Cottus rhotheus	torrent sculpin
13	Cottus sp.	unknown sculpin
14	Unknown sp.	unknown fish
15	Gasterosteus aculeatus	three-spine stickleback
16	Oncorhynchus clarki	cutthroat trout
17	Oncorhynchus kisutch	coho salmon
18	Oncorhynchus mykiss	rainbow trout/steelhead
19	Oncorhynchus nerka	sockeye salmon
20	Oncorhynchus sp.	unknown Oncorhyncus sp.
21	Oncorhynchus tshawytscha	Chinook salmon
22	Prosopium williamsoni	mountain whitefish
23	Ptychocheilus oregonensis	northern pikeminnow
24	Rhinichthys cataractae	longnose dace
25	Rhinichthys falcatus	leopard dace
26	Rhinichthys osculus	speckled dace
27	Rhinichthys sp.	unknown dace
28	Rhinichthys umatilla	Umatilla dace
29	Richardsonius balteatus	redside shiner
30	Salvelinus confluentes	bull trout
31	Salvelinus fontinalis	brook trout
32	Salvelinus sp.	unknown Salvelinus sp.
33	Oncorhynchus clarki/mykiss hybrid	cutthroat/rainbow trout hybrid
34	Cyprinid sp.	unknown Cyprinind sp.
35	Juvenile Oncorhynchus clarki or mykis	uvenile cutthroat or rainbow trou

The CV attempts to make comparisons between variables by standardizing the measure of variation. The signal to noise ratio also allows for comparison among variables but describes the variability due to measurement error relative to the variability among sites. Thus, this measure provides a context with which to interpret variability when criteria to define "acceptable" values is lacking. If the variability due to measurement error is small relative to the variability among sites for a given protocol, then using that protocol will be effective in discerning differences among sites for a given metric. As a general guide, Kaufman et al. (1999) suggests that a signal to noise ratio >10 is very precise, a signal to noise ratio of 2-10 is of moderate precision, and signal to noise ratio <2 suggests that the protocol is not likely to be useful in discerning changes in the metric of interest.

In short, we caution that the use of simple descriptive statistics to estimate variance components decreases the ability to generalize results, which is an important consideration if one is attempting to use a case study to inform sampling designs for a larger universe of projects (i.e., one of the ISEMP's goals). As such, when employing an Analysis of Variance (ANOVA) one must carefully consider whether model components are random or fixed effects. If, for example, multiple crews are used to measure a variable at several sites, although commonly assumed to be fixed effects, we view this set of sites as a subset of the potential sites to be visited and a subset of the potential number of crews that might sample these sites, and thus both terms should be considered random effects. If assumed to be random effects then variance estimates are inflated to represent the larger scale being considered.

We partitioned the variance in this dataset as variability between sites and a combination of variability between repeat visits and unexplained variability, which we refer to as observation error (repeat visit + noise) and describe the residual term with sites and residuals as random components. We used SAS PROC MIXED to provide true estimates of the variability in mixed and random effects models (as opposed to SAS PROC GLM; Littell et al. 1996). Best Linear Unibased Predictors were used to estimate mean and standard error of each repeated site. From this we created 95% CIs, and coefficients of variation. The signal to noise ratio was estimated by dividing site variation by residual variation.

Results

Exploratory Data Analysis (EDA)

Based on simple exploratory techniques (Figure 56), it appears that the observed abundance of species 5 through 7 (*Catostomus spp*), 11 through 14 (*Cotus spp*), 16 through 22 (*Oncorhynchus spp*) and 29 (*Richardsonius spp*) exhibit diel patterns.

In order to determine whether the results varied by site or survey method we fit a model with the main effects; site and survey technique first, followed by time of survey, and species and generated an ANOVA (Table 28).

Table 28. ANOVA testing effect of day or night and species after fitting site and survey for snorkel survey data from the Wenatchee subbasin.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Site	7	214813	30688	0.2696	0.9655	
Survey	1	91466	91466	0.8036	0.3704	
Daynight	1	45304	45304	0.398	0.5284	

Species	30	10045903	334863	2.9421	5.6E-07	***
Residuals	532	60552014	113820			

***:Significance at alpha=0.001

The results of model two demonstrate that site and survey do not significantly influence the dependent variable (counts or observations). Thus we fit a second model with only species, day or night and species, and day and night interactions (equation 2).

$$FishCnt = \beta_0 + \beta_1 Q + \sum_{i=2}^{33} \beta_i (Species)_i + \sum_{i=34}^{65} \beta_i (Species)_i (Q) + \varepsilon \qquad (2)$$

Where Q = 0 and Q = 1 for nighttime and daytime counts, respectively. Testing the following hypotheses:

H_0: $\beta_1 = 0$ and/or $\beta_{34,}\ \beta_{35,\ldots\ldots}\ \beta_{65}=0$

H_A: $\beta_1 \neq 0$ and/or $\beta_{34,}\ \beta_{35,\ldots\ldots}\ \beta_{65}\neq 0$

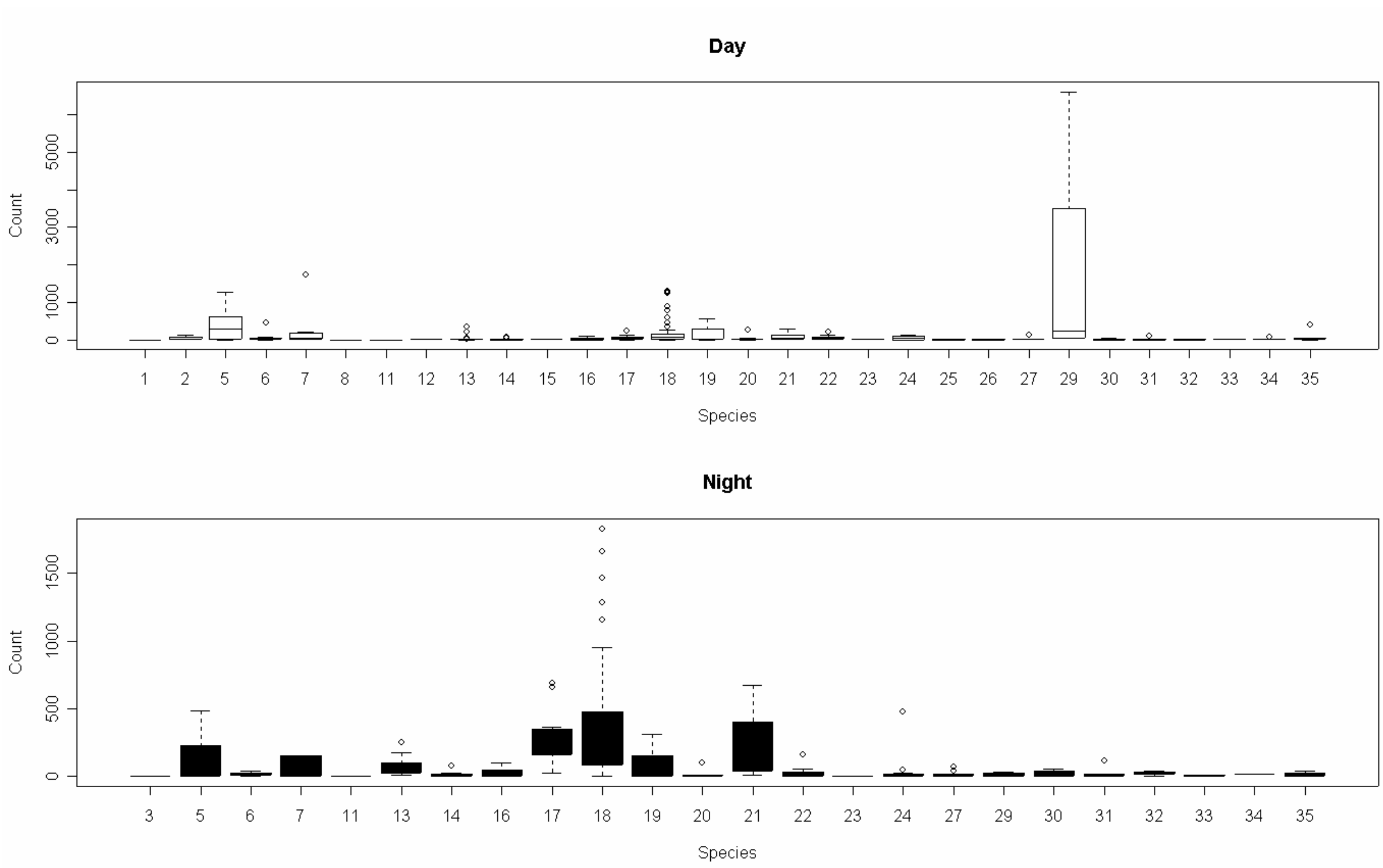

Figure 56. Number of enumerated fish of each species during day and night snorkel surveys in the Wenatchee subbasin.

In the second model species and the interaction were significant, thus the main effect (day/night, Table 29) was retained in the model (McCullagh and Nelder 1983, Netter et al. 1996). However the model fit and data were heavily skewed (outliers occur at larger observations) and the model is leptokurtic (more in the tails than expected, Figure 57); thus we fit a third model that utilized a log-linear structure (equation 3).

Table 29. ANOVA with only species and day night interactions from snorkel survey data collected in the Wenatchee subbasin.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Daynight	1	85310	85310	0.8397	0.3599	
Species	30	9956714	331890	3.2669	3.10E-08	***
Daynight:Species	22	8282480	376476	3.7057	4.74E-08	***
Residuals	518	52624997	101593			

***:Significance at alpha=0.001

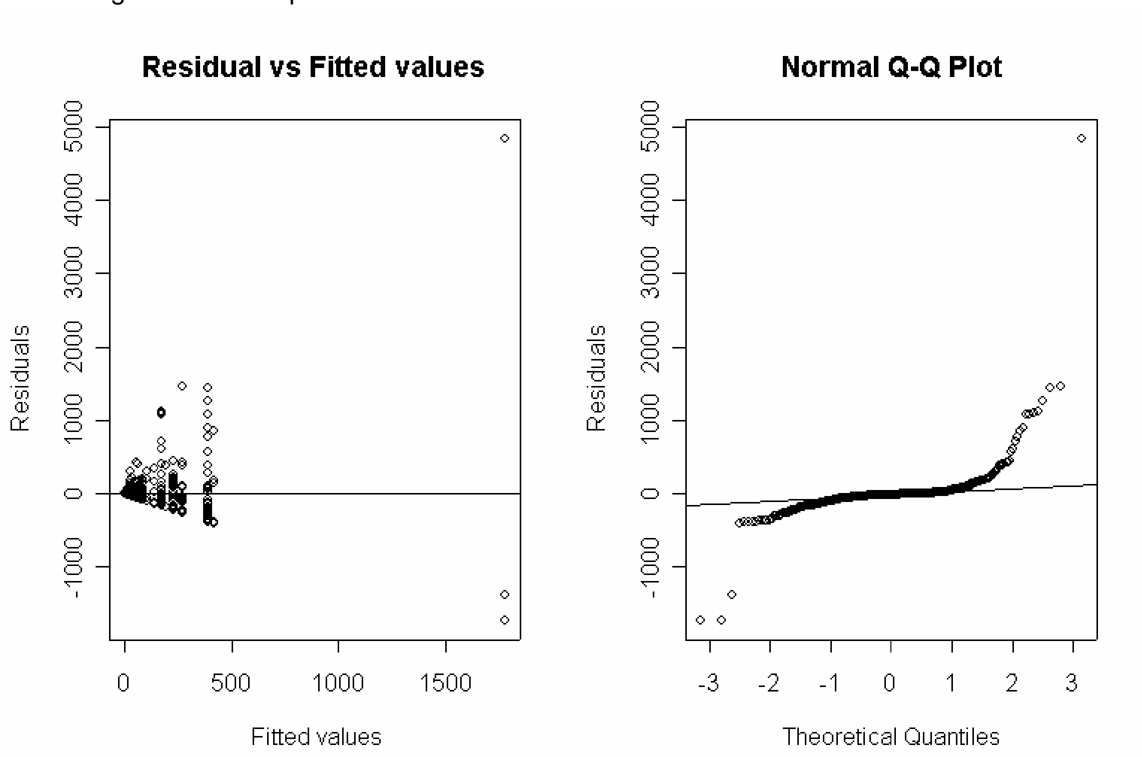

Figure 57. Residual diagnostics of model 2 from day and night snorkeling data from the Wenatchee subbasin.

Model three used the structure shown below:

$$\ln(FishCnt) = \beta_0 + \beta_1 Q + \sum_{i=2}^{33} \beta_i (Species)_i + \sum_{i=34}^{65} \beta_i (Species)_i (Q) + \varepsilon \qquad (3)$$

Where Q = 0 and Q = 1 for nighttime daytime surveys, respectively. Testing the following hypotheses:

H_0: $\beta_1 = 0$ and/or $\beta_{34,}$ $\beta_{35,}$…….. β_{65}=0

$\beta_1 \neq 0$ and/or $\beta_{34,}$ $\beta_{35,}$…….. $\beta_{65} \neq 0$.

The fit of model three was less skewed (Figure 58), and both the main and interaction effects were significant (Table 30).

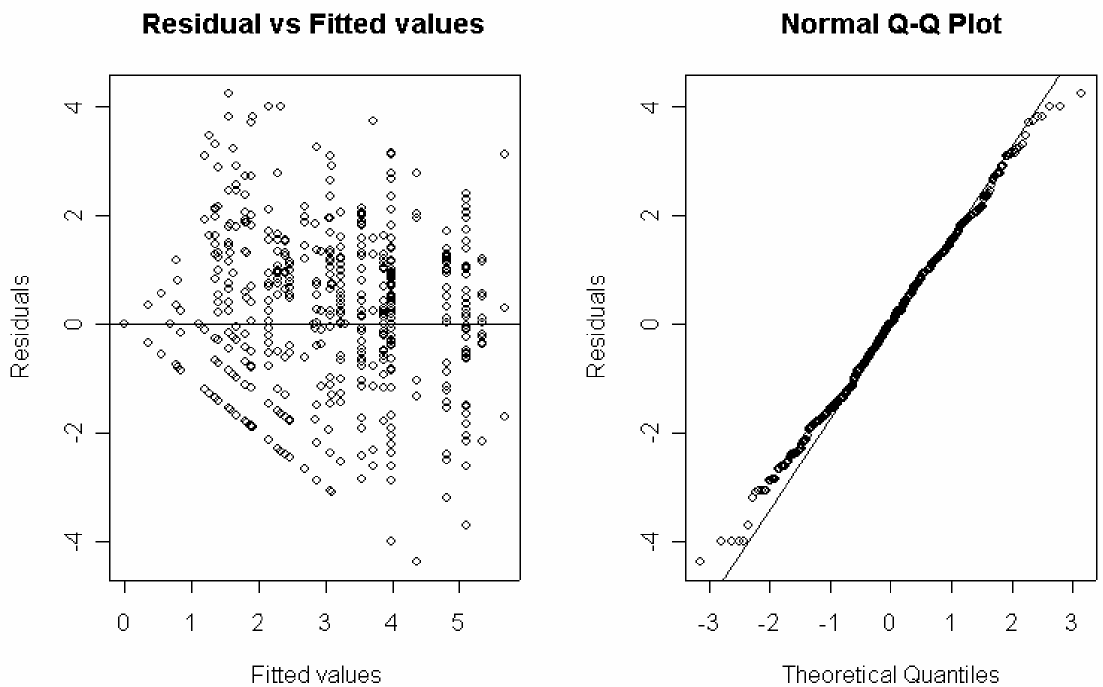

Figure 58. Residual diagnostics of model 3 from day and night snorkeling data from the Wenatchee subbasin.

Table 30. ANOVA on a log-linear model with species and day-night interaction using Wenatchee subbasin snorkeling survey.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Daynight	1	25.66	25.66	9.8891	0.001758	**
Species	30	745.83	24.86	9.583	<0.001	***
Daynight:Species	22	204.06	9.28	3.5753	1.22E-07	***
Residuals	518	1343.84	2.59			

** Significance at alpha=0.01

***Significance at alpha=0.001

Finally, because the data are counts, we evaluated a fourth model with a Poisson error structure; where:

$$LP = \beta_0 + \beta_1 Q + \sum_{i=2}^{33} \beta_i (Species)_i + \sum_{i=34}^{65} \beta_i (Species)_i (Q) + \varepsilon \qquad (4)$$

and LP is the linear predictor on our dependent variable (the log of fish counts). An Analysis of Deviance (ANODEV) was performed using GLM in R software with a Poisson model and a log-link (Table 31).

Table 31. ANODEV for model four in order fitted using a Poisson error structure and Log-link using day and night snorkel survey data collected in the Wenatchee subbasin.

Variables	Df	Deviance	Residual df	Residual dev	P(>|Chi|)
Daynight	571	180907			
Species	1	765	570	180142	2.63E-168
Daynight:Species	30	67268	540	112874	0
Residuals	22	20120	518	92754	0

Model 4 appears to be over-dispersed with a goodness-of-fit Chi square statistic (with 518 degrees of freedom) equaling zero**.** Therefore the model was tested using F-tests rather than Chi-square (Neter et. al. 1996, Dr. Loveday Conquest and Dr. John Skalski, University of Washington, Seattle, WA personal communication). Using an F-test (Table 32), the model fit appears similar to model two, although it is less leptokurtic (Figure 59).

Table 32. ANODEV for model four using an F-test on day and night snorkel data collected in the Wenatchee subbasin.

Variables	Df	Deviance	Resid df	Residual dev	F-stat	F-crit	Pr(>F)
Daynight	571	180907					
Species	1	765	570	180142	2.42	5.05	0.24
Daynight:Species	30	67268	540	112874	10.73	1.59	0.00
Residuals	22	20120	518	92754	5.11	1.21	0.00

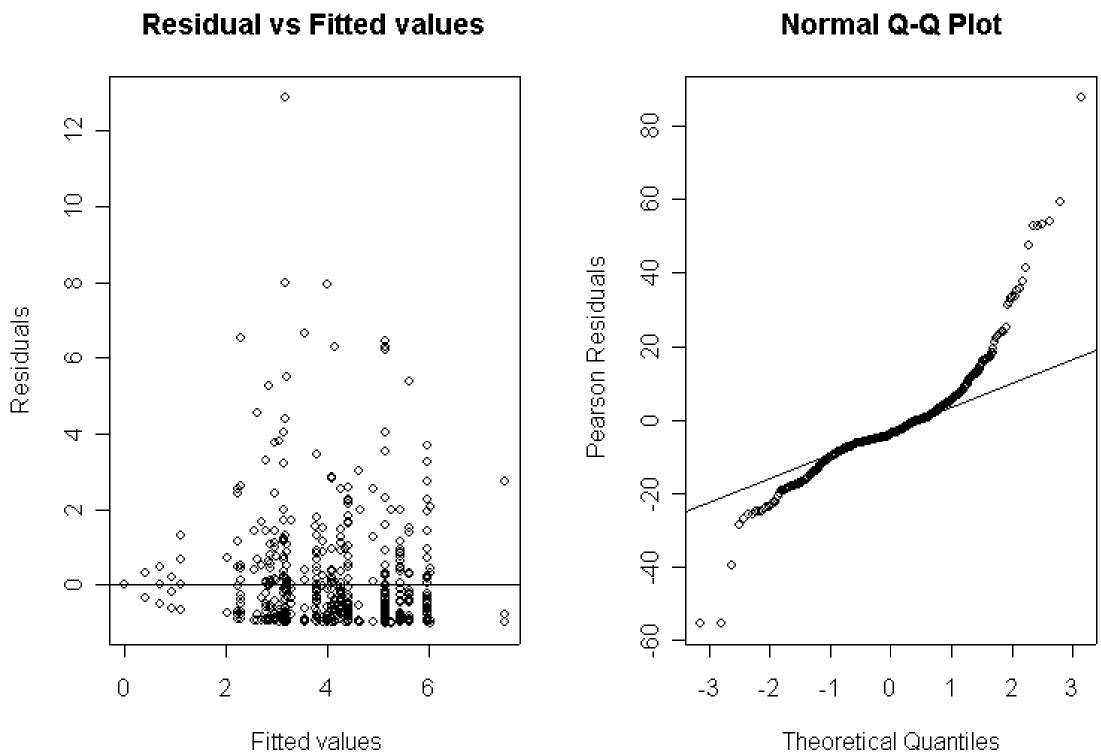

Figure 59. Residual diagnostics of model four from analysis of day and night snorkel data collected in the Wenatchee subbasin.

Nearly all estimates of fish abundance for snorkel surveys for total salmonids were higher at night than in the day, resulting in an R = 0.8 (Figure 60). Confidence intervals surrounding snorkel count estimates were large for both overall mean (Table 33) and mean by repeated site (Figure 61). Both the CV and the signal to noise ratio to suggests that variables are of moderate precision, with nighttime snorkel estimates being more precise and higher signal to noise ratio.

Table 33. The variance estimates across sites and residual comprised of variability between repeat visits and unexplained random error.

Survey Type	Site Variance	Residual Variation (Repeat + Unexplained)	Degrees of Freedom	Mean Estimate	Upper 95% CI	Lower 95% CI	Coefficient of Variation	Signal: Noise Ratio
Daytime	2.042	0.576	3	217.21	924.75	51.02	13.74	3.545
Nighttime	1.55	0.324	3	632.72	2210.92	181.07	9.9	4.789

Note: variance estimates are in ln values based on four repeat visits to four sites. Mean of estimates across sites and confidence intervals are back-transformed. CV and signal to noise ratios are provided.

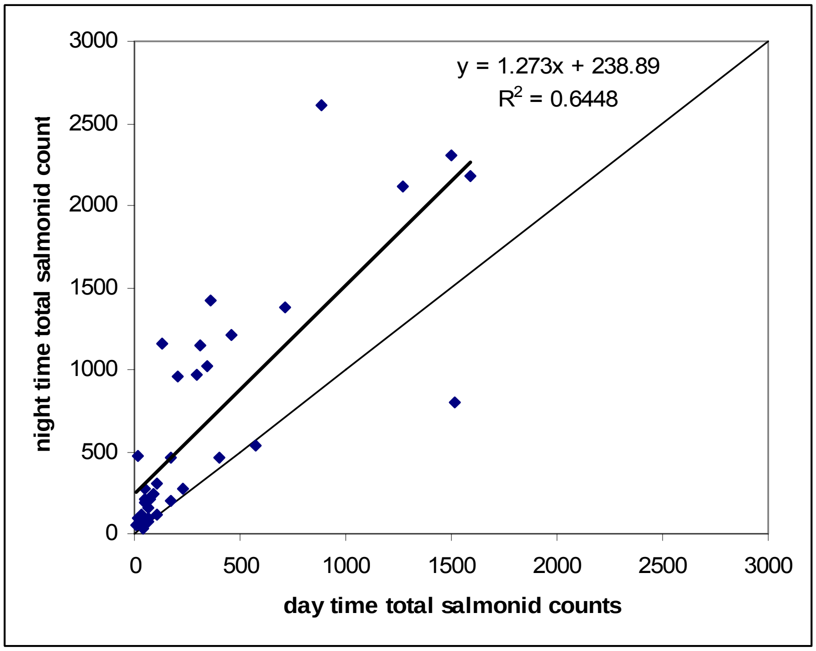

Figure 60. The relationship between total salmonids counted in daytime versus nighttime snorkel surveys from the Wenatchee subbasin. Thin diagonal line represents 1:1 line.

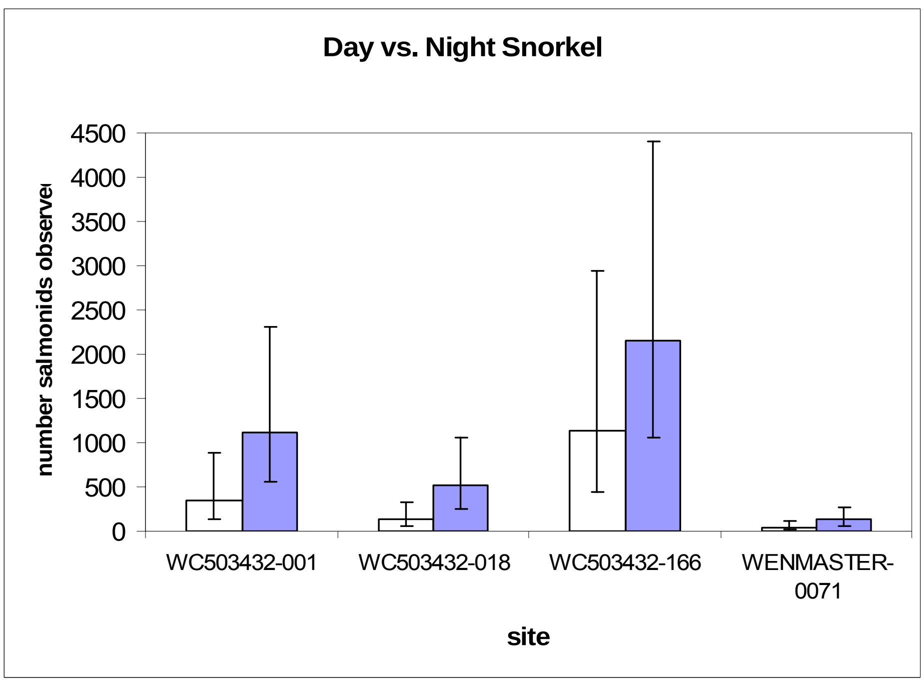

Figure 61. Daytime (open) and nighttime (shaded) estimates of number of total salmonids at 4 sites from day and night snorkel surveys in the Wenatchee subbasin. Means and confidence intervals are predicted from random effects model.

Conclusion/ Discussion

Of the four GLM models tested, a log-linear error structure provided the best fit to the data. However, as demonstrated by these preliminary analyses, interpretation using only a single metric of precision can be misleading. Therefore, we recommend that protocols be evaluated with all three metrics. In general, the highest precision is achieved when CI (%CI) and coefficients of variation are small and the signal to noise ratio is high. If the CI (%CI) and coefficients of variation are large and the signal to noise ratio is small, then the protocol is likely imprecise. However, under some circumstances, all three metrics may not agree and interpretation becomes less straightforward. For example, the CI or the % CI may appear large, yet the signal to noise ratio will also be large, perhaps driven by an imprecise estimate of site distribution, and hence an imprecise estimate of the CI or %CI. As stated above, a high signal to noise ratio would suggest that relative to other sources of variability, the measurement error is small. However, when the CI or %CI is large and the signal to noise ratio is large, we urge caution when interpreting the signal to noise ratio, since it may be driven by large differences among sites while differences within a given stream may be small. Documenting very small changes over time within a stream with a given protocol may be difficult if measurement error is large relative to the mean. Conversely, if the CI or % CI is small and the signal to noise ratio is small, then the precision of a given protocol may be high but the contrast between different streams is small.

Decomposing Site Specific Variability on Fish count data: A Primer using the Wenatchee Data

IMW data have been collected in the Wenatchee River watershed at various locations. In this analysis we attempt to organize the variation in fish count data by site and species, and then explain the variability in fish count data for one species, juvenile Chinook salmon (*Oncorhynchus tshawytscha*). In this manner, we demonstrate how some of the information collected over the past few years can be used to explain variability in fish counts. However, some caveats are identified as the sites are not collected using a balanced design, thus the data are essentially observational in nature.

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Time Line

Data collection has occurred during fiscal years 2005 and 2006, and will be continued during the fiscal years 2007 – 2009 contract period. Preliminary analyses have been performed and are expected to be complete during fiscal year 2007. At that time, a more complete design for data collection will be constructed. A final analysis of the protocols is expected in fiscal year 2008.

What's been accomplished so far

Based on the analysis in the previous section and this section, we show that there is a large amount of variability in juvenile fish abundance among the 45 sites sampled on the Wenatchee. In the previous section an analytical approach for assessing variation across sites in species abundance based on whether sampling was conducted during the day or at night was presented. In this section, methods demonstrating the variability across species and sites are developed, additional analyses focusing on juvenile Chinook salmon abundance and the use of GIS based data metrics or direct stream reach (site) specific metrics to parse variation are also presented. Based on the initial analysis (GIS) geological code (region in the Columbia Basin), valley bottom gradient, basin relief, and valley bottom-geological region interactions are useful in predicting abundance ($r^2 = 0.78$). Of the directly sampled measures, we found that bankfull width, percent deciduous canopy cover and percent coarse gravel are important in determining abundance ($r^2 = 0.66$). Including both GIS and direct measures gave the best result, with all the GIS variables from the initial analysis, and percent deciduous canopy cover, and deciduous canopy cover-geological region interaction ($r^2 = 0.91$) terms included in the final model.

The approach presented here is a tool to show how we can predict abundance as a function of available data. However, because the experimental design that guided the collection of these data was not constructed to address these specific objectives; inferential power is limited. This is essentially an observational study that incorporates some of the available data and explains site-specific variability as a function of some GIS and direct sample estimates.

Fluctuations in abundance over time should be taken into account when using these models because they are influenced by temporal and spatial variability in fish behavior, elements of which, such as distribution, have a non-random biologically-based component. It should also be noted that the data used here are also a function of spawner cohort strength, which is not included in this analysis.

Materials and Methods

We summarized the Wenatchee snorkel data by site and species and whether sampling was conducted during the day (1) or night (0) (Table 34 and Table 35, respectively). Counts are either a function of a single or multiple site visit, with multiple visits corrected to represent the average count over all visits. In addition, where multiple surveys were conducted we present the CV across day-time or night time surveys (Table 36 and Table 37).

We used exploratory data analysis techniques to demonstrate species variation by site. Based on those results we constructed a model from the previous analysis with site as a covariate in order to further decompose the variance. Since both the number of sites represented in day and night counts and the number of visits in each site were unbalanced, the order in which variables were introduced into the analysis was important.

The model used was:

$$\ln(FishCnt) = \beta_0 + \sum_{i=1}^{45} \beta_i Site_i + \beta_{46} Q + \sum_{i=47}^{79} \beta_i (Species)_i + \sum_{i=80}^{112} \beta_i (Species)_i (Q) + \varepsilon \qquad (1)$$

Where Q = 0 and Q = 1 for nighttime and daytime surveys, respectively. The following hypotheses were tested:

H_0: $\beta_{46} = 0$ and/or $\beta_{47,}\, \beta_{48,}\ldots\ldots\ \beta_{112}=0$

H_A: $\beta_{46} \neq 0$ and/or $\beta_{47,}\, \beta_{48,}\ldots\ldots\ \beta_{112}\neq 0$

Table 34. Average species count across site for daytime surveys.

SiteName	CACA	CACO	CARHSP	CASP	CC	COBA	COCON	CORH	COSP	CYPR	FISH	GAAC	JCTRB	ONCL	ONHY	ONKI	ONMY	ONNE	ONSP	ONTS	PRWI	PTOR	RHCA	RHFA	RHOS	RHSP	RIBA	SACO	SAFO	SASP
WC503432-001				4					5	45						47	197			145	17					2				
WC503432-002														41	2															
WC503432-006														1			138											32		
WC503432-011				2					2							1	266			30			8							
WC503432-015														44															1	
WC503432-017																	144			41	83									
WC503432-018			583	42	200						15					124	34	2		28	23									
WC503432-021		16	28	18	13	1			20		73			1		7	55		13	257	45	2	62	1		2	53			
WC503432-029																	89													
WC503432-032					150				1	14			402			1	17		49	8			1			2				
WC503432-038																	23			77	75							3		
WC503432-043														66																
WC503432-046											1			3.5			46		3									3		
WC503432-049									55		11						10												17	
WC503432-152																	81													
WC503432-155									3		14			2		1	911			279										
WC503432-166					4		1		3		4.5		47			88	721			125	47		1						1	1
WENMASTER-0008																	52													
WENMASTER-0011																				22	9									
WENMASTER-0012														92																
WENMASTER-0020																	110													
WENMASTER-0021		3	1277	462	1744			3	15		7	27				41	24		40	2	104		126			4	6606			
WENMASTER-0030	1	111	21	1	19				329		5					1	92		3	144	198	13	49	2	3	4	391			
WENMASTER-0039			1	12	53				2		1						4	568		2	42									
WENMASTER-0042				30	3				21		35					25	334	1	2	12	124		94		1	129	53			
WENMASTER-0045																	222		1											
WENMASTER-0050											7			1			126		2				107							
WENMASTER-0052														2															107	
WENMASTER-0054																	129			39	61							1		
WENMASTER-0055									7		2						1		1	16	2									
WENMASTER-0060											1		26	31			1													
WENMASTER-0071							1		2		3		1	1			20			17	4							11	1	5
WENMASTER-0093																	41													
WENMASTER-0099											1			4														33		
WENMASTER-0100														1			134		268									1		
WENMASTER-0148																	172													
WENMASTER-0151														11																
WENMASTER-0152														5			6		4									2		
WENMASTER-0164											2						89											1		
WENMASTER-0195									1		1						24			5									2	
WENMASTER-0231									2					1			1													
WENMASTER-0237																	69													
WENMASTER-0246									28								3												28	
WENMASTER-0266									213								111											1	28	
WENMASTER-0269																	225													
Avg Cnt over all visits	1	43	416	63	273	1	1	3	24	26	10	27	100	19	2	59	173	190	35	82	45	8	50	2	2	24	1776	9	17	3

Table 35. Average species count across site for nighttime surveys in the Wenatchee subbasin.

SiteName	CAMA	CARHSP	CASP	CC	COCON	COSP	CYPR	FISH	JCTRB	ONCL	ONHY	ONKI	ONMY	ONNE	ONSP	ONTS	PRWI	PTOR	RHCA	RHSP	RIBA	SACO	SAFO	SASP
WC503432-001			25			32	17					172	453			440	9.6		47	22	16			
WC503432-002										97	7													
WC503432-006													151									51		
WC503432-011						8							37			10			22					
WC503432-015										69														
WC503432-018		200	17			34		26				416	119	1		129	34		1	5				
WC503432-032			2	150	1	45						24	521			132	1		6.5	70				
WC503432-046									1	2			64									1		
WC503432-155						38							443			126								
WC503432-166		3.5	1		3	143			40	1		290	1267		53	367	31		5.5	7.3	1	2	1	
WENMASTER-0008													192											
WENMASTER-0020													310											
WENMASTER-0039	2	151	19	3	3	59		23		1			21	308	4	202	161	1	4	1	18	1		
WENMASTER-0045										1			268											
WENMASTER-0050								3		1	3		1158						479	5				
WENMASTER-0052										4													116	
WENMASTER-0055					2	150		1					4			425	29					41		
WENMASTER-0060									10	63														
WENMASTER-0071					3	99		1	1				62			38	2.8					38	1	29
WENMASTER-0099										5												29	1	
WENMASTER-0100								3			1		459		1							3		
WENMASTER-0148													458											
WENMASTER-0152										32	1		12		10							39		
WENMASTER-0164													241									3		
WENMASTER-0195					3	48			23	1			26		7	36						6	18	2
WENMASTER-0237													161											
Avg Cnt over all visits	2	137	18	77	3	71	17	14	15	23	3	272	392	103	21	227	25	1	53	16	13	23	23	20

Table 36. Coefficients of variations where multiple counts are available for day counts from the Wenatchee subbasin.

SiteName	CACA	CACO	CARHSP	CASP	CC	COBA	COCON	CORH	COSP	CYPR	FISH	GAAC	JCTRB	ONCL	ONHY	ONKI	ONMY	ONNE	ONSP	ONTS	PRWI	PTOR	RHCA	RHFA	RHOS	RHSP	RIBA	SACO	SAFO	SASP
WC503432-001				###					0.7	0.9						0.6	0.6			0.5	0.8					###				
WC503432-002														###	###															
WC503432-006														###			###											###		
WC503432-011				###					###							###	###			###			###							
WC503432-015														0.1															0	
WC503432-017																	###			###	###									
WC503432-018			0.06	0.5	####						###					0.9	0.8	###		0.9	0.4									
WC503432-021		###	####	###	####	###			###		###			###		###	###		###	###	###	###	###	###		###	####			
WC503432-029																	0													
WC503432-032					####				0.4	0.6			#####			###	1.3		###	1			###			###				
WC503432-038																	###			###	###							###		
WC503432-043														###																
WC503432-046											###			0.2			0.5		###									###		
WC503432-049									###		###						###												###	
WC503432-152																	0													
WC503432-155									0		###			###		###	0.5			0.1										
WC503432-166					####		###		0.5		0.5		#####			0.2	0.8			0.8	0.6		0.0						0.0	###
WENMASTER-0008																	0.1													
WENMASTER-0011																				###	###									
WENMASTER-0012														###																
WENMASTER-0020																	###													
WENMASTER-0021		###	####	###	####			###	###		###	###				###	###		###	###	###		###			###	####			
WENMASTER-0030	###	###	####	###	####				###		###					###	###		###	###	###	###	###	###	###	###	####			
WENMASTER-0039			####	###	####				###		###						###	###		###	###									
WENMASTER-0042				###	####				###		###					###	###	###	###	###	###		###		###	###	####			
WENMASTER-0045																	0		###											
WENMASTER-0050											###			###			###		###				###							
WENMASTER-0052														###															###	
WENMASTER-0054																	###			###	###							###		
WENMASTER-0055									###		###						###		###	###	###									
WENMASTER-0060											###		1.081	0.4			###													
WENMASTER-0071							###		0.4		0.7		#####	###			0.8			0.5	0.7							0.7	0.0	###
WENMASTER-0093																	###													
WENMASTER-0099											###			###														###		
WENMASTER-0100														###			###		###									###		
WENMASTER-0148																	###													
WENMASTER-0151														###																
WENMASTER-0152														###			###		###									###		
WENMASTER-0164											###						###											###		
WENMASTER-0195									###		###						###			###									###	
WENMASTER-0231									###					###			###													
WENMASTER-0237																	0.1													
WENMASTER-0246									###								###												###	
WENMASTER-0266									###								###											###	###	
WENMASTER-0269																	###													

Variance undeterminded due to 1 visit only

Table 37. Coefficients of variation where multiple counts are available for night counts from the Wenatchee subbasin.

SiteName	CAMA	CARHSP	CASP	CC	COCON	COSP	CYPR	FISH	JCTRB	ONCL	ONHY	ONKI	ONMY	ONNE	ONSP	ONTS	PRWI	PTOR	RHCA	RHSP	RIBA	SACO	SAFO	SASP
WC503432-001			0.44			0.3	###					0.2	0.502			0.3	1		###	0.6	1.3			
WC503432-002										###	###													
WC503432-006													#####									###		
WC503432-011						###							#####			###			###					
WC503432-015										###														
WC503432-018		1.2	0.68			0.7		1.7				0.7	0.627	0		1.2	0.4		###	0.8				
WC503432-032			####	###	####	0.9						###	1.167			1.1	0		0.5	###				
WC503432-046									###	###			0.612									###		
WC503432-155						0.9							0.727			0								
WC503432-166		0.6	####		####	0.6			###	###		0.3	0.541		1.3	0.3	0.6		0.8	0.8	###	###	###	
WENMASTER-0008													#####											
WENMASTER-0020													#####											
WENMASTER-0039	###	###	####	###	####	###		###		###			#####	###	###	###	###	###	###	###	###	###		
WENMASTER-0045										###			#####											
WENMASTER-0050								###		###	###		#####						###	###				
WENMASTER-0052										###													###	
WENMASTER-0055					####	###		###					#####			###	###					###		
WENMASTER-0060									###	###														
WENMASTER-0071					####	0.5		###	###				0.689			0.6	0.8					0.4	0	0.3
WENMASTER-0099										###												###	###	
WENMASTER-0100								###			###		#####		###							###		
WENMASTER-0148													#####											
WENMASTER-0152										###	###		#####		###							###		
WENMASTER-0164													#####									###		
WENMASTER-0195					####	###			###	###			#####		###	###						###	###	###
WENMASTER-0237													#####											

Variance undeterminded due to 1 visit only

Results

Exploratory Data Analysis on Site abundances

Site-specific numbers (Table 38) were used to describe the variation in counts (abundance) across species (31) and across sites (45) in the following graphs (Figure 62 and Figure 63).

Table 38. Site-specific numbers used in exploratory data analysis on site abundances.

SiteName	Site No
WC503432-001	1
WC503432-002	2
WC503432-006	3
WC503432-011	4
WC503432-015	5
WC503432-017	6
WC503432-018	7
WC503432-021	8
WC503432-029	9
WC503432-032	10
WC503432-038	11
WC503432-043	12
WC503432-046	13
WC503432-049	14
WC503432-152	15
WC503432-155	16
WC503432-166	17
WENMASTER-0008	18
WENMASTER-0011	19
WENMASTER-0012	20
WENMASTER-0020	21
WENMASTER-0021	22
WENMASTER-0030	23
WENMASTER-0039	24
WENMASTER-0042	25
WENMASTER-0045	26
WENMASTER-0050	27
WENMASTER-0052	28
WENMASTER-0054	29
WENMASTER-0055	30
WENMASTER-0060	31
WENMASTER-0071	32
WENMASTER-0093	33
WENMASTER-0099	34
WENMASTER-0100	35
WENMASTER-0148	36
WENMASTER-0151	37
WENMASTER-0152	38
WENMASTER-0164	39
WENMASTER-0195	40
WENMASTER-0231	41
WENMASTER-0237	42
WENMASTER-0246	43
WENMASTER-0266	44
WENMASTER-0269	45

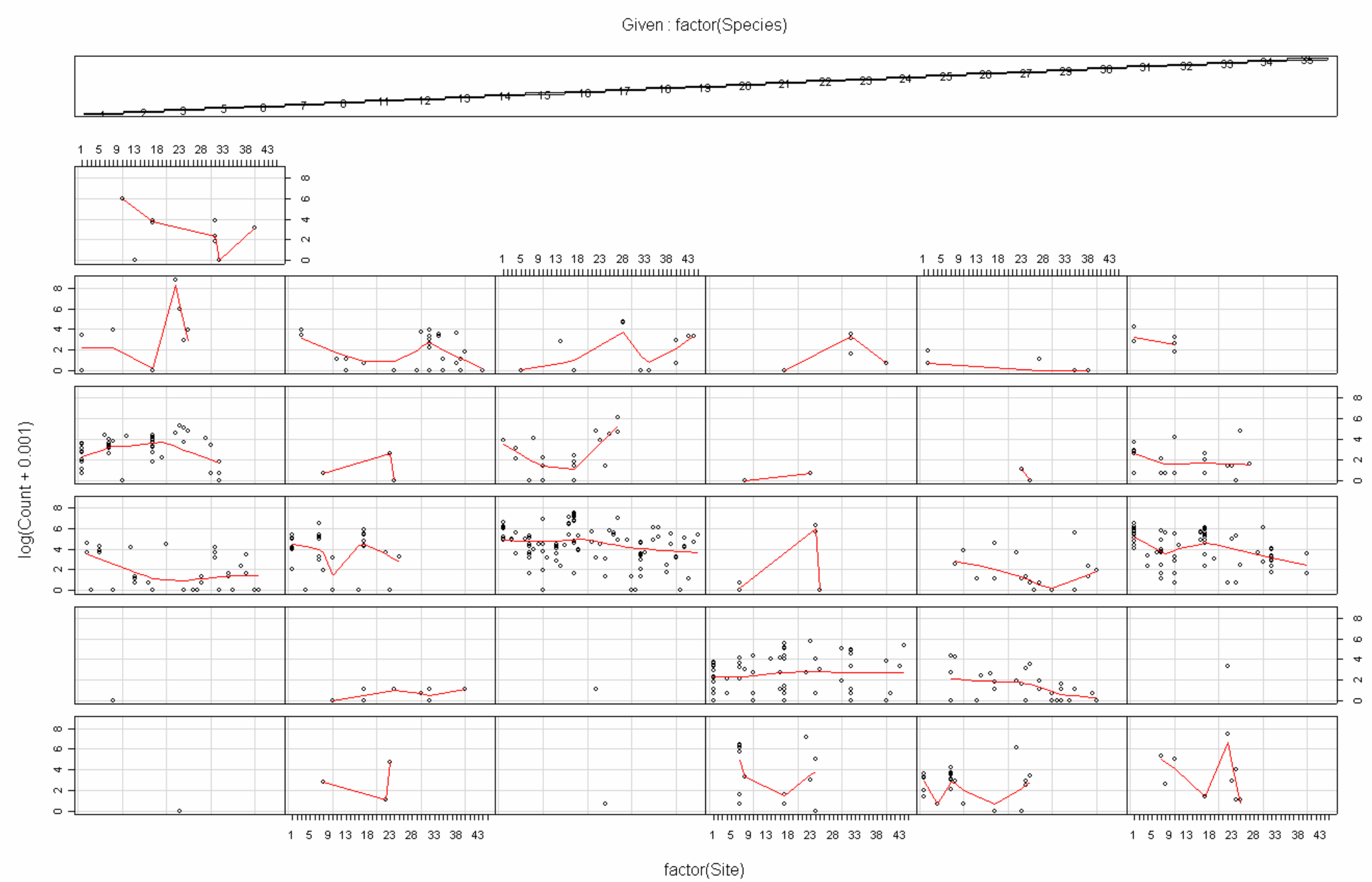

Figure 62. Variation in counts (y-axis) across sites (x-axis) and species (separate panels where description of species is given in previous section Table 27, Note species 4, 9, 10, and 28 are absent across all sites).

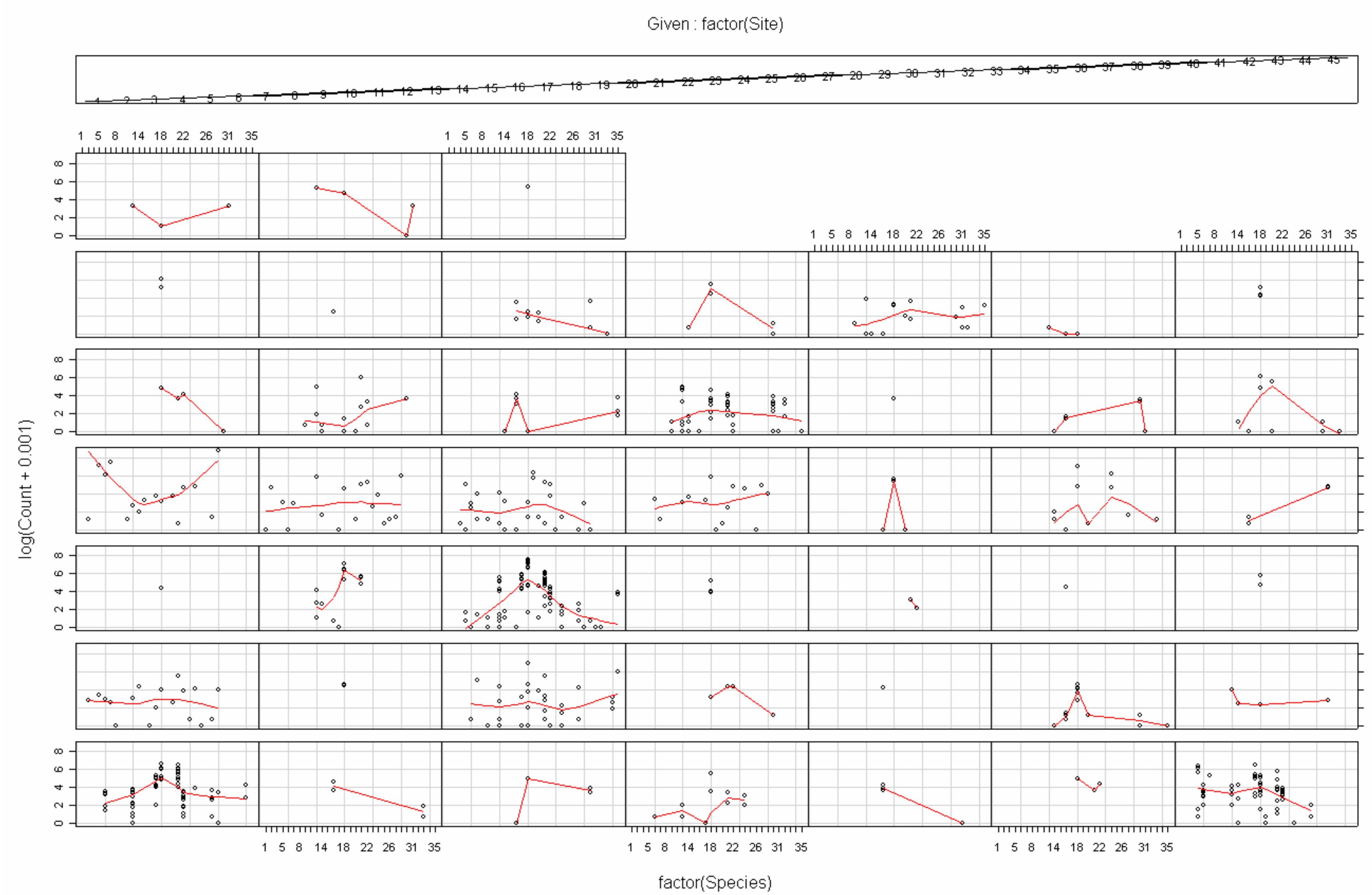

Figure 63. Variation in counts (y-axis) across species (x-axis) and site (separate panels where description of site is given in Table 38).

Based on Figures 62 and 63, we observe species variation is quite constant for some species across site (*Oncorhynchus clarki, O. nerka* and *Oncorhynchus spp*.; Figure 62), and is quite different for others (species *Rhinichthys cataractae*, *Salvelinus confluentus* , *Salvelinus fontinalis*, and *Salvelinus sp*.; Figure 62). However, Figure 63 illustrates species richness is a function of site, with a greater number of species present at some sites as opposed to others. This suggests that some sites have attributes that are more favorable to multiple species and/or that the attributes of some sites improve the fish visibility. When the site-specific information is parsed by different strata (day or night; Figures 62 and 63, respectively), the interaction between species, site and observation becomes important. The most obvious fact that becomes apparent is that fewer sites have nighttime surveys. However, in cases that we do we have nighttime surveys, more fish are observed (in sites 17 and 24, for example). This result is not surprising given the results of the previous analysis.

When we developed an ANOVA with site as a covariate and the log-response model (that gave the best fit from the previous section) the results indicate that all three factors are important in the observed count (Table 39). This was a common trend regardless of the order in which the variables were introduced in the analysis. In addition, the day-night interaction with species was significant regardless of the order in which variables were introduced; although the sums of squares changed depending on the order (Table 40).

Table 39. An ANOVA testing for the effect of site, day or night and species on data collected in the Wenatchee subbasin.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Site	44	318.98	7.25	2.7413	6.65E-08	***
Daynight	1	40.17	40.17	15.1898	0.0001106	***
Species	30	647.96	21.6	8.1673	< 2.20E-16	***
Residuals	496	1311.69	2.64			

***:Significance at alpha=0.001

Table 40. ANOVA testing effect of day night interactions after adding the main effects from Table 39.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Site	44	318.98	7.25	2.9815	5.15E-09	***
Daynight	1	40.17	40.17	16.5207	5.68E-05	***
Species	30	647.96	21.6	8.8829	< 2.20E-16	***
Site:Daynight	25	36.06	1.44	0.5933	0.9422	
Species:Daynight	22	183.89	8.36	3.4377	3.94E-07	***
Residuals	449	1091.73	2.43			

Residual diagnostics of the model including the significant interaction term are shown in Figure 64. There appears to be minimal skew in the model and no clear pattern in the residuals.

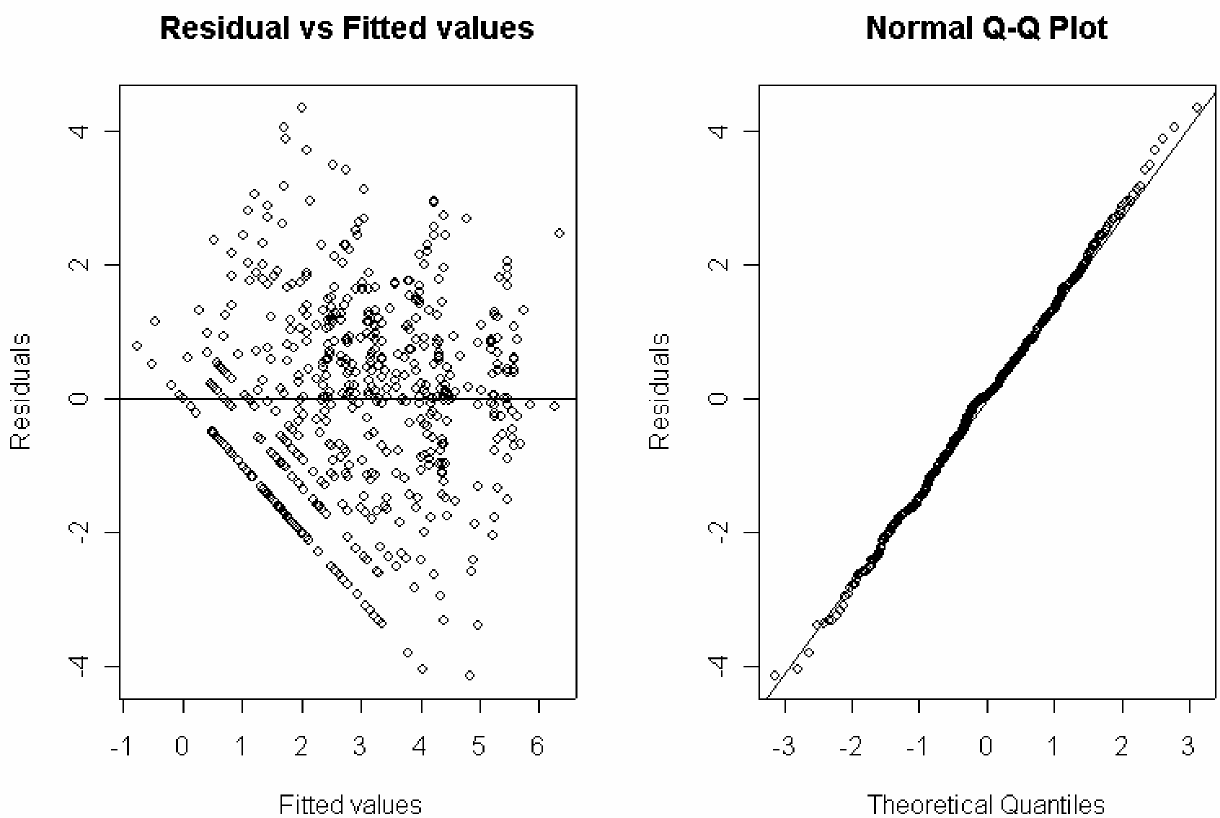

Figure 64. Residual diagnostics of the final model with species (day:night) interactions.

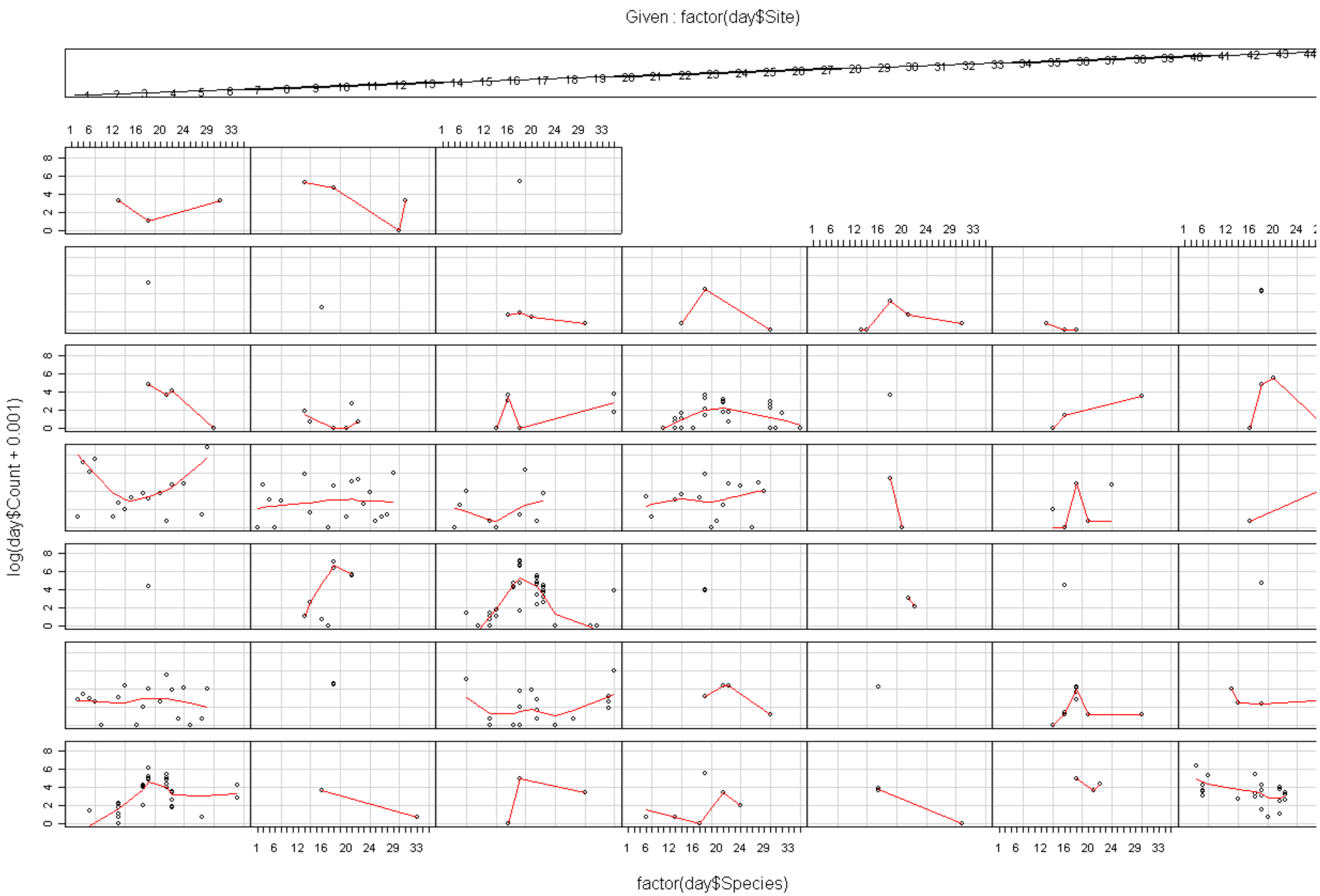

Figure 65. Variation in counts (y-axis) across species (x-axis) and site as a function of daytime survey (separate panels where description of site is given in Table 38).

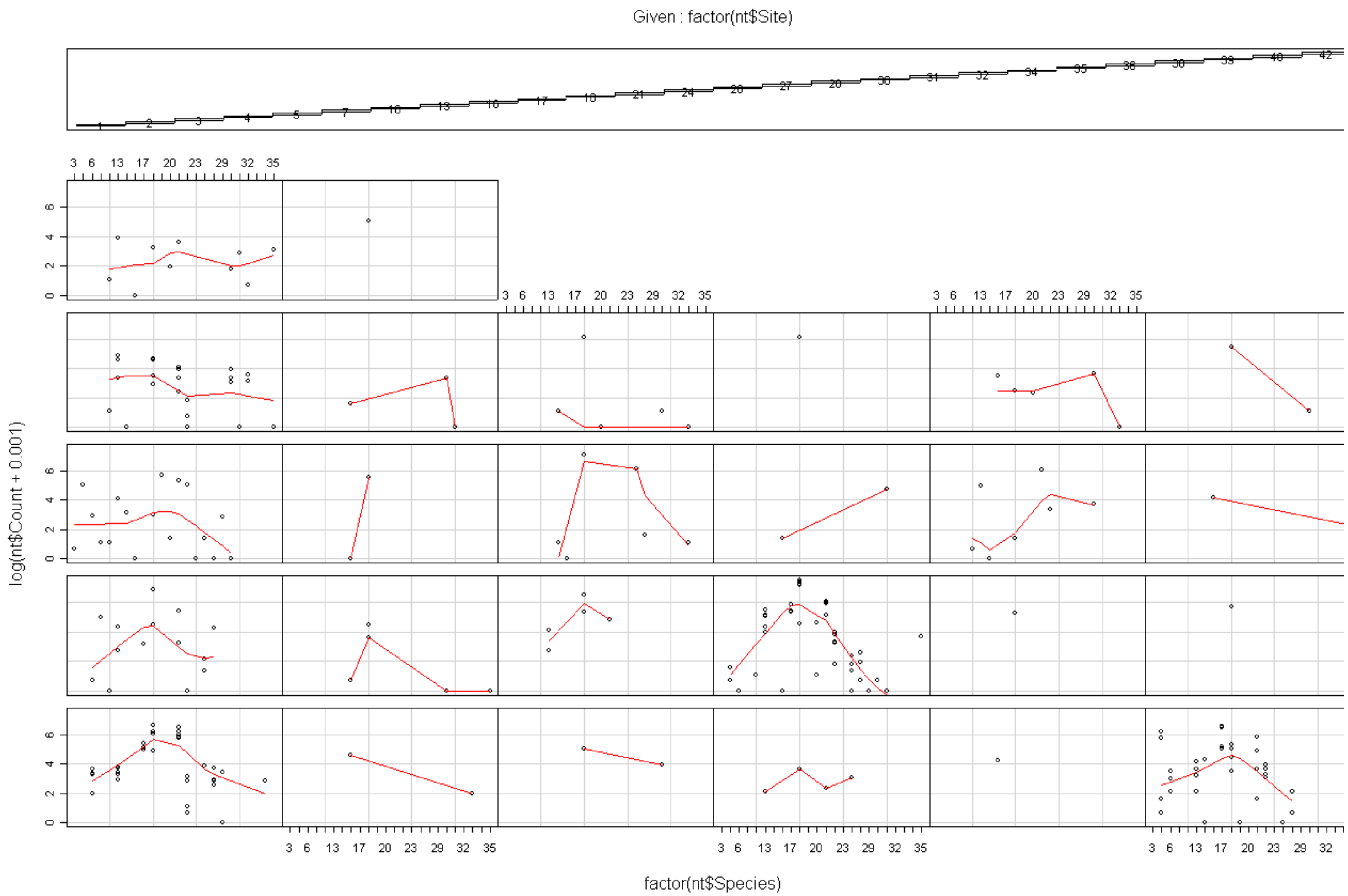

Figure 66. Variation in counts (y-axis) across species (x-axis) and site as a function of nighttime survey (separate panels where description of site is given in Table 38).

Fish Abundance as Function of Site specific Covariates

Given that few sites had repeat visits, and that variation within sites is high (Tables 39 and 40), analyzing fish density or abundance estimates as a function of site specific covariates is statistically limited. We used juvenile Chinook salmon to develop techniques, and focused across sites and daytime counts as a function of habitat attributes in an attempt to explain that variability as a function of habitat characteristics. Bias corrections could be made to these estimates depending on whether day or nighttime counts are the dependent variable. However, since habitat characteristics vary from GIS attributes to specific channel characteristics, we focused on 2 separate analyses: 1) with only GIS attributes, and 2) with direct measures of habitat characteristics.

GIS Based Attribute Analysis

We used a simple explanatory model to decompose fish count data on one species, juvenile Chinook salmon. The models are shown below:

$$\ln(FishCnt) = \beta_0 + \sum_{i=1}^{16} \beta_i G[I] + \varepsilon \qquad (2)$$

We looked at 16 different GIS along with interactions with the categorical variables shown below:

- Ecological Region (Categorical)
- Geological Region (Categorical)
- Basin Area
- Basin Relief
- Drainage Density
- Stream Order (Categorical)
- Naiman Valley Bottom (VB) type (Categorical)
- Valley Bottom Gradient
- Road density
- Riparian Road Index
- Elevation
- Rosgen Channel Type (Categorical)
- Mean Channel Gradient

Species pe (Categorical)

- Entrenchment Ratio
- Sinuosity

Exploratory Data Analysis on GIS Based attributes

Simple exploratory data analysis suggests that certain variables coincide with higher fish abundance; namely, ecoregion 2 and 4, and geographical regions 2, 3, and 5 appear more likely to have higher fish abundances. In addition, stream order types 3 and 4 coincide with a higher likelihood of juvenile Chinook salmon observations. Juvenile Chinook salmon were observed more commonly in Naiman valley type 2, 6 and 11 as are Rosgen Type 3 channels, and bedform types 5 and 6 (Figure 67).

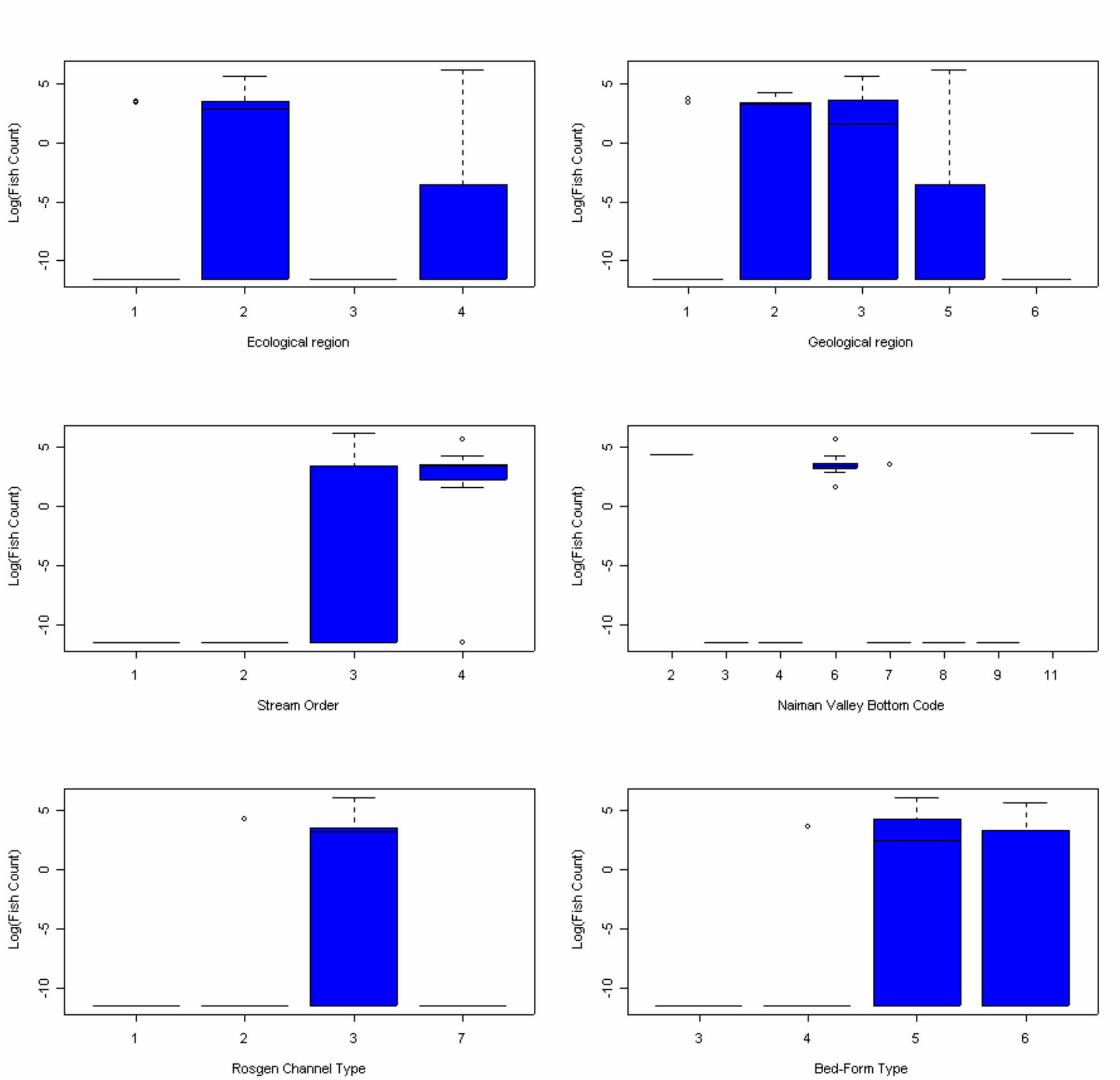

Figure 67. Chinook abundance by different categorical GIS variables.

Lower valley gradient, lower channel gradient, lower elevation, larger basin and larger basin relief tend to have a higher incidence of juvenile Chinook (Figure 68). In addition, juvenile Chinook salmon observations increased as channel complexity increased (e.g., greater sinuosity).

Based on the exploratory data analysis, we constructed a model using geological region as the main effect and then adding covariates; including basin relief, channel gradient, and elevation (Table 41).

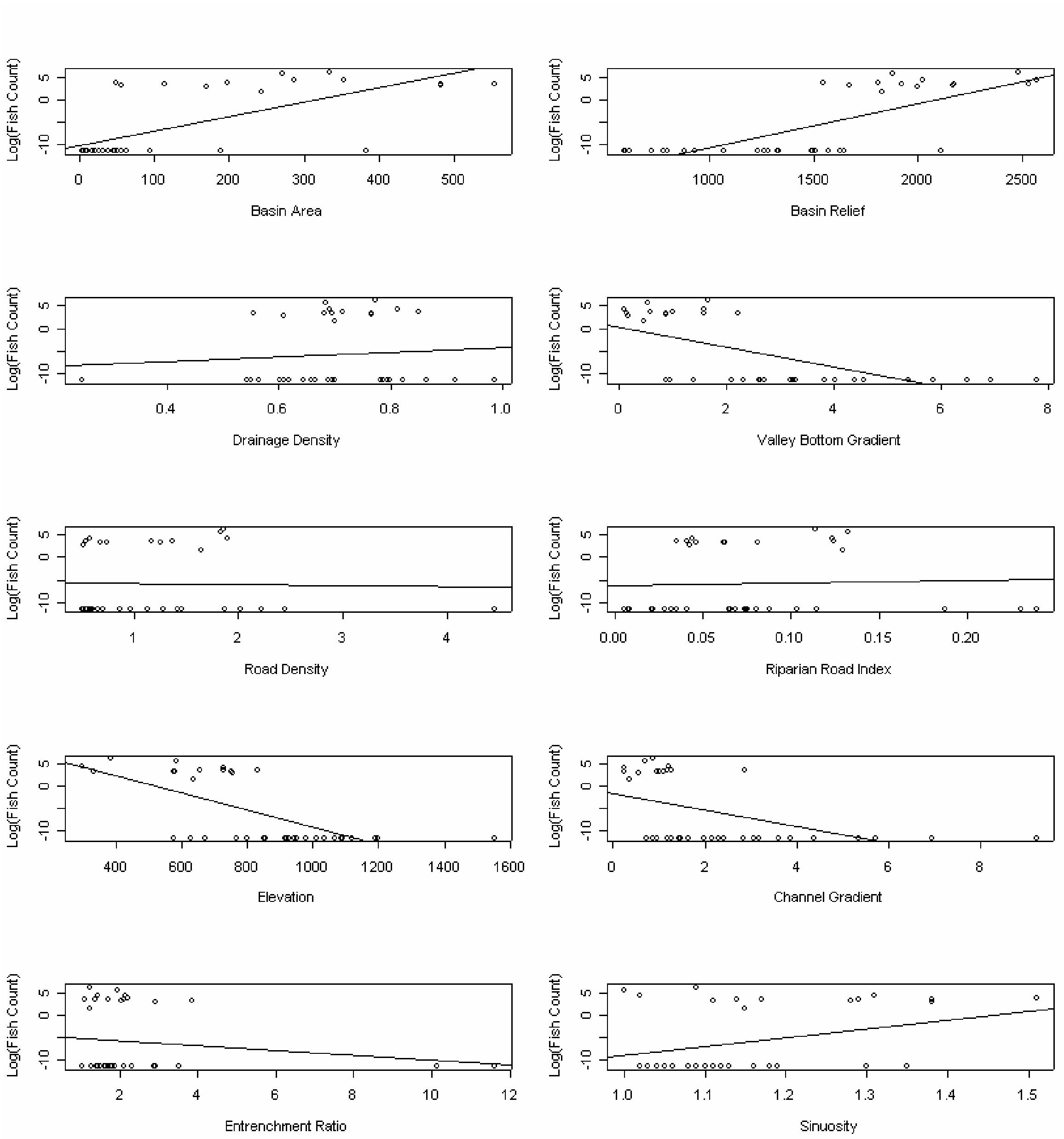

Figure 68. Chinook abundance by different continuous GIS variables.

Table 41. ANOVA for juvenile Chinook salmon daytime counts as a function of GIS attributes.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Geological Code	4	392.84	98.21	4.5208	0.00633	**
Basin Relief	1	861.32	861.32	39.6484	9.72E-07	**
Valley B Gradient	1	7.8	7.8	0.3589	0.55413	
Elevation	1	72.34	72.34	3.33	0.07911	*
Residuals	27	586.55	21.72			

*Significance at α=0.1
**Significance at α=0.001

Even though elevation is significant, both basin relief and channel gradient are also significant depending on the order with which they are introduced to the model. This is primarily due to the fact that the design is unbalanced with respect to the distribution of sampling in different geological regions (Table 42 and Table 43).

Table 42. ANOVA for juvenile Chinook salmon daytime counts as a function of GIS attributes in different order.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Geological Code	4	392.8	98.2	4.5	0.006	**
Valley B Gradient	1	547.2	547.2	25.2	0.000	**
Basin Relief	1	321.9	321.9	14.8	0.001	**
Elevation	1	72.3	72.3	3.3	0.079	*
Residuals	27	586.6	21.7			

*Significance at α=0.1
** Significance at α=0.001

Table 43. ANOVA for juvenile Chinook salmon daytime counts as a function of GIS attributes in different order.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Geological Code	4	392.8	98.2	4.5	0.006	**
Elevation	1	858.78	858.78	39.5318	9.96E-07	***
Valley B Gradient	1	57.77	57.77	2.6594	0.11455	
Basin Relief	1	24.9	24.9	1.146	0.29386	
Residuals	27	586.55	21.72			

** Significance at α=0.001

Depending on the order of entry of the variables in the analysis, we observe that either elevation or both valley bottom gradient and basin relief (with elevation being peripherally significant) were important variables. From Figure 41, we can demonstrate that there is a high degree of correlation between different GIS habitat attributes (e.g., valley bottom gradient and channel gradient and basin area and basin relief). Thus, introducing both variables into an analysis creates statistical issues related to multi-colinearity. The object of this analysis was to use variables that made biological and statistical sense in the final model. However, due to an unbalanced design, where geological regions were not equally sampled (using that as the basis of the stratification), different variables may be significant depending on the order of their entry into the linear model (Tables 41, 42, and 43).

We did test for interaction between geological region, and elevation, valley bottom gradient, and basin relief. The only term that was significant in interaction with geological area was valley bottom gradient. Even if we added basin relief, the interaction term was still significant (Table 44). Thus, we dropped elevation from our final model and used valley bottom gradient, and basin relief and geological type as covariates. The residual diagnostics of this model also appeared better than any of the other two models.

Table 44. Correlation (ρ) amongst various measures collected on GIS attributes that match to Chinook abundance.

	BsnArea	BsnRelf	DrainDens	VBGrad	RdDens	RipRdIndx	Elev	ChanGrad	BFTypCd	Entrench	Sinuos
BsnArea	1.00										
BsnRelf	0.83	1.00									
DrainDens	0.12	0.04	1.00								
VBGrad	-0.64	-0.73	-0.02	1.00							
RdDens	-0.06	-0.26	0.63	0.16	1.00						
RipRdIndx	0.06	-0.17	0.26	0.22	0.58	1.00					
Elev	-0.74	-0.78	-0.56	0.56	-0.23	-0.14	1.00				
ChanGrad	-0.55	-0.56	0.17	0.84	0.15	0.01	0.36	1.00			
BFTypCd	0.26	0.25	-0.20	-0.45	-0.04	0.10	-0.11	-0.55	1.00		
Entrench	-0.26	-0.25	0.14	0.07	-0.03	-0.05	0.24	0.07	-0.05	1.00	
Sinuos	0.04	0.17	0.04	-0.35	-0.28	-0.27	-0.03	-0.20	0.04	0.41	1.00

It is likely that a number of models could be constructed that would return a similar fit ($r^2 = 0.78$). Residual diagnostics are shown below (Figure 69). The figure indicates that the model over predicts lower abundances and under predicts larger abundances. Adding additional covariates on site-specific habitat attributes may help improve the direct sampling estimates. We tested a GLM structure with a Poisson family and a Log-link. The results were not encouraging (in terms of improving the previous fit) and were comparable to the previous model, which we chose as our final model (Table 45).

Table 45. Final model ANOVA used in explaining day Chinook samples and counts.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Geological Code	4	392.8	98.2	5.864	0.002	**
Valley B Gradient	1	547.2	547.2	32.674	0.000	**
Basin Relief	1	321.9	321.9	19.221	0.000	**
Geological Code: Valley BB Grad	3	240.2	80.1	4.781	0.009	**
Residuals	25	418.7	16.8			

** Significance at α=0.01

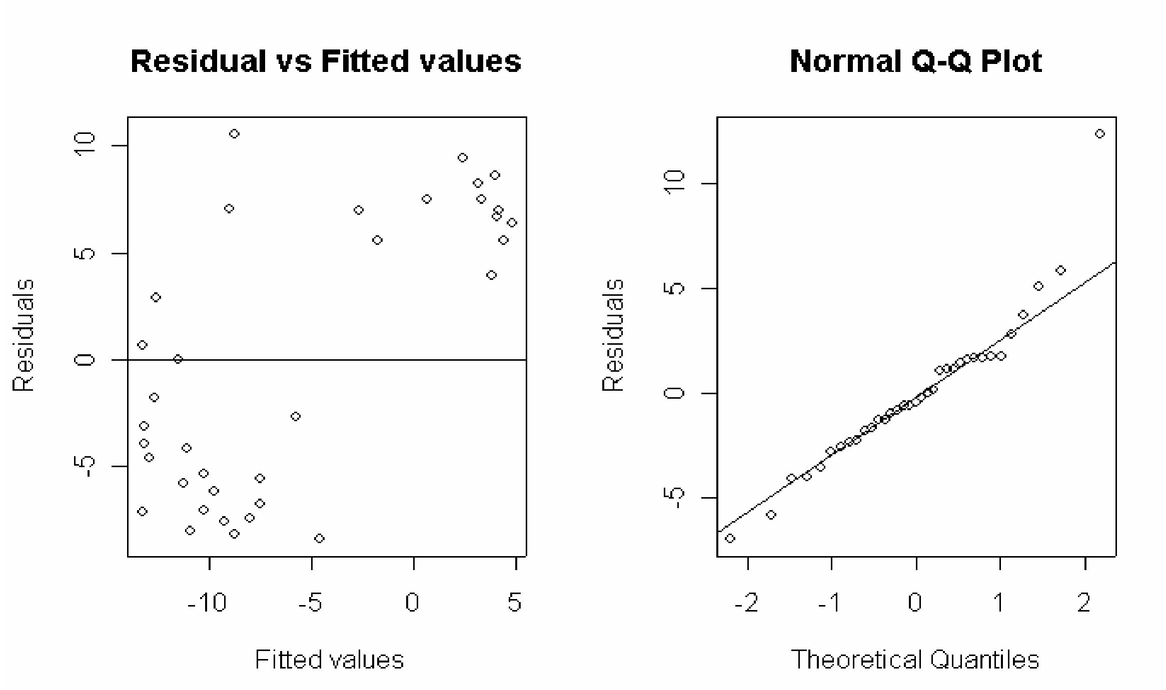

Figure 69. Residual diagnostics for model using just GIS data.

Direct Sampling Habitat Attributes Analysis

Numerous habitat variables were collected through direct sample estimates in the ISEMP data collection program in the Wenatchee River basin. The following variables (65) were collected and used in this analysis (Table 46). As expected, a number of these variables are highly correlated (Table 47, Table 48, Table 49, Table 50 and Table 51). Due to multi-collinear patterns, we chose a subset of the data with lower correlation, and employed a model similar to equation (2), using primarily continuous variables (other than dominant substrate characteristics) to predict juvenile Chinook abundance.

Table 46. Empirical habitat variables collected on juvenile Chinook salmon samples in the Wenatchee subbasin.

Broad Habitat Category	Habitat Variable
Reach length (m)	Reach length (m)
Mean wetted width (m)	Mean wetted width (m)
Wetted surface area (ha)	Wetted surface area (ha)
	% Fines
	% Sand
	% Fine Gravel
	% Coarse Gravel
	% Cobbles
	% Small Boulders
	% Large Boulders
	% Hardpan
	% Rough Bedrock
	% Smooth Bedrock
	% Concrete
	% Wood
	% Other
	Dominant Substrate
	Dominant Substrate Code
Substrate Characteristics	Mean % Embeddedness
	LWD >10 cm dia
	LWD >15 cm dia
Number of pieces of LWD per	LWD >30 cm dia
	Plunge Pools
	Scour Pools
	Dammed Pools
Number of pools per km	Total Pools
Residual Pool Depth (cm)	
	Algae
	Macrophytes & Bryophytes
	Large Wood
	Brush
	Live Trees & Roots
	Overhanging Vegetation
	Undercut Banks
	Boulders
Mean % Fish Cover	Artificial Structures
	Backwaters, Alcoves, & Sidepools (#/km)
	Off-Channel Pools (#/km)
	Off-Channel Ponds (#/km)
	Oxbows (#/km)
	Side Channels (#/km)
Off-Channel/Side Channel Habitat	Total Length of Side Channels (m)
	Mean Bankfull Depth (cm)
	Mean Bankfull Width (m)
Bankfull Widths and Depths	Width/Depth Ratio
% of Unstable Banks	
	Coniferous Canopy
	Deciduous Canopy
	Broadleaf Evergreen Canopy
	Mixed Canopy
% Riparian Canopy	No Canopy
	Mining
	Logging
	Pasture, Range, or Hay Fields
	Row Crops
	Walls, Dikes, or Revetments
	Buildings
	Inlet/Outlet Pipes
	Landfill/Trash
	Park/Lawns
	Paved or Cleared Lot
	Unpaved Roads, Trails, & Railroads
	Paved Roads, Trails, & Railroads
Mean Riparian Disturbance (Weighted by Proximity to Channel)	All Roads, Trails, & Railroads
Percent Canopy Cover	Percent Canopy Cover

Table 47. Correlation on substrate characteristics collected in the Wenatchee subbasin.

	WetSurfArea	*PFine*	*PSnd*	*PFnGrav*	*PCrsGrav*	*PCob*	*PSmBld*	*PLgBld*	*PHrdpn*	*PRBedr*	*PSBedr*	*PConcr*	*PWood*
WetSurfArea	1.00												
PFine	-0.15	1.00											
PSnd	0.12	0.25	1.00										
PFnGrav	0.14	-0.02	0.59	1.00									
PCrsGrav	-0.05	-0.18	0.08	0.32	1.00								
PCob	0.10	-0.30	-0.69	-0.49	-0.13	1.00							
PSmBld	0.00	-0.16	-0.64	-0.52	-0.39	0.42	1.00						
PLgBld	-0.16	-0.30	-0.47	-0.42	-0.24	0.21	0.58	1.00					
PHrdpn	0.23	0.06	-0.05	-0.21	-0.27	0.10	-0.13	-0.22	1.00				
PRBedr	-0.16	-0.17	-0.31	-0.37	-0.33	-0.02	0.16	0.23	0.14	1.00			
PSBedr	-0.10	-0.18	0.18	0.33	-0.11	-0.15	-0.09	0.03	-0.23	-0.01	1.00		
PConcr	0.25	0.03	0.38	0.33	-0.02	-0.34	-0.24	-0.17	0.25	-0.07	-0.05	1.00	
PWood	-0.21	0.13	-0.03	-0.17	-0.18	-0.21	-0.09	0.08	-0.19	-0.13	-0.03	-0.15	1.00

Table 48. Correlation on pool area collected in the Wenatchee subbasin.

	PEmbedd	*LWD10*	*LWD15*	*LWD30*	*TotPool*	*ResPlDpth*
PEmbedd	1.00					
LWD10	0.07	1.00				
LWD15	0.02	0.99	1.00			
LWD30	-0.02	0.95	0.98	1.00		
TotPool	0.24	0.59	0.55	0.51	1.00	
ResPlDpth	0.11	0.21	0.21	0.18	0.61	1.00

Table 49. Correlation on fish cover/side-channel habitat collected in the Wenatchee subbasin.

	FCAlgae	*CMacroBry*	*FCLrgWd*	*FCBrsh*	*FCLvTrRt*	*FCOvrhVeg*	*FCUndrBk*	*FCBlders*	*FCArtif*	*Bckwtr*	*Oxbow*
FCAlgae	1.00										
FCMacroBryo	-0.03	1.00									
FCLrgWd	-0.18	0.24	1.00								
FCBrsh	-0.27	0.02	0.31	1.00							
FCLvTrRt	-0.11	-0.30	-0.10	0.43	1.00						
FCOvrhVeg	-0.19	0.03	0.19	0.67	0.44	1.00					
FCUndrBk	-0.15	-0.18	0.11	0.56	0.28	0.73	1.00				
FCBlders	-0.05	-0.13	-0.32	-0.31	-0.03	-0.30	-0.16	1.00			
FCArtif	0.29	-0.13	-0.20	-0.05	0.08	-0.06	-0.03	0.08	1.00		
Bckwtr	-0.09	-0.15	0.14	0.29	0.04	0.07	0.12	0.17	-0.23	1.00	
Oxbow	-0.04	-0.12	-0.06	-0.08	0.01	-0.07	-0.05	-0.11	-0.05	-0.09	1.00

Table 50. Correlation on bankfull width characteristics collected in the Wenatchee subbasin.

	SidChanNb	*SidChanLgtl*	*BkflWdth*	*WD*	*PUnstBk*	*CanConifer*	*CanDecid*	*CanMix*	*CanNone*
SidChanNb	1.00								
SidChanLgth	0.40	1.00							
BkflWdth	-0.26	0.20	1.00						
WD	-0.27	0.29	0.66	1.00					
PUnstBk	-0.10	-0.24	-0.14	-0.27	1.00				
CanConifer	0.03	0.02	-0.28	0.01	-0.16	1.00			
CanDecid	-0.03	-0.13	0.24	-0.02	-0.08	-0.72	1.00		
CanMix	0.00	0.11	-0.03	-0.01	0.18	-0.50	-0.13	1.00	
CanNone	-0.03	-0.01	0.39	-0.01	0.23	-0.56	0.44	-0.18	1.00

Table 51. Correlation on riparian cover characteristics collected in the Wenatchee subbasin.

	RDMine	RDLog	RDPasture	RDCrop	RDDike	RDBldg	RDPipe	RDLndfill	RDPark	RDLot	RDAllRd
RDMine	1.00										
RDLog	-0.04	1.00									
RDPasture	-0.03	0.06	1.00								
RDCrop	-0.04	0.06	-0.04	1.00							
RDDike	0.35	-0.08	-0.07	0.16	1.00						
RDBldg	-0.06	-0.02	0.06	0.56	0.62	1.00					
RDPipe	-0.04	-0.05	-0.04	0.07	0.02	0.45	1.00				
RDLndfill	-0.07	0.05	0.28	0.84	0.29	0.62	0.09	1.00			
RDPark	-0.05	-0.05	-0.05	0.35	0.57	0.94	0.60	0.44	1.00		
RDLot	-0.06	0.07	-0.06	0.87	0.03	0.38	0.02	0.77	0.20	1.00	
RDAllRd	0.35	0.16	-0.13	-0.08	0.11	-0.15	0.10	0.00	-0.14	0.17	1.00

Exploratory Data Analysis

Exploratory data analysis was conducted on different in-stream characteristics summarized by Figures 70 through 74. Regressions are summarized with r^2 values in Table 52. Depending on those outcomes, we chose a second set of predictors for a model analogous to equation 2:

$$\ln(FishCnt) = \beta_0 + \sum_{i=1}^{x} \beta_i H[I] + \varepsilon \qquad (3)$$

where H(I) is a directly sampled habitat attribute (rather than a GIS-based attribute as in equation 2) and 1 to x refers to the attributes listed in Table 46.

The results of the EDA and single variable analysis indicate that wetted surface area, percent coarse gravel, percent large boulders, overhanging vegetation, mean bankfull width, width to depth ratio, deciduous canopy, landfill, paved roads, parks and lawns adjacent to the stream, and percent canopy cover are all significant at $\alpha = 0.05$. However, some of these variables are correlated, and based on the order of residual variation explained by the model we performed a step-wise regression analysis. On further investigation (Figure 74), it appears that percent canopy cover is a spurious relationship (indicating a negative trend as more canopy cover appears on streams).

Table 52. Independent variable analysis, R^2 and significance levels.

Broad Habitat Category	Habitat Variable	R^2	Significance level (Pr(>|t|))
Reach length (m)	Reach length (m)	NA	
Mean wetted width (m)	Mean wetted width (m)	NA	
Wetted surface area (ha)	Wetted surface area (ha)	0.36	0.001
Substrate Characteristics	% Fines		NS
	% Sand		NS
	% Fine Gravel		NS
	% Coarse Gravel	0.1409	0.0263
	% Cobbles		NS
	% Small Boulders	0.102	0.0614
	% Large Boulders	0.1191	0.0423
	% Hardpan		NS
	% Rough Bedrock		NS
	% Smooth Bedrock		NS
	% Concrete	0.09493	0.0718
	% Wood		NS
	% Other		NS
	Dominant Substrate	NA	
	Dominant Substrate Code	NA	
	Mean % Embeddedness		
umber of pieces of LWD per kı	LWD >10 cm dia		NS
	LWD >15 cm dia		NS
	LWD >30 cm dia	0.08198	0.0954
Number of pools per km	Plunge Pools	NA	
	Scour Pools	NA	
	Dammed Pools	NA	
	Total Pools		NS
Residual Pool Depth (cm)		0.07915	0.101584
Mean % Fish Cover	Algae		NS
	Macrophytes & Bryophytes		NS
	Large Wood		NS
	Brush	0.1102	0.0514
	Live Trees & Roots		NS
	Overhanging Vegetation	0.1377	0.0282
	Undercut Banks		NS
	Boulders		NS
	Artificial Structures		NS
Off-Channel/Side Channel Habitat	Backwaters, Alcoves, & Sidepools (#/km)		NS
	Off-Channel Pools (#/km)	NA	
	Off-Channel Ponds (#/km)	NA	
	Oxbows (#/km)		NS
	Side Channels (#/km)		NS
	Total Length of Side Channels (m)		NS
Bankfull Widths and Depths	Mean Bankfull Depth (cm)	NA	
	Mean Bankfull Width (m)	0.3789	8.29E-05
	Width/Depth Ratio	0.1188	0.0426
% of Unstable Banks		NA	
% Riparian Canopy	Coniferous Canopy		NS
	Deciduous Canopy	0.3309	0.000301
	Broadleaf Evergreen Canopy		NS
	Mixed Canopy		NS
	No Canopy	0.1768	0.0119
Mean Riparian Disturbance (Weighted by Proximity to Channel)	Mining		NS
	Logging		NS
	Pasture, Range, or Hay Fields		NS
	Row Crops	0.08537	0.0885
	Walls, Dikes, or Revetments		NS
	Buildings		NS
	Inlet/Outlet Pipes		NS
	Landfill/Trash	0.1621	0.0165
	Park/Lawns	0.1346	0.0302
	Paved or Cleared Lot	0.1594	0.0175
	Unpaved Roads, Trails, & Railroads		
	Paved Roads, Trails, & Railroads		
	All Roads, Trails, & Railroads		NS
Percent Canopy Cover	Percent Canopy Cover	0.5283	7.65E-07

NA Data unavailable
NS Not Significant

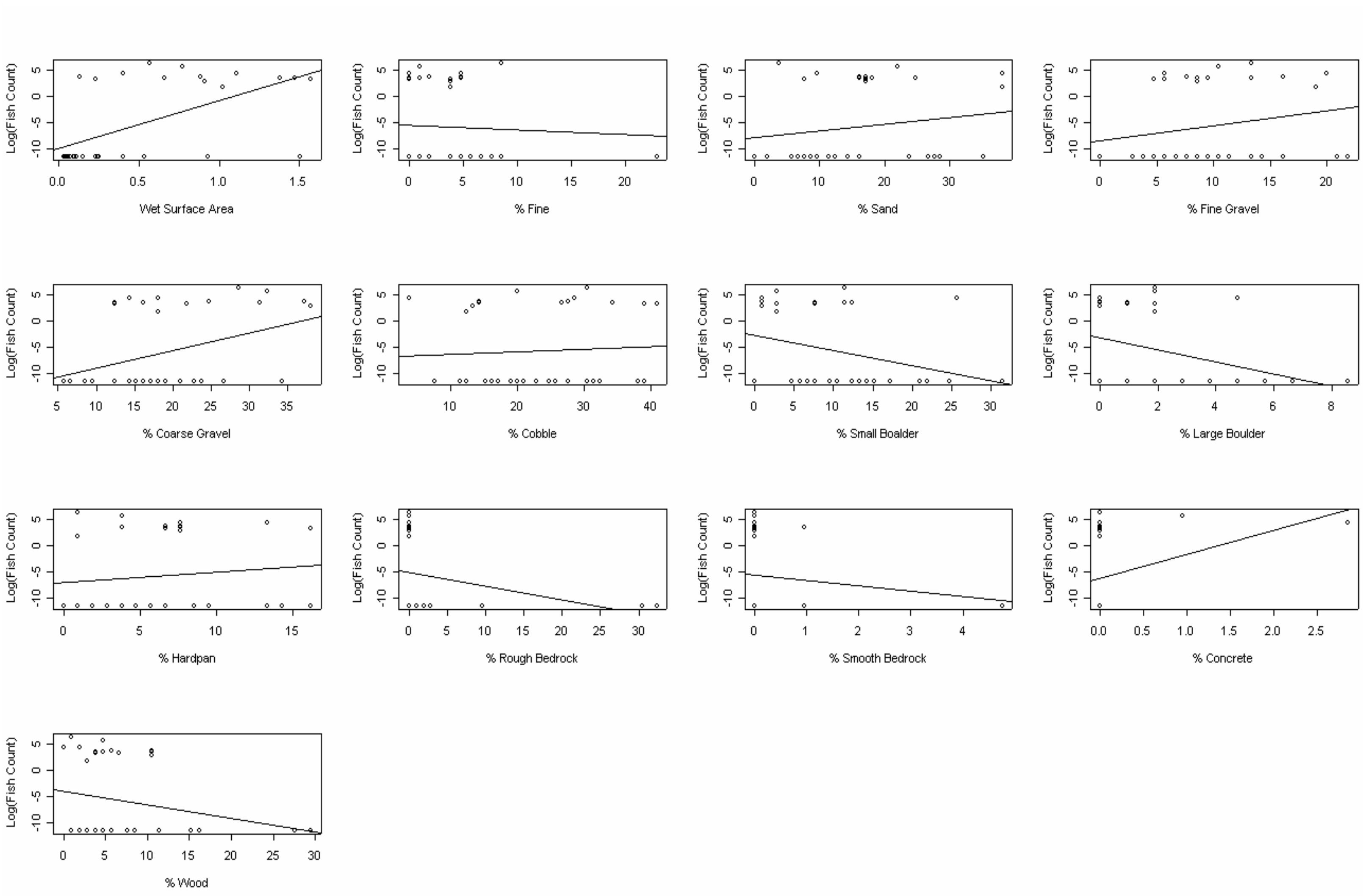

Figure 70. Relationship between substrate characteristics and juvenile Chinook abundance.

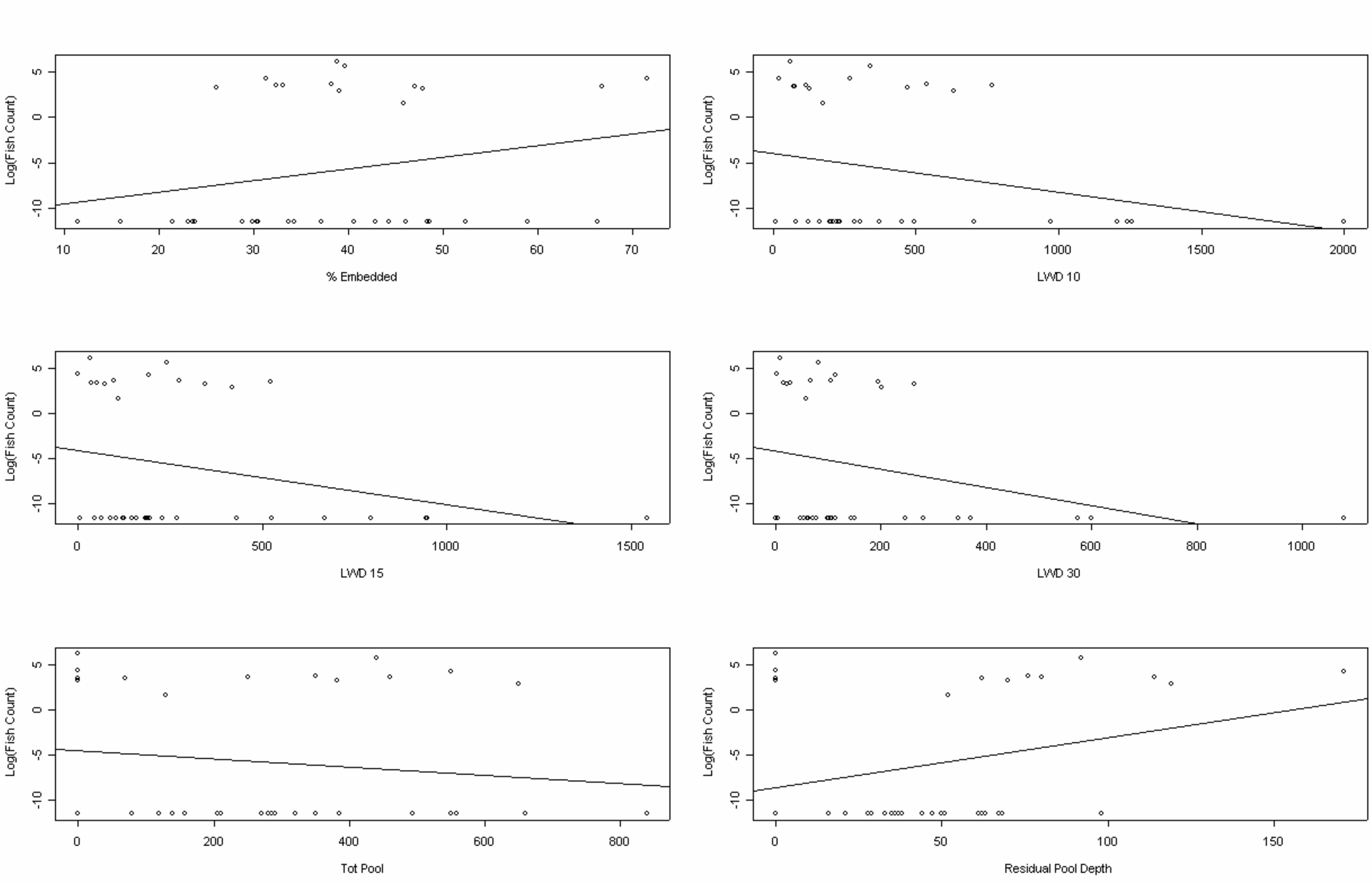

Figure 71. Relationship between pool characteristics and juvenile Chinook abundance.

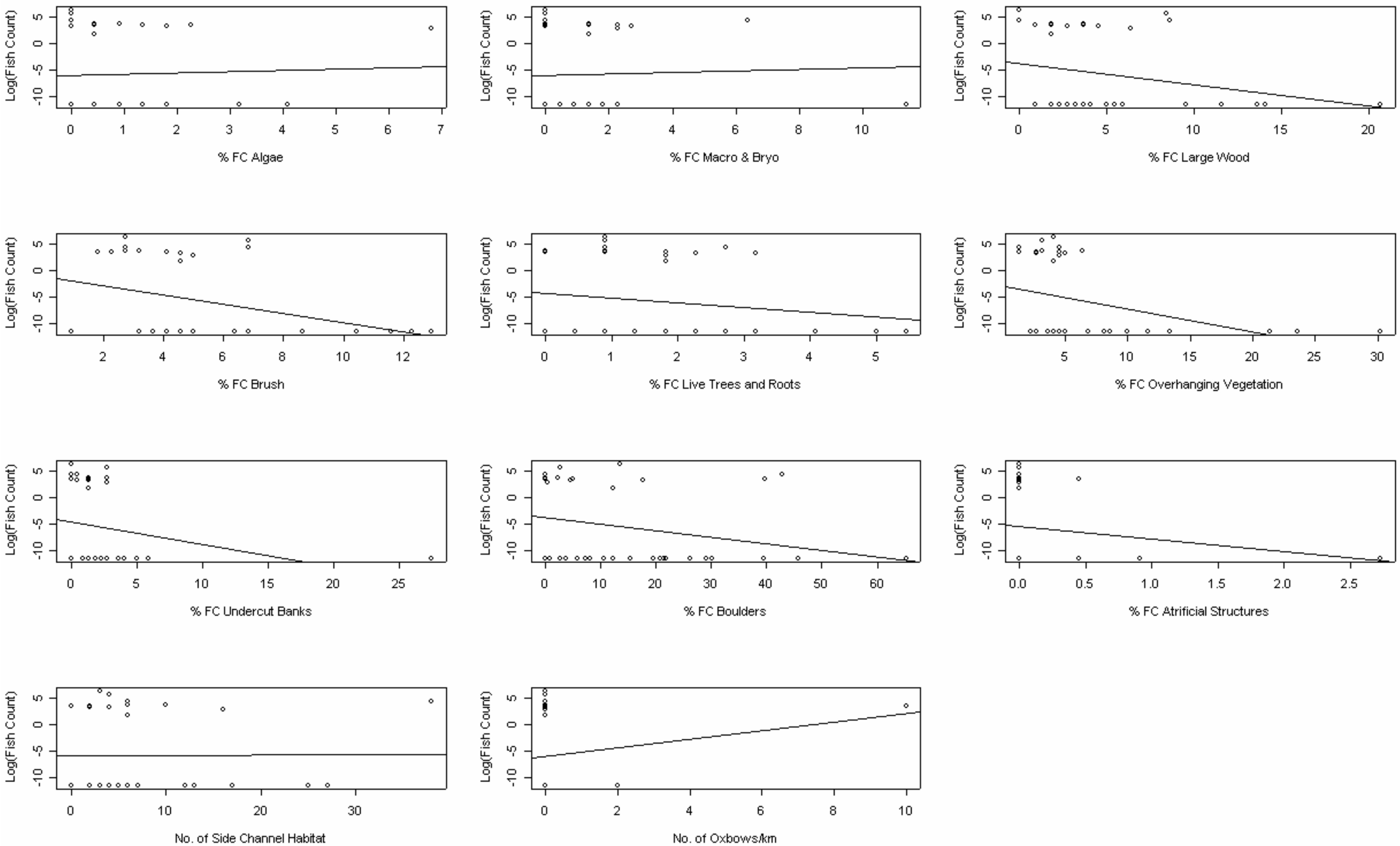

Figure 72. Relationship between fish cover and side channel characteristics, and juvenile Chinook abundance.

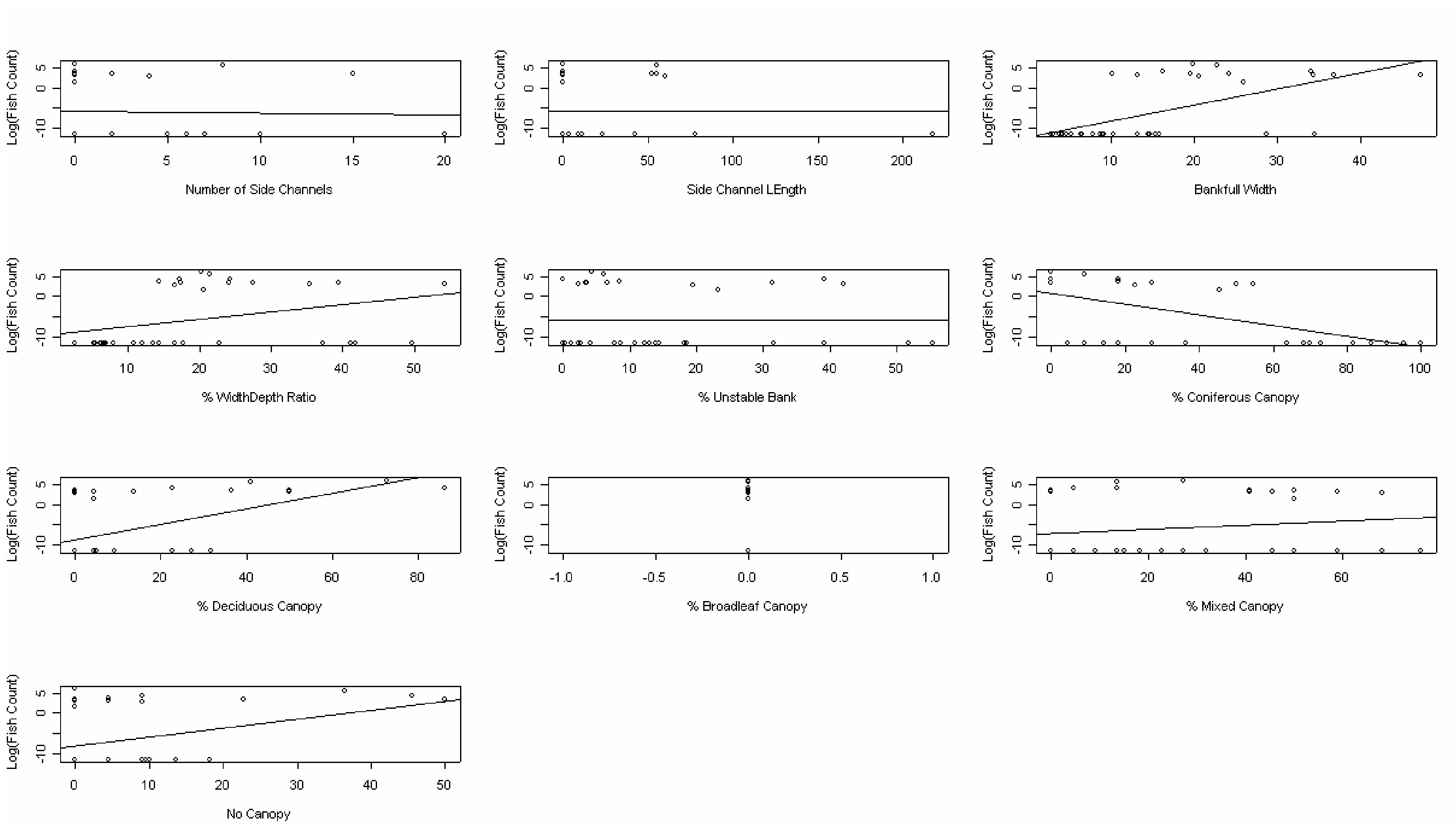

Figure 73. Relationship between bankfull width characteristics and juvenile Chinook abundance.

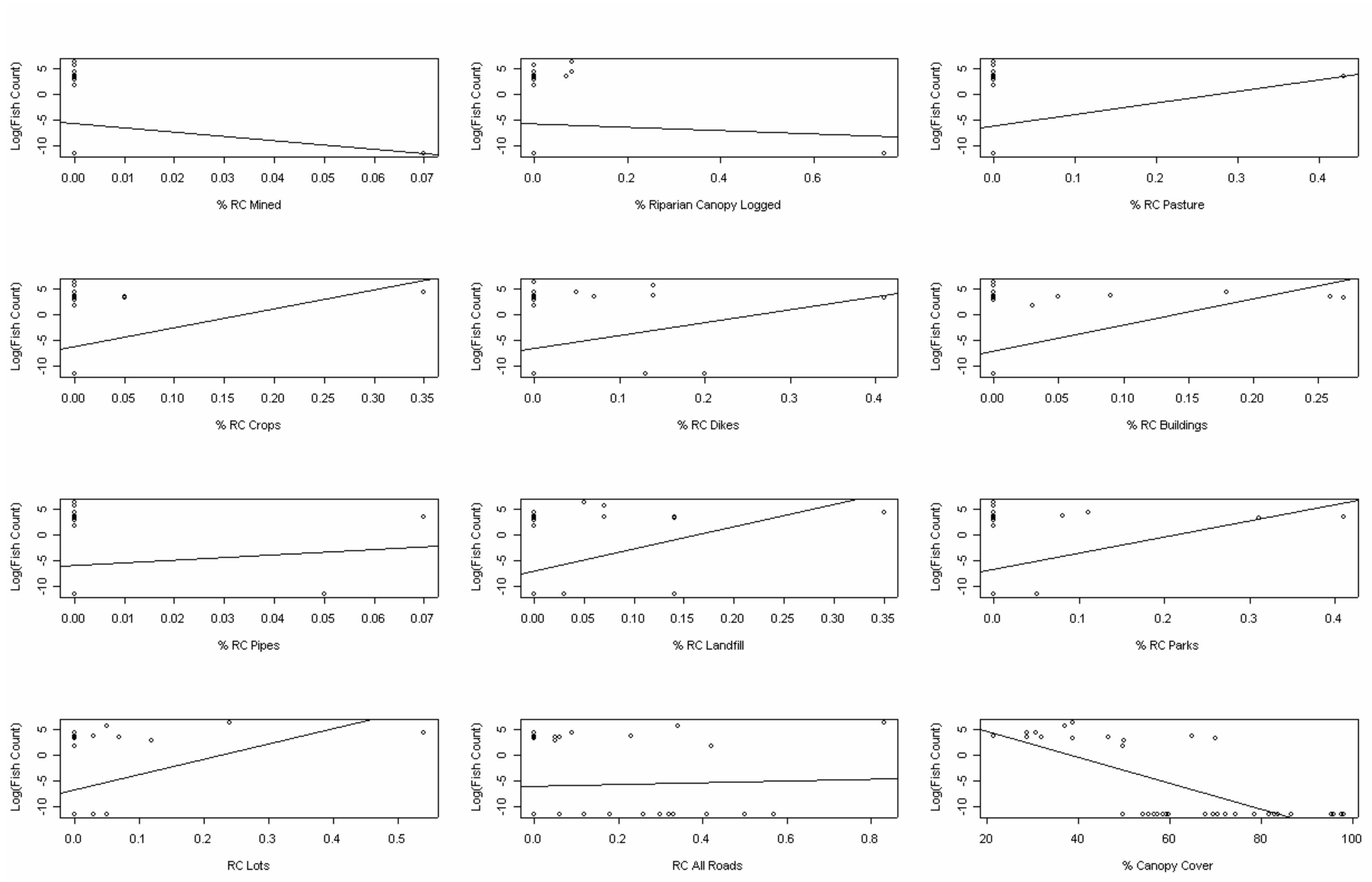

Figure 74. Relationship between riparian cover characteristics and juvenile Chinook abundance.

Multiple Variable Models

The model developed using stepwise regression and equation 3 is shown below (Table 53) with residual diagnostics (Figure 75). The order of variables introduced in the analysis is extremely important. As indicated in Table 52 above, any of the variables introduced in the single variable analysis are important, and will be significant if introduced as the initial variable. However, as we chose our variables in order of their explanatory power (power to explain the residual variation), we started with bankfull width and then went down the list (other than percent canopy cover and no canopy which appear to be spurious relationships).

We introduced various variables (Table 52) into the model with bankfull width as the first variable and introducing other variables in increasing order of explanatory power. The final model had an $r^2 = 0.66$ (Table 53). Residual diagnostics indicate some systematic patterns in the final model (Figure 75). However, if it is coupled with the GIS attributes it may improve in explanatory power or may not. We included the three variables to the initial GIS based model (Table 54) and decompose variance as shown by the ANOVA.

Table 53. Final ANOVA for a model explaining Chinook abundance using directly sampled measures.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Bankfull width	1	727.85	727.85	34.6615	1.69E-06	**
Canopy Cover Deciduous	1	374.13	374.13	17.8167	0.0001969	**
Percent Coarse Gravel	1	167.89	167.89	7.9952	0.0081445	**
Residuals	31	650.96	21			

** Significance at α=0.01

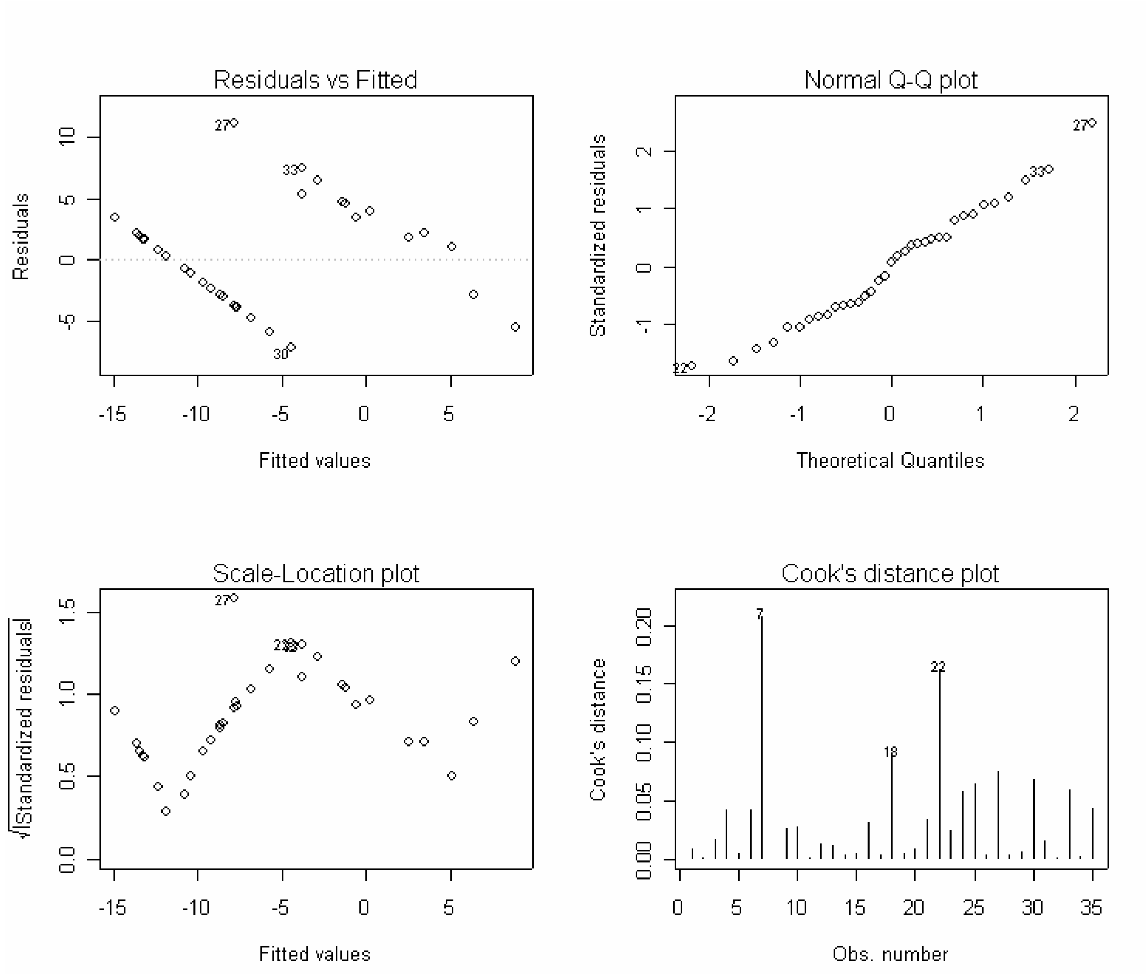

Figure 75. Residual diagnostics of the model using continuous direct sampled measures to predict Chinook abundance.

GIS and direct sample model

We thus combined the model obtained from equation 3 and Table 44 and added the variables obtained in Table 53. We used a number of permutations and combinations of these variables and the model with the highest explanatory power is shown below (Table 54). This model explains 91% of the residual variation in the juvenile Chinook data ($r^2 = 0.91$), with residual diagnostics shown in Figure 76. The model still appears to have platykurtic behavior, which is probably a function of the available data on juvenile Chinook salmon.

Table 54. Final ANOVA for a model explaining Chinook abundance using directly sampled measures and GIS attributes.

Variables	Df	Sum Sq.	Mean Sq.	F- value	Pr(>F)	Significance
Geological Code	4	392.84	98.21	12.80	1.97E-05	**
Valley B Gradient	1	547.21	547.21	71.32	3.42E-08	**

Basin Relief	1	321.90	321.90	41.96	2.03E-06	**
Canopy Cover Deciduous	1	187.57	187.57	24.45	6.84E-05	**
Geological Code:Valley Basin Gradeint	3	215.61	71.87	9.37	0.0003955	**
Geological Code:canopy Cover	3	94.58	31.53	4.11	0.0192926	*
Residuals	21	161.12	7.67			

*Significance at α=0.05
** Significance at α=0.001

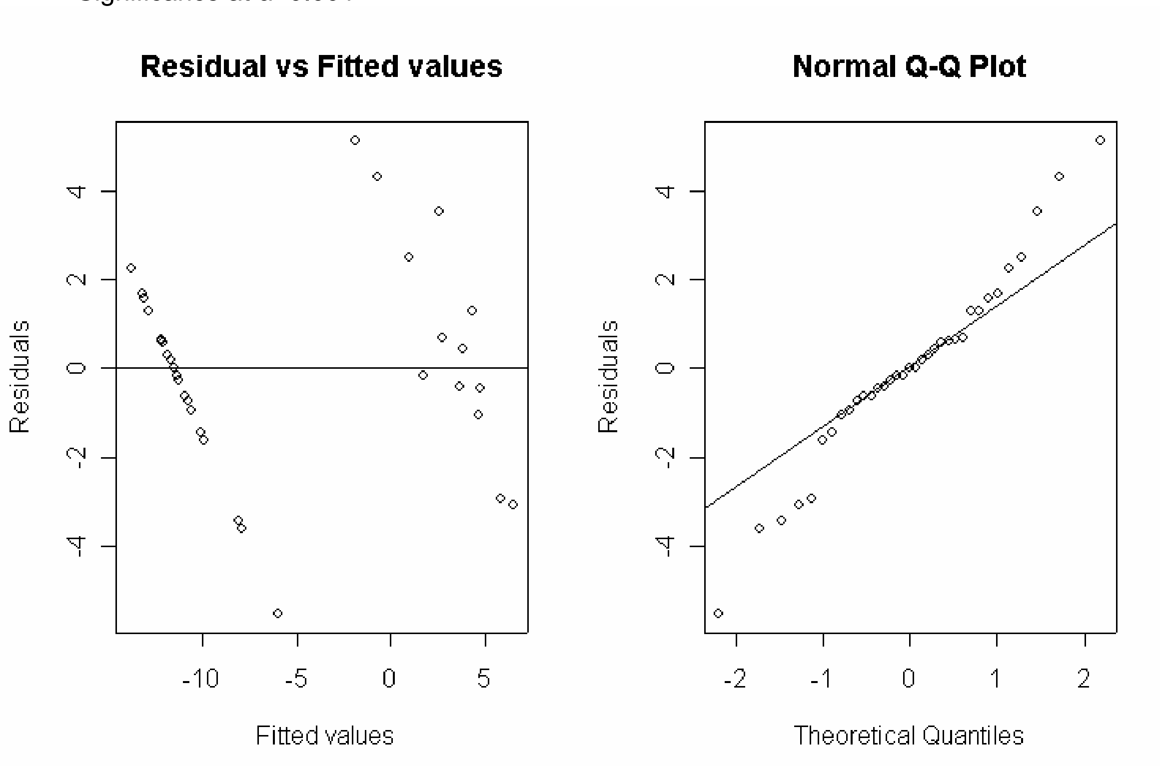

Figure 76. Residual diagnostics of the final model using both GIS and direct sampled measures.

Caveats of the Analysis

The approach presented here is a tool to show how we can project abundance as a function of available data. However, since data were not collected with any clear experimental design to answer some specified objectives, statistical power was low. This is essentially an observational study that incorporates some of the available data and explains site specific variability as a function of some GIS and direct sample estimates. Fluctuations in abundance over time should be taken into account while using these models as fish behavior has temporal as well as spatial variability. Finally, fish are not random in their behavior and are driven by some biological mechanisms. In addition, the data here is also a function of the cohort strength of the spawners, which is missing from this analysis.

Future Steps

We will extend a similar analysis to steelhead data and possibly other species of interest. We will also incorporate some temporal variability in the data with multiple years. In addition, the density will be corrected for spawning abundance from the corresponding reaches in subsequent analysis. We will also try and develop the following 2 methods described below:

Building Nested Models from GIS Data

Based on the above data, and possible mechanistic reasons for channel characteristics, EDA and GLM based analysis will be extended from GIS data to direct sampled estimates. This in turn may be of critical importance to juvenile abundance. So, in our previous model, we will explore a relationship between GIS characteristics, an additional temporal environmental covariate (e.g. flow or snowpack) to predict percent wetted area and bankfull width, along with pool area. Thus a mechanistic model to explain fish density in a particular region of the Wenatchee can be made.

Using Predictive Model Based Techniques using Bootstrap Sampling

Based on Step 1 above, we can develop predictive models to determine juvenile Chinook abundance by geological region on the Columbia.

Evaluating Mark-Recapture Approaches to Survival Estimates for Migratory Salmonids

Mark-recapture techniques have been used extensively in fisheries research in the Columbia River Basin. PIT tags, in particular, have been utilized to evaluate survival across a variety of life stages for anadromous fishes in the Columbia River and its major tributaries. More recently, there has been an increase in the use of PIT tags in small stream applications to investigate factors (i.e., abiotic parameters) affecting the survival of resident and anadromous fishes within small tributaries. Furthermore, there have been recent advances and applications in PIT tag technology, as PIT tag detection arrays, which are operationally similar to those present at the major hydropower facilities on the Columbia and Snake River systems, have been installed in many tributary systems. PIT tag detection arrays allow for individual recaptures of fish marked with PIT tags as they migrate through a detection array system within a river channel; thus additional recapture events are possible, resulting in more precise estimates within mark-recapture analyses. However, the life-history strategies of resident fish and species that do not have obligate migratory life-history expressions (i.e., steelhead, bull trout, etc.) present a number of challenges in the data organization of individual-specific mark-recapture data. These challenges warrant evaluation of alternative approaches to mark- recapture analyses.

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Eco Logical Research, Inc.

Time Line

This analysis is ongoing. The initial exploratory phases have demonstrated the limitations of the currently available analytical approaches to evaluate mark-recapture data as applied to juvenile anadromous fishes and PIT tag detections. The next phase of the work, fiscal years 2007-2008 will be to develop specific analytical tools optimized to the data generated by PIT tag detection arrays. These next generation products will be generally useful for the fisheries management community in the Pacific Northwest.

What's been accomplished so far

Introduction

The objective of this work is to discuss the use of mark-recapture techniques in fisheries research where PIT tags and detection arrays are used to estimate vital rates. In particular, we discuss different types of data, the benefits and pitfalls of specific mark-recapture models, illustrate an example with field data from the SFJD, and finally, discuss further analyses necessary for the design of robust mark-recapture studies.

Data types

Mark-recapture research often involves using different sampling methodologies for marking and recapture events. For example, active sampling (i.e., electrofishing) produces different data types than passive sampling where PIT tag detection arrays are used. Figure 77 depicts an example of a research site where three types of data are possible. First, there are initial tagging data, which can occur throughout the study area (Areas A and B). Tagging data is often spatially explicit, where specific sample units are used for initial marking, and these units are repeatedly sampled for recapture events. In addition to spatial considerations, tagging events are generally temporally explicit as they correspond to specific sampling occasions. In mark-recapture studies, this temporal component is the result of an implicit assumption of most mark-recapture models, where sampling events occur over finite time periods. Secondly, there are active recapture data. This corresponds to fish that were previously captured and marked, and are actively recaptured, either at repeat sample units or through interval sampling. Finally, there are recaptures that occur at the PIT tag detection arrays, which are generally similar to active recaptures, but PIT tag detection arrays run continuously, and recaptures may occur at any time period.

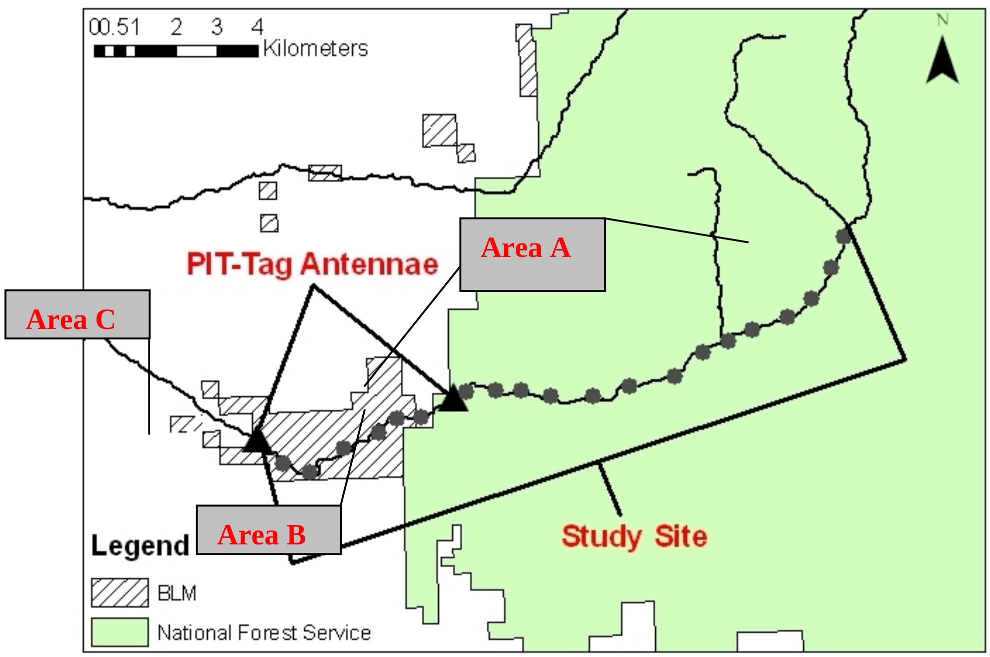

Figure 77. Example of a study site containing two PIT tag detection arrays. Area A corresponds to the section of the study area upstream of both antennae; Area B corresponds to the section of the study area between the antennae, and Area C corresponds to the area downstream of both antennae.

Mark-recapture survival analyses

Within stream systems, mark-recapture data is generally evaluated with “open” mark-recapture models to estimate population-level parameters such as survival. In general, mark-recapture models are flexible in their ability to incorporate individual and environmental covariates, as well as varying levels of effort across different sampling occasions. For example, it is possible to evaluate how differences in individual parameters, such as growth or condition, and/or changes in the habitat (i.e., water temperatures), affect survival across different age-classes of fish. Thus, researchers can use mark-recapture models to evaluate how survival is linked mechanistically to different environmental and/or habitat characteristics.

This document examines a steelhead mark-recapture project on the SFJD to illustrate the analytical challenges where multiple data types are collected over various temporal scales. In particular, we focus on two open mark-recapture models, Cormack-Jolly-Seber and Barker models and discuss the benefits and pitfalls of using each approach when considering the analyses of PIT-tag and PIT tag detection array mark-recapture data.

Cormack-Jolly-Seber Model

The Cormack-Jolly-Seber (CJS) model or variations of the CJS model are commonly used to estimate apparent survival with mark-recapture data. CJS models use maximum likelihood theory to estimate the probability of survival from one occasion to the next occasion. CJS models are often sufficient to analyze complex datasets, yet are simple with only two parameters and are relatively insensitive to violations of assumptions (*see* Krebs 1999 for description of assumptions). Under a CJS model, three capture-recapture occasions are required for estimates of apparent survival (Φ) and capture probability (p). Each parameter can vary by time, group, etc. and individual (e.g., condition) and environmental covariates can be incorporated into analyses to examine the effects of different biotic and abiotic factors on survival and capture probability. Generally the precision of survival estimates and the ability to delineate survival across different groups is largely driven by recapture probability (Cooch and White 2006).

CJS models cannot delineate between emigration events and mortalities, thus apparent survival estimates may be biased low unless robust estimates of emigration can be used to calculate estimates of true survival (Forsman et al. 1992). For species that exhibit variable juvenile migration patterns (e.g., steelhead), it can be critical to quantify emigration rates across different relevant time periods. Estimates of emigration are possible through the use of screw traps, or through recapture events at PIT tag detection arrays located at the boundaries of a particular research site.

CJS models require inputs of discrete sampling occasions, which may occur at different temporal resolutions, and generally correspond to the temporal inference of the research (e.g., monthly survival). Analyzing PIT-tag and PIT tag detection array mark-recapture data presents unique challenges for assimilating data to be analyzed within CJS models. In particular, when PIT tag detection arrays are used within a mark-recapture framework, there can be questions as to the relevant "sampling occasion" as data is collected continuously through time. Splitting sampling occasions into finer temporal periods (i.e., week vs. month) generally results in lower recapture probabilities as fewer individuals may be recaptured within each time period; this generally results in reduced precision in survival estimates and reduced power to detect changes in survival across groups, treatments, etc. On the contrary, grouping continuous recaptures across longer temporal periods into one sampling occasion (i.e., season vs. month) may result in higher capture probabilities (and increased precision) as more individuals are included at this temporal scale. However, this approach presents challenges as to the temporal scale of inference and violates the assumptions of sampling occurring over a finite time period and homogeneity among individuals.

Barker Model

The Barker model may present a unique alternative to CJS models for evaluating mark-recapture projects that use continuous sampling events through PIT tag detection arrays. Similar to the CJS models, the Barker model also uses maximum likelihood theory, requires three sampling occasions to estimate survival, and the precision of estimates is largely driven by capture probability. However, the Barker model differs significantly from the CJS model in the number of parameters and the data outputs. First, there are 7 parameters in the Barker model, including 5 parameters in addition to survival and capture probability. Next, the Barker model provides estimates of survival (S), not apparent survival (Φ; as estimated in CJS models), as emigration rate is estimated and incorporated into survival estimates. An additional parameter to the CJS model is an estimate of site fidelity (F), and emigration can be calculated as 1-F. Thus, where estimates of emigration are suspect, the Barker model may provide more accurate estimates of survival than CJS models.

Similar to the CJS model, the Barker model also requires distinct sampling occasions but differs from the CJS as information collected between sampling occasions can be included as data inputs. Thus, continuous sampling, which generally occurs through the use of PIT tag detection arrays in stream mark-recapture studies, can be incorporated into survival analyses without binning the data into different sampling occasions. While the Barker model appears to be a more comprehensive approach than CJS analyses for analyzing mark-recapture data where PIT tag detection arrays are used, the increase in the number of parameters may prevent the usage of this model without relatively high capture probabilities and large sample sizes.

Example of mark-recapture analyses

Study site and design

We examined juvenile steelhead mark-recapture data collected in two tributaries of the SFJD, Black Canyon Creek and Murderers Creek (Figure 78). This data is part of a larger collaborative project, initiated in 2003, with researchers from OSU, ODFW, and USU. The SFJD contains populations of resident, fluvial, and anadromous rainbow trout/steelhead, and delineation between life-history types is often not possible as juveniles. The initial focus of this project was to assess juvenile fish growth and movement across a wide variety of habitat types to evaluate the complex interactions of biotic and abiotic factors on these parameters. The nature of the mark-recapture data in the SFJD allows for the evaluation of other population-level parameters (i.e., survival) over varying temporal and spatial scales.

Three sentinel sampling sites of 1 km in length were established in each system, and each site was sampled three times annually, corresponding to early summer, early fall, and early winter. In addition to sentinel sampling sites and occasions, there was extensive sampling that occurred between the sentinel sites both spatially and temporally (hereafter interval sampling). However, interval sampling did not occur over repeated sampling events at specific locations (i.e., sentinel sites), and therefore fish initially tagged during the interval sampling events were not included in these analyses as marking events. Recaptures during the interval sampling were only included in the Barker model, to evaluate sentinel site fidelity. During all sampling occasions, a variety of techniques were used for active marking and recapturing fish.

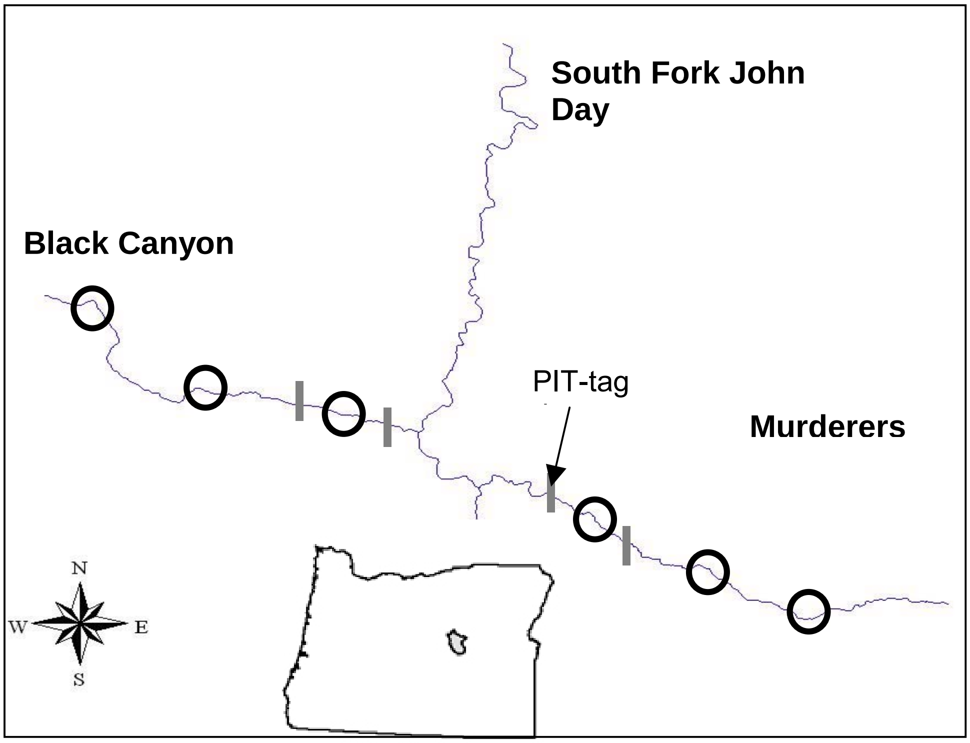

Figure 78. Primary study area in the South Fork of the John Day subbasin showing the approximate location of the sentinel sites and PIT-tag detectors on Murderers and Black Canyon Creeks.

In addition to active sampling events, PIT tag detection arrays were installed in each system. Two PIT tag detection arrays were installed in Murderer's Creek in 2005. An upper PIT tag detection array was installed 7.4 km upstream from the confluence with the SFJD, and was operational for 3 months during the summer 2005. A second PIT tag detection array was installed in Murderer's Creek 0.9 km upstream from the confluence with the SFJD that was operational from in September 2005 through late December. In Black Canyon Creek, one PIT tag detection array was installed approximately 1.5 km upstream from the confluence with the SFJD that was operational from May 2005 through September 2005. PIT tag detection arrays allowed for continuous recaptures of both sentinel and interval fish that moved through a particular PIT tag detection array.

We performed two separate survival analyses for the SFJD data. For the purpose of these analyses, we used four sampling occasions (early summer 2005 through early summer 2006). First, we used CJS models to illustrate differences in apparent survival across systems. Since CJS models do not account for emigration, field estimates of emigration were used to calculate survival (*S*) as:

$$\frac{\text{apparent survival}\,(\Phi)}{(1 - \text{average annual emigration rate (e)})} \qquad (1)$$

We calculated annual survival by adjusting each survival estimate by seasonal emigration (Equation 1) and multiplying the survival estimates for each period (summer, fall, and winter) together. Thus, we reported seasonal estimates of apparent survival, and an annual estimate of survival. Next, we used the Barker model for the Murderer's Creek data as a comparison with the CJS model. Here we used the same four sampling events used in the CJS analysis, but incorporated both active recapture events that occurred during interval sampling and PIT tag detection array recaptures between sentinel sampling occasions.

All analyses were performed in Program MARK (see Program MARK website at: www.warnercnr.colostate.edu/~gwhite/mark/mark.htm). We established a set of *a priori* models where we included components of site and time. We used Program MARK to generate the likelihood function value and estimate the appropriate Akaike Information Criterion (AIC_c; bias adjusted for small sample size) value for each model that we evaluated. AIC incorporates the principle of parsimony by balancing model variance (uncertainty) and bias, where few model parameters may result in a biased model with low variance, and models with many parameters may have little bias yet high amounts of uncertainty (Burnham and Anderson 1998). The models were ranked according to the lowest AIC_c score, and the difference in AIC_c values (ΔAIC_c) between models was used to calculate an Akaike weight for each model (exp ($-0.5\Delta AIC_c$)/sum of exp ($-0.5\ \Delta AIC_c$) all models). For the purposes of this document, we reported the results from the top model (lowest AIC value).

Results

From sentinel sampling across 2005, 478 juvenile steelhead were marked during the three sampling occasions in Murderer's Creek, and 713 fish were marked in Black Canyon Creek. In Murderer's Creek, the top CJS model suggested no differences in apparent survival across the three sentinel sites, but there were significant differences in apparent survival across periods (Figure 79). Similar to Murderer's Creek, we found significant differences in survival across time, but no significant differences in across sites in Black Canyon Creek during this period. However, site was included in the top models, and Site 3 consistently exhibited the lowest survival across the three time periods.

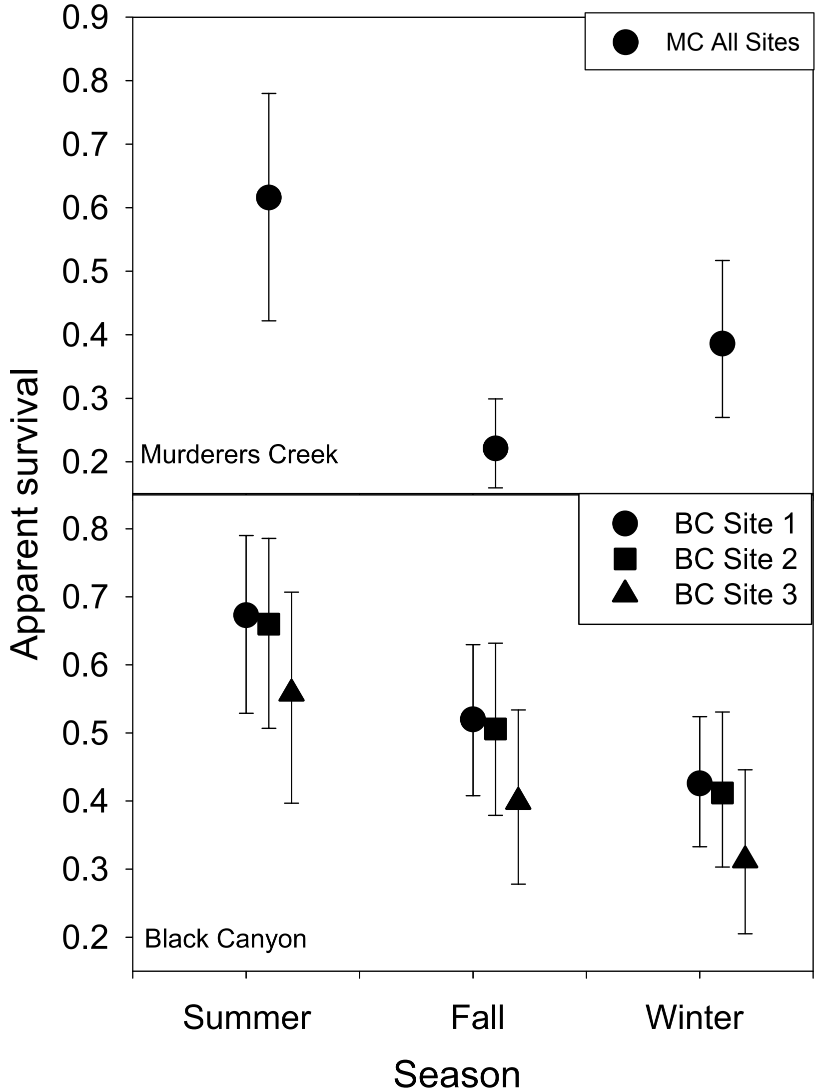

Figure 79. Cormack-Jolly-Seber (CJS) estimates of survival for Murderer's Creek and Black Canyon Creek, John Day subbasin, OR, for the 2005-2006 period.

Recent estimates of emigration suggest that emigration rates in Murderer's Creek and Black Canyon Creek were 11.6% and 3.2%, respectively during the fall of 2005 (Tattam, *unpublished data*); however, these estimates were based on recaptures at a screw trap located below the confluence of with Murderer's Creek and SFJD; thus, mortalities and fish residing in the mainstem SFJD upstream of the screw trap would have biased these estimates low. Furthermore, estimates of emigration rates were not possible across seasons, and emigration rates may increase substantially during the winter season (Tattam, *personal communication*); however, we had to assume similar emigration rates for the winter period for lack of available data. Annual apparent survival estimates (mean values) were estimated as 0.053 for Murderer's Creek (no site delineation) and 0.149, 0.137, and 0.069 for site 1, site 2, and site 3, respectively in Black Canyon Creek; estimates of true survival, when emigration rates were included, were slightly higher for both systems (Table 55).

Table 55. Estimates of annual apparent survival using CJS mark-recapture models, emigration rates, and annual survival for Murderers Creek and Black Canyon Creek, John Day subbasin, OR, from 2005-2006.

	Annual Apparent Survival (CJS)	Fall and Winter Emigration Rate (%)	Annual Survival (CJS)	Annual Survival Estimate (Barker Model)
Murderer's Creek				
Sites 1-3	0.0525	13.6	0.083	
Black Canyon				
Site 1	0.149	3.2	0.159	
Site 2	0.137	3.2	0.147	
Site 3	0.069	3.2	0.076	

Barker analyses for Murderer's Creek yielded a similar result to the CJS analyses where time, but not site, was included in the top model. Significant differences in survival estimates across fall and winter periods were observed between the Barker and CJS model (Figure 80). There are three things to note from this figure. First, survival (Barker model) and apparent survival (CJS model) estimates were not significantly different during the summer period suggesting limited emigration. Emigration rate during this period was estimated by the Barker analysis as 12.2% (95% CI = 5-58%). Next, survival estimates were significantly different across models during the fall period. Again, emigration rate, which was estimated at 75% by the Barker model, was incorporated into these analyses. High emigration rates in Murderer's Creek during this period are confirmed with movement data (Tattam, *personal communication*), but are substantially different than field-calibrated estimates from screw trap data. Finally, while it appears that survival estimates (Barker) were significantly lower than apparent survival estimates, these results are not dependable as precise estimates of F (site fidelity) were not possible with this data. Ultimately this is a result of too few sampling occasions to estimate F during this third period, thus the survival estimates were confounded by invalid estimates of F.

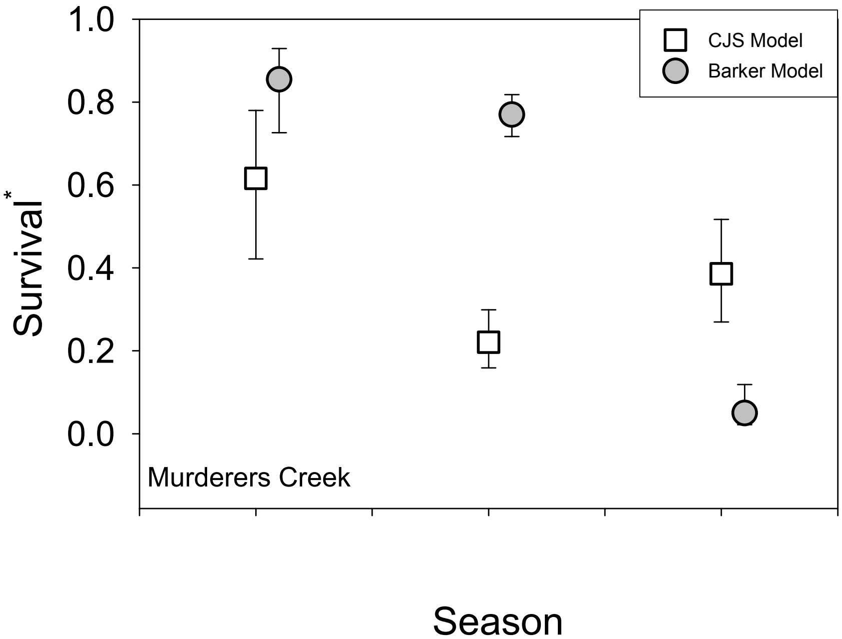

Figure 80. A comparison of Cormack-Jolly-Seber (CJS) and Barker model estimates of survival. * indicates that CJS estimates correspond to apparent survival estimates.

Conclusions and Future Considerations

Mark-recapture analyses allow for estimates of survival across life-stages and life-history forms, both of which are critical for population-level analyses (i.e., population viability analyses) and evaluations of the effectiveness of different management practices (i.e., habitat restoration projects). Recent advances in mark-recapture methods, such as PIT tag detection arrays, can increase sample sizes and potentially increase the precision and accuracy of targeted estimates; however, there needs to be strong consideration of the appropriate study designs and analytical approaches. In this document, we discussed the different data types and two analytical approaches typically used in fisheries mark-recapture research. The purpose of this document was to illustrate typical data types used in mark-recapture studies where PIT tag detection arrays are involved and different analytical models to evaluate survival to highlight future considerations for efficient and effective mark-recapture research in the Columbia River Basin.

Modeling species survival through mark-recapture techniques can be challenging for species that exhibit variable life-history strategies. In particular, evaluating watershed-specific survival for fish can be problematic as fish may be constantly emigrating from the watershed of interest. Since some open mark-recapture models (CJS), do not delineate between mortalities and emigration events, survival estimates can be biased low where estimates of emigration are not possible. The use of PIT tag detection arrays has enabled continuous sampling events in mark-recapture projects, thus allowing for estimates of emigration rate, which may provide more robust estimates of survival. However, the detection efficiency of PIT tag detection arrays can be problematic due to rapid changes in water conditions, power outages, and the destruction of PIT tag detection arrays due to debris/ice flows (Zydlewski et al. 2006). Furthermore, reconstructing PIT tag detection arrays after debris incidents can be problematic during seasons where high precipitation occurs. For example, the lower antennae site in Murderer's Creek was destroyed by ice flows during December 2005, and water conditions prevented reinstalling the antennae until water levels dropped to near base flows. Thus, annual estimates of emigration may be biased low, and robust estimates of survival may not be possible. While the CJS model is a simple approach to estimate survival, the inability of this model to account for emigration may limit the inference from such analyses where large amounts of emigration occur.

The effects of emigration rates on apparent survival, the continuous sampling at PIT tag detection arrays, and less than perfect detection efficiencies to quantify emigration at PIT tag detection arrays predicate the need for alternative mark-recapture models for migratory species. As previously mentioned, an inherent assumption of CJS models is that marking and recapture events occur over finite time periods relative to the interval length between sampling events. For our CJS analyses, we included only sentinel mark-recapture data, but were unable to include recaptures at PIT tag detection arrays and from interval sampling (an additional 103 recapture events for sentinel fish); additionally, sampling sites were not repeatedly visited by field crews, and therefore, we significantly reduced the overall number of marked fish in this analysis (1,506 total fish marked during sentinel and interval sampling; 478 fish marked during sentinel sampling). As illustrated in the SFJD example, a Barker model may be used to overcome the problems associated with using CJS models to evaluate survival for migratory fish. However, the increase in the number of parameters in Barker models suggests that larger sample size and/or greater sampling efforts may be required for reliable estimates as demonstrated by the large confidence intervals surrounding parameter estimates. In lieu of this increase in the number of parameters, further analyses are needed to evaluate the benefits of different sampling approaches (i.e., active sampling during interval periods) for the Barker model. Additionally, there needs to be a formal evaluation of the tradeoffs between sample size and capture probability, to better understand the most effective approach for designing mark-recapture studies where Barker models will be used.

For these analyses, we focused on the comparison of two mark-recapture models to evaluate watershed-level survival over temporal periods. Our results highlight the importance of quantifying emigration rates across all seasons for migratory fish. Our next step will be to evaluate the discrepancies between survival estimates from the CJS and Barker models reported in this document using simulations of field data collected in the SFJD. Simulation analyses will provide insight into potential bias associated with each model and help guide the design and analysis of future mark-recapture projects. Furthermore, we will expand these analyses to larger spatial levels to consider different sampling designs, including sentinel sampling and continuous sampling, when estimating survival through the Columbia hydropower system. We will evaluate necessary sample sizes and compare the use of both CJS and Barker models for spatial analyses of survival.

Invertebrate Productivity Monitoring Project

A study has been initiated as part of the John Day pilot project to develop an indicator of food resource availability for juvenile salmonids. Juvenile salmonids depend on aquatic and terrestrial macroinvertebrate drift as their primary food resource (Elliott 1973), and numerous studies suggest that macroinvertebrate abundance may explain variation in salmonid growth and survival in freshwater rearing environments (Cada et al. 1987; Filbert and Hawkins 1995; Nislow et al. 1998). While macroinvertebrate sampling is common among habitat monitoring programs throughout the Columbia River Basin, the metrics obtained from this sampling have been developed to describe water quality rather than food availability. The goal of the macroinvertebrate study in the John Day subbasin is to determine if a metric of invertebrate food abundance could serve as a surrogate to secondary production, providing a means to estimate production potential of juvenile rearing habitat.

Funding Agencies

Bonneville Power Administration

National Oceanic and Atmospheric Administration

Contractors

Eco Logical Research, Inc.

Time Line

This analysis and data collection is ongoing. The preliminary results to date are based on initial field sampling and analysis, the second and final year of the project will yield final results and recommendations on improved monitoring protocols for assessing aquatic habitat productivity. These next generation products will be generally useful for the fisheries management community in the Pacific Northwest.

What's been accomplished so far

Determining how habitat features function to limit the production of juvenile salmonids is of crucial importance to the restoration of salmonid populations. An understanding of the ecological factors controlling stream salmonid productivity can provide insight into where restoration actions should be prioritized, and help predict the response of salmonid populations to habitat restoration. A common paradigm in fisheries management has been to develop indices of rearing habitat quality based on the assessment of physical habitat features. These indices are the product of correlative studies that link physical habitat features with fish abundances and distribution (Fausch et al. 1988; Horne 1983). Correlative approaches of this type may be unreliable for several reasons. They fail to relate habitat variation with measures of individual performance such as growth, a metric that may provide a more proximate measure of a fish's experience in its environment (Rosenfeld 2003). Further, these approaches emphasize the importance of physical habitat characteristics, ignoring the importance of biotic habitat features such as prey availability (Poff and Huryn 1998).

An alternative approach to estimate production potential of stream environments relies on development of more mechanistic relationships between individual salmonid performance and stream habitat features. For example, monitoring longitudinal stream temperature has been proposed as a means to rapidly assess the carrying capacity of stream habitats. Known thermal tolerances of salmonid species allow characterization of streams sections as physiologically suitable, marginal, or unsuitable (Magnuson et al. 1979). Further, through its control on salmonid metabolism, stream temperatures function as a primary determinant of juvenile salmonid growth potential. While stream temperature sets the physiological limitations for salmonid growth, actual growth requires that an adequate supply of food is available to meet metabolic demands. Unfortunately, the degree that juvenile salmonid foraging rates vary in response to invertebrate abundances is little understood. Through a better understanding of this relationship, a monitoring tool would be created allowing accurate estimates of salmonid growth to be attained through collection of temperature and macroinvertebrate information.

To develop this monitoring approach, the Invertebrate Productivity Monitoring Project is pursuing the following objectives:

1. Development of an invertebrate sampling protocol that could be incorporated into the federal RME program (i.e. a sampling design that balances affordability with the sampling effort necessary to meet monitoring project goals).
2. Identify an invertebrate metric descriptive of prey availability that when combined with temperature could be used to estimate fish growth.
3. Determine if a crosswalk could be created between a food availability metric and metrics commonly used by monitoring programs to evaluate water quality. This relationship potentially would allow interpretation of past and future invertebrate information as it directly relates to salmonid production.

Objective 1: Developing a field sampling protocol

Characterizing the variance of in an indicator is of primary importance when developing a sampling protocol. Lack of understanding in the natural variation inherent in an indicator can lead to inaccurate assessments and difficulties in trend detection (Larsen et al. 2001). Invertebrate assemblages have been shown to exhibit considerable variation in abundance across both time and space (Allan 1987; Shearer et al. 2002). In the SFJD, a hierarchical sampling approach has been taken to describe variation in drift and benthic invertebrate abundances across multiple spatial and temporal scales.

During the summer of 2005, drift samples were taken with 2 to 4 replicate nets in each riffle, with 1-3 riffles sampled at each of seven sentinel sites (see *Juvenile Production Project* in the John Day chapter) to describe the spatial variability within sites and between sites, respectively. Samples were also collected during the morning, mid-day, and evening over 3 consecutive days for 3 months to describe temporal variability within days, between days, and throughout the season, respectively. A hierarchically nested sampling approach of this type allows for partitioning sources of temporal and spatial variance in a random effects ANOVA design (Littell et al. 1996). Quantifying the sources and magnitudes of sampling variability will allow estimation of sample sizes and sampling frequencies that balance the need for robust estimates of prey availability with the cost associated with increasing sampling effort.

Temporal and spatial variance components as estimated through preliminary analysis of 2005 invertebrate sampling have revealed several considerations relevant to protocol development (Figure 81). Spatial variation in drift density between reaches, and within reaches accounted for 11% and 2% of total variance, respectively. These finding suggest that characterization of drift density at the reach scale could be achieved by focusing sampling efforts at a limited number of locations within a reach. A much greater proportion of variation was attributable to temporal fluctuations in drift density. Roughly 45% of the total variation in drift density was due to seasonal changes. Variability across consecutive days (within season) and diel differences accounted for 2% and 12% of the total variation, respectively. These variance estimates for drift density result in a signal (reach) to noise (other spatial and temporal sources of variation) ratio of 0.12, suggesting that additional consideration in sample sizes and sampling designs will have to be considered prior to consideration of drift density as a suitable metric for monitoring habitat quality for juvenile salmonids.

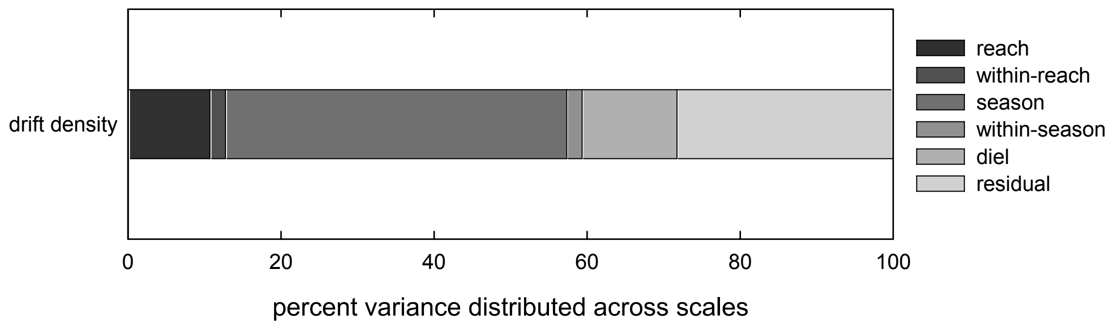

Figure 81. Temporal and spatial variance components for drift density (individuals/100 m^3) from summer 2005 invertebrate drift sample collections.

2006 invertebrate sample collections

During the summer of 2006, an additional set of invertebrate drift samples were collected at the sentinel sites on the SFJD tributaries. This set of samples took advantage of the insight gained through preliminary analysis of 2005 drift and *O. mykiss* stomach sampling to develop an approach that may provide a more robust picture of food availability among the sentinel sites. During the summer of 2006, invertebrate drift samples were collected using mesh nets constructed of a larger diameter mesh (1000 µm). These samples were much less prone becoming clogged, an inherent problem of invertebrate drift sampling that can have substantial impacts on the accuracy of sample quantification. Further, drift sampling using larger diameter mesh size will focus sampling effort on larger invertebrate size classes that occur with the greatest frequency in the diet of juvenile salmonids.

Invertebrate sampling during the 2006 summer season was devoted to the reevaluation of temporal and spatial sources of variability, and refinement of a sampling protocol for collection of invertebrate drift abundances. During mid-June, invertebrate samples were collected at one sentinel site on three SFJD tributaries. On each stream, three distinct riffles (within-reach) at each sentinel site were sampled over the course of three consecutive days (within-season). This sampling will be used to identify the number of drift samples that may be necessary to quantify food abundance within a reach over a short period of time for a desired level of precision. Preliminary analysis of the variation associated with 2006 sample collections show a large difference in drift density between distinct stream reaches (signal), which accounts for roughly

67% of the total variation in drift density. Variation within reaches and within seasons (noise) explains roughly 18% and 0% of the total sampling variation, respectively (Figure 82). When compared only to sampling variation within a reach and over short time periods, the signal (reach) to noise (within-reach, within-season, residual) ratio for drift density is 2.01. While some of the improvement in signal to noise ratio between samples collected in 2005 and 2006 is attributable to the reduced number of spatial and temporal sources of variation considered in the analysis, it is also likely that reducing net clogging has also improved the accuracy of drift sample collections. These same analyses will be conducted on drift biomass, which we expect to be less variable than drift density.

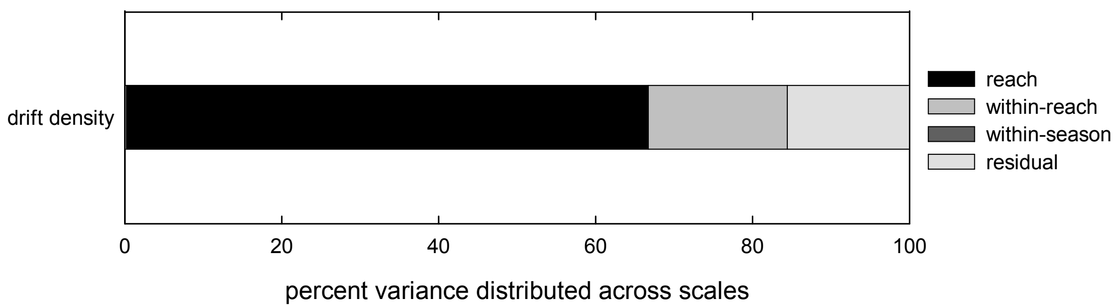

Figure 82. Temporal and spatial variance components for drift density (individuals/100 m^3) from summer 2006 invertebrate drift sample collections.

During the summer of 2006, several adjustments to a drift sampling design were taken in an attempt to overcome additional sources of temporal sampling. To compensate for diel variability, drift samples were collected for entire 24 hr periods. These 24 hr samples were collected at frequent intervals throughout the field season in an attempt to track seasonal changes in the magnitudes of drifting invertebrate abundances throughout the salmonid summer growth season.

Invertebrate sample processing

Much of the cost associated with invertebrate sampling stems from the effort required to separate invertebrate samples from the accompanying detritus and the enumeration of density or biomass. In addition to development of an optimal field sampling protocol, the Invertebrate Productivity Monitoring project is evaluating the accuracy and cost effectiveness of laboratory processing activities.

Invertebrate drift samples regularly include a large amount of debris, and separation of invertebrates from this debris accounts for approximately 75% of the total cost to process invertebrate samples. The amount of detritus collected, and therefore the amount of effort required for sample processing is inversely related to the mesh diameter of drift nets. Evaluation of diet samples collected throughout the sentinel sites revealed that juvenile *O. mykiss* select for large prey items at a higher proportion than they occur in the environment (Figure 83).

To avoid processing large amounts of small invertebrates (< 2 mm total body length) and reduce the amount of detritus in a sample, samples can be rinsed through coarse mesh sieves prior to processing in the lab. Rinsing samples through a 500 *um* mesh sieve results in a 65%

decrease in the processing time of samples that were collected in a 250 *um* mesh drift net. On average, greater than 90% of the total sample biomass is retained by 500 *um* mesh. These observations support the cost benefits of using a larger mesh size when processing invertebrate samples. Further, sampling invertebrate drift using larger diameter mesh nets would help to eliminate net clogging during field sampling.

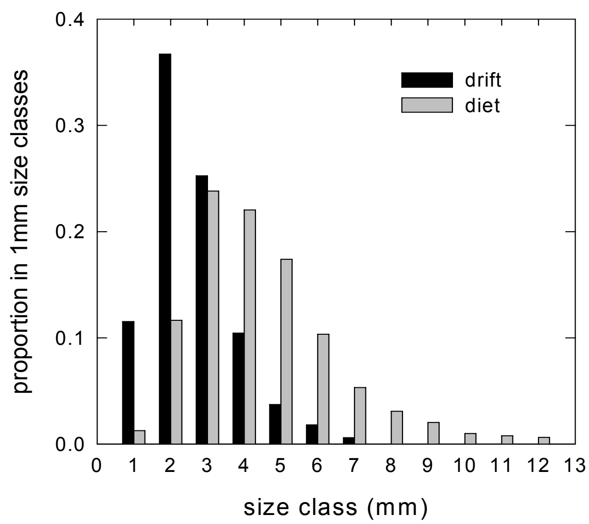

Figure 83. Proportion of invertebrates in 1mm size classes occurring in the drift (as sampled by a 250 μm mesh drift net) and as *O. mykiss* stomach contents.

Accurate determination of biomass is an essential component of trophic studies. Several methods for quantifying invertebrate biomass are commonly used, most straightforward of which is the direct weighing of preserved or dried specimens. Another common approach is the estimation of biomass based on relationships between linear measurements or total volume of invertebrates to unpreserved invertebrate mass. The majority of monitoring programs preserve invertebrate samples in a 95% solution of ethanol. Preservation of invertebrates in ethanol has been shown to alter the wet weight, dry weight, length, and volume of invertebrate samples, making accurate quantification difficult following preservation. The Macroinvertebrate Productivity Monitoring Project is taking efforts to quantify the degree that ethanol preservation alters measurements commonly used in biomass determination. These efforts will provide conversions for unbiased estimation of invertebrate biomass. This effort will also provide an opportunity to evaluate the costs and benefits associated with various methods of biomass determination.

Objective 2

Between the summers of 2004 and 2006 approximately 10,000 juvenile *O. mykiss* have been PIT tagged in the SFJD to monitor their movement, thermal experience, and growth rates. The bulk of this monitoring effort has been conducted by the Juvenile Salmonid Production Project at 3 sentinel sites on each of Murderer's Creek, Black Canyon Creek, and one site on Deer Creek. These sites represent a broad range of habitat characteristics and thermal regimes, making them ideal locations to evaluate how local populations of juvenile *O. mykiss* respond to reach specific habitat conditions. Results to date suggest that temperature alone does not explain observed variability in juvenile *O. mykiss* growth rates.

To address the importance of food availability as a determinate of juvenile *O. mykiss* growth, the Invertebrate Productivity Monitoring Project has collected invertebrate drift and benthic samples at all seven sentinel sites during the summers of 2005 and 2006. In addition, diet samples of roughly 30 *O. mykiss* have also been sampled at each sentinel site to evaluate the relative importance of specific invertebrate taxa and prey size classes as prey items. From this information, several metrics of invertebrate abundance will be derived that are thought to be descriptive of food resource availability that include the total density (number of individuals) and biomass of aquatic invertebrates. Metrics of invertebrate abundance that provide the best description of prey availability will be selected based on their correlation with *O. mykiss* consumption rates as estimated through bioenergetics modeling.

Bioenergetics models offer an attractive tool for studying relationships between fish growth and environmental factors such as prey availability and temperature (Hanson et al. 1997). Bioenergetics models are based on an energy budget equation where:

$$\text{Consumption} = \text{growth} + \text{metabolism} + \text{wastes}$$

In this equation, consumption is estimated as the sum of energy attributed to growth, temperature dependent metabolic requirements, and waste. Variation in metabolic rates as a function of temperature has been studied extensively in the laboratory for many salmonid species, and exhibits low variation among individuals (Rand et al. 1993). Thus, the bioenergetics model can be used to estimate consumption over a range of environmental conditions for time intervals where fish growth and stream temperature information are available (Stewart et al. 1981). Coupling of the extensive juvenile *O. mykiss* growth, temperature, and invertebrate food availability sampling in the SFJD may allow development of a relationship between fish consumption and prey abundance. From this simple relationship, bioenergetics modeling could be used to estimate salmonid growth potentials for stream reaches where temperature and invertebrate information have been collected. This information would allow inference into how these factors may be limiting production.

Objective 3

Unfortunately, drift samples have not been sampled in most monitoring programs. However, if there is relationship between benthic invertebrate counts and drift biomass then benthic invertebrate sampling from past and current monitoring programs can be used to provide an indirect estimate of fish growth. In addition to the drift samples collected in this project, benthic samples have also been collected at each sentinel site for each sample date using kick net methods common in other monitoring programs. In addition, the PIBO monitoring program, which currently collects kick net samples of benthic invertebrates, agreed to sample ~ 35 of their sites (2 reps each) to provide paired samples for this project to develop this relationship.

Growth potential models

The ISEMP John Day pilot project is developing a model to map potential fish growth across stream reaches of the John Day by combining models that estimate heat budgets based on physical inputs and bioenergetics models that use these heat budgets and invertebrate abundance information to estimate fish growth.

Funding Agencies
Bonneville Power Administration
National Oceanic and Atmospheric Administration

Contractors
Eco Logical Research, Inc.

Time Line

This analysis and data collection is ongoing. The preliminary results to date are based on initial field sampling and analysis, the ongoing project will yield results and recommendations on improved monitoring and analysis approaches for assessing aquatic habitat productivity and restoration potential. These next generation products will be generally useful for the fisheries management community in the Pacific Northwest.

What's been accomplished so far

The ISEMP John Day pilot project is developing a model to map potential fish growth across stream reaches of the John Day by combining models that estimate heat budgets based on physical inputs and bioenergetics models that use these heat budgets and invertebrate abundance information to estimate fish growth.

The Heat Source model (Boyd and Kasper 2002) used in the John Day TMDL process uses physical processes to define a heat budget for a reach. These physical processes (e.g. the rate that solar inputs heat water) are somewhat more predictable than ecological interactions. Watershed Sciences is developing algorithms to process LiDAR information that can be used as direct inputs into the Heat Source model. As is done in the TMDL process, impacts of different scenarios, such as the increase of the riparian canopy through a riparian fencing project or increased discharge by purchasing instream water rights, on stream temperature can be estimated with the Heat Source model.

The rate at which respiration and the maximum consumption rate changes as a function of temperature and body size has been determined for several fish species (Hanson et al. 1997). These processes have been summarized into bioenergetic models that allow for examination of factors affecting growth and consumption rates. The basic physiological processes affecting these rates exhibit little variability among individuals. Bioenergetics models use a mass balance equation to describe growth as:

$$\text{Growth} = \text{consumption} - (\text{respiration} + \text{wastes})$$

Respiration and waste can be further divided into more specific functions that have been well established in the laboratory (Hanson et al. 1997). The equation can also be rewritten as:

Consumption = growth+(respiration + wastes)

Therefore growth and temperature can be measured in the field and consumption required to maintain metabolism and obtain the observed growth rates can be estimated with the bioenergetics model (Figure 84). Consumption is generally described as the P-value or the percent of the maximum consumption possible at a given temperature. A P-value of 1.0 suggests that fish are consuming at their maximum capacity. Generally P-values are much less than 1.0 with P-value~0.4 often observed (Railsback and Rose 1999).

What is less well understood are the ecological relationships determining the amount of food consumed and thus a prediction of growth rate. One potential use of the invertebrate information (drift and/or benthic samples) collected in the SFJD (see Invertebrate Production Project) is to develop a relationship between prey density and temperature dependent consumption rates. Relationships between prey density and percent maximum consumption (as estimated by the bioenergetics model) have been observed with other fishes with some success. This simple relationship could be used to estimate growth potential of different stream reaches that have temperature information and invertebrate abundance estimates. Incorporated with the Heat Source model, which describes temperature regimes under restored and current conditions, these sets of models could identify where temperature and invertebrate production limits fish production. Restoration activities addressing these factors can then be prescribed for these reaches.

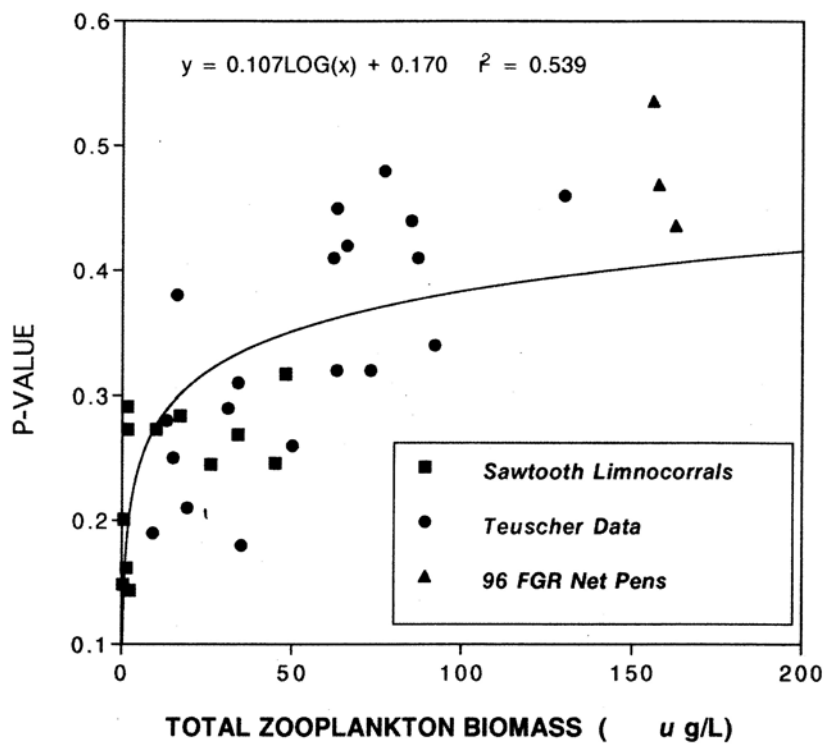

Figure 84. The proportion of the size and temperature dependent maximum consumption rate (P-VALUE) observed for juvenile kokanee as a function of the average density of zooplankton biomass available over the period growth was observed. Data were

collected in limnocorrals in Redfish Lake, ID, and in limnocorrals and net pens in Flaming Gorge Reservoir, UT/WY (from Budy 1996).

Below is a description of steps that have or will be taken to develop the model described above. We provide some preliminary results of a growth profile based on a temperature profile observed with TIR in the SFJD River. We plan to incorporate long-term temperature, LiDAR, flow, and habitat information to parameterize the Heat Source model for the SFJD subbasin as model development continues.

Methods

A multi-step approach is described in this report on how growth potential will be estimated on a reach-by-reach basis in the John Day. First, we will use empirical temperature data collected by temperature loggers and interpolated between loggers using TIR imagery. Ideally, we would characterize the daily or weekly longitudinal temperature profile of streams over a one-year period. For each reach and each time step a growth rate would be estimated assuming a P-value. Growth would be added over the year and compared to the maximum growth rate possible at an optimal temperature and given P-value (Frame A, Figure 85). A longitudinal profile of relative growth could then be summarized (Frame A, Figure 85).

Next, we plan to use the Heat Source model to describe longitudinal temperature profiles. Information requirements for Heat Source will be collected and formatted for parameter inputs. The model will be calibrated and validated against observed temperature profiles. The model can then be used to estimate temperature changes and ultimately fish growth potential under different scenarios (Frames A&B, Figure 85). This model must assume a constant P-value across space and time, which may be unreasonable for several reasons discussed below, but in particular because food resources may not be distributed equally across space. Therefore, a model that looks at food resources will also be evaluated.

The aim of the Invertebrate Production Project is to describe food availability to *O. mykiss* by reach. Drift nets are used to sample invertebrates, the major food item for *O. mykiss*, and correlate this to consumption rates observed in the Juvenile Production Project as was done by Budy and Luecke (1996). If this relationship can be determined for *O. mykiss* then this can be combined with the Heat Source/bioenergetics model to address the assumption of a constant P-value across space (Figure 86). In addition, attempts are being made in the Invertebrate Production Project to predict invertebrate abundance through temperature, and perhaps other habitat features, to get a better description of temporal and spatial patterns of food resources that will address the assumption of constant P-values through time and interpolate between reaches without invertebrate data. Finally, fish growth estimates can be combined with empirical fish densities to estimate total fish production or g fish·m-2·yr (Figure 86).

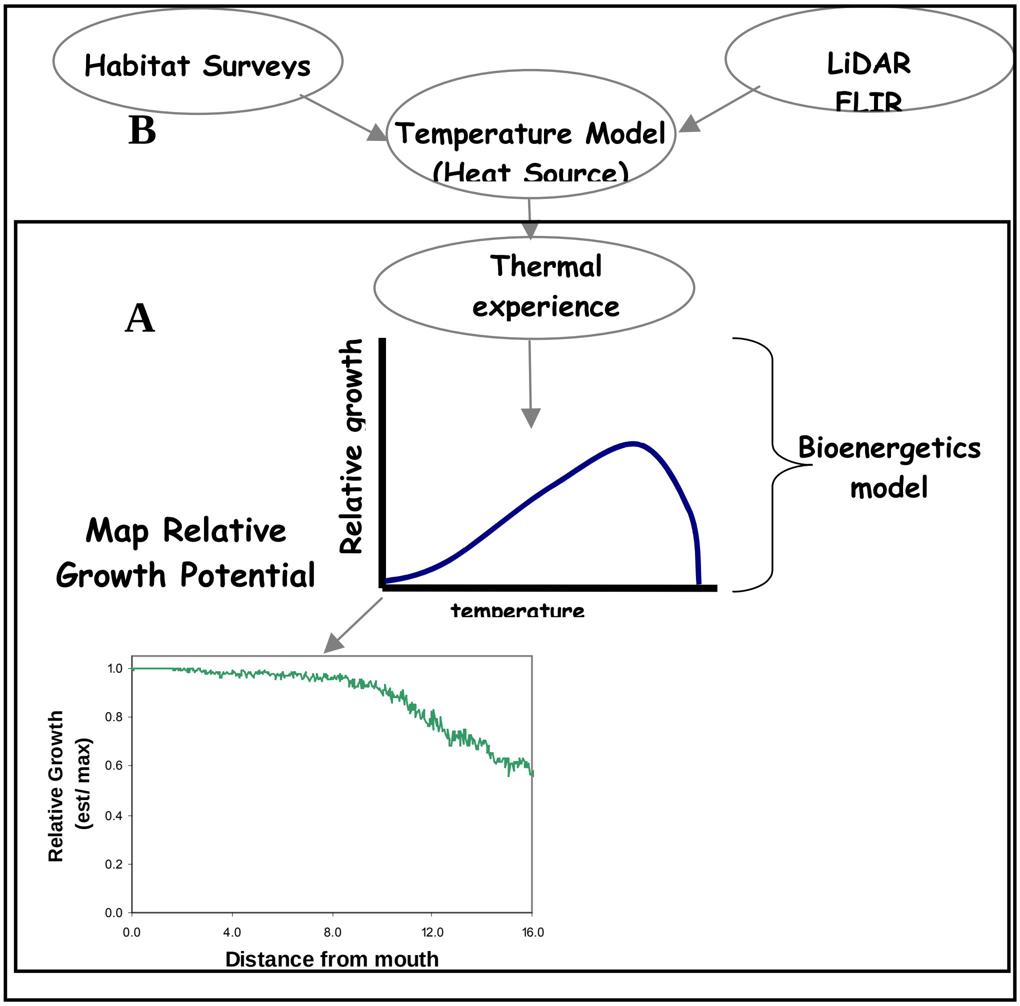

Figure 85. (A) Schematic of the approach used to estimate relative growth potential (as proportion of maximum growth achievable under optimal temperature and given *P*-value) using temperature profiles. (B) Schematic of how the Heat Source model would be used to describe temperature profiles and linked to model A.

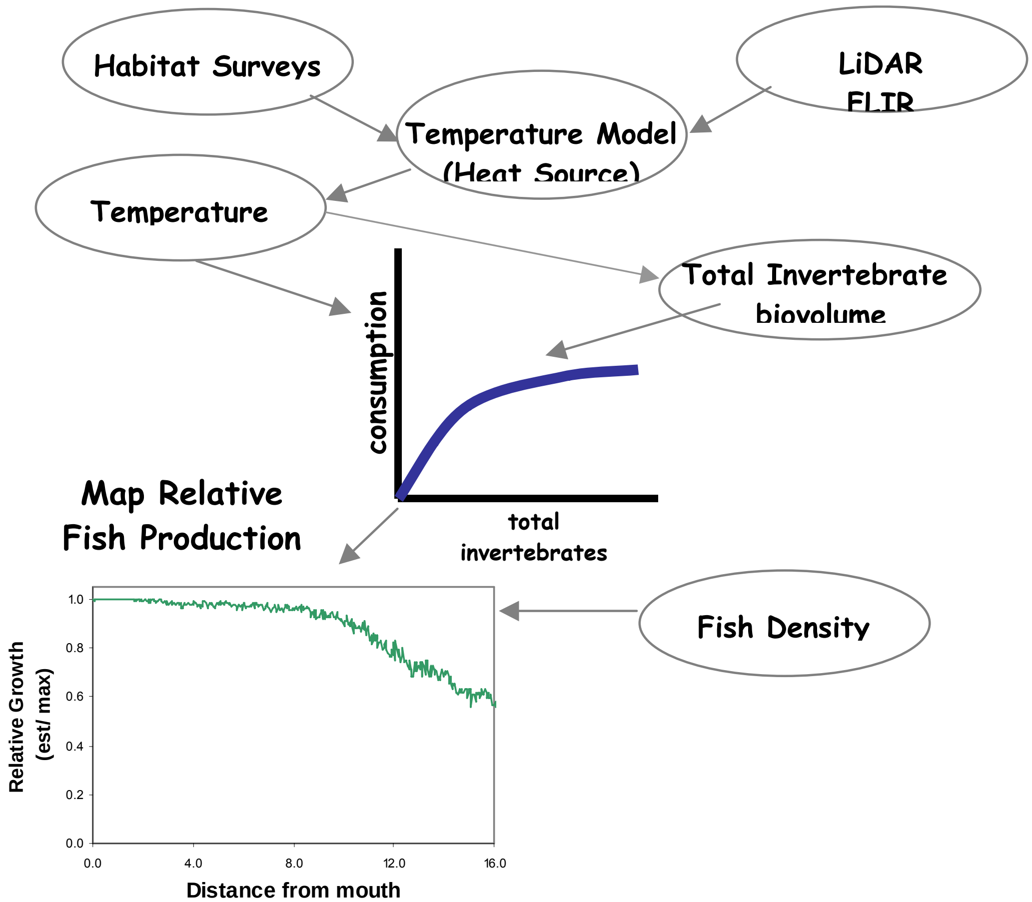

Figure 86. Schematic of the approach used to estimate relative fish production potential (as proportion of maximum growth achievable under optimal temperature and given P-value) using temperature profiles estimated by the Heat Source model, empirical information invertebrates or estimates through habitat/invertebrate relationships, the relationship between invertebrates density and consumption rate, and empirical fish densities.

Bioenergetics model

We used the equations described in the Wisconsin bioenergetics model for steelhead (Hanson et al. 1997). The physiological processes responsible for *O. mykiss* growth have been extensively evaluated in the laboratory and are well understood and documented (Rand et al. 1993). Some of these parameter settings have been revised and documented in Railsback and Rose (1999). We used the same parameter settings for the consumption, respiration, specific dynamic activity, egestion, and excretion equations as described in Railsback and Rose (1999; Table 56). We also used the same energy densities for prey and red band trout (*O. mykiss*) and P-value = 0.4 as in Railsback and Rose (1999; Table 56). We developed the same temperature dependence curve for relative growth rate for a 10 g red band trout at P-value of 0.4 as depicted in (Railsback and Rose 1999; Figure 87).

Table 56: The parameter settings used in the Wisconsin bioenergetics model (Hanson et al. 1997) for red band trout in the South Fork of the John Day River. Parameters are same as those used by Railsback and Rose (1999).

Equation and parameter	Value
Consumption equation 3	
CA	0.628
CB	-0.3
CQ	3.5
CTO	25.0
CTM	22.5
CTL	24.3
CK1	0.20
CK4	0.20
Respiration equation 2	
RA	0.013
RB	-0.217
RQ	2.2
RTO	22
RTM	26
RTL	0
RK1	0
Activity	1.3
SDA	0.175
Prey energy density	2,500 J/g
Predator energy density	5,900 J/g

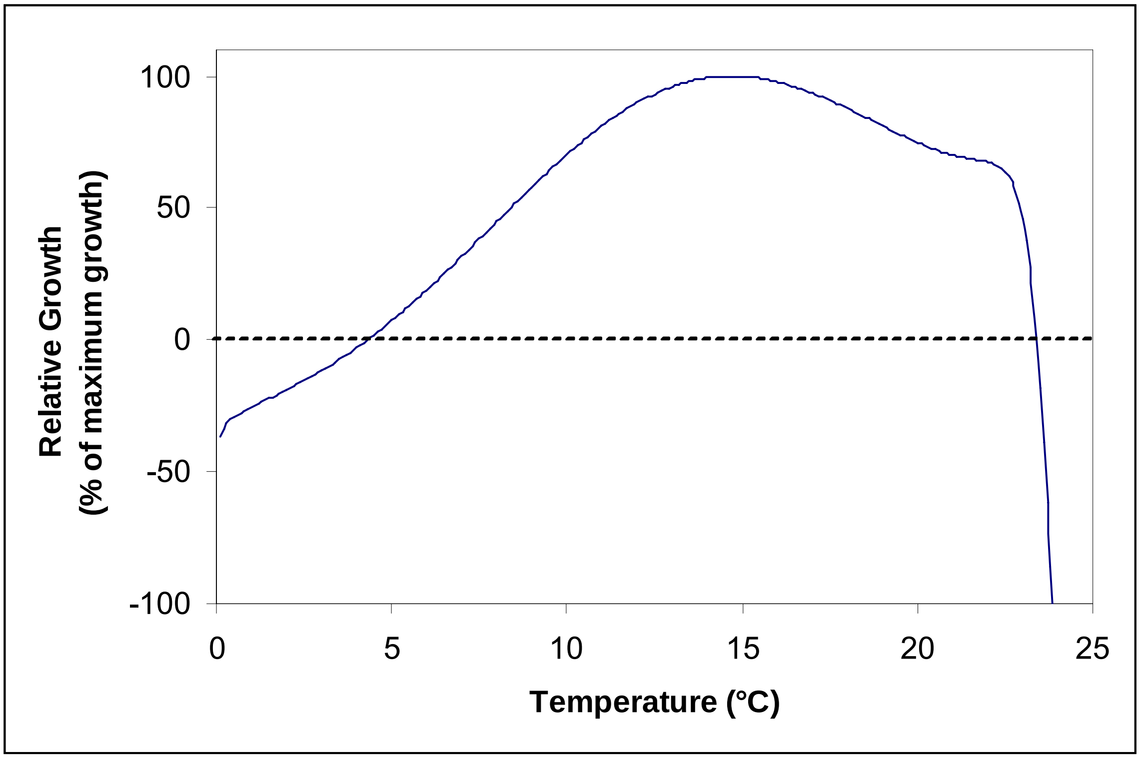

Figure 87. The growth potential of a 10 g red band trout as a percentage of the maximum growth that can occur for a P-value=0.4. Optimal temperature at this P-value is 14.7 °C.

South Fork John Day Stream Temperature Modeling

LiDAR, TIR, and ground level data will be incorporated into the Heat Source stream temperature model. LiDAR data was collected on the South Fork John Day River, Murderers Creek, and Black Canyon Creek in March 2005. LiDAR products include 1-meter resolution bare earth and vegetation rasters. TIR stream temperature data was collected in August 2004. The TIR data provides a continuous longitudinal temperature profile of the stream. Ground level data, including stream flows, hourly instream temperatures and channel morphology measurements are also available.

The model input/output nodes will be evenly spaced a maximum of every 50 m along the stream (optimal distance step will be determined during model set up and calibration). The following Heat Source inputs will be derived using automated GIS sampling routines (using the TTools extension).

Model inputs derived from LiDAR data include:

- Stream flow paths
- Stream elevation
- Stream gradient
- Stream aspect
- Topographic shade angles
- Vegetation locations and heights

Model inputs derived from TIR data include:

- Longitudinal stream temperature profile
- Tributary inflows
- Spring inflows
- Hyporheic inflows
- Point source return flows

Heat Source will generate outputs at the same distance step used for the inputs. Primary outputs will include hourly stream temperature and effective shade values.

The model will be calibrated to the year that the TIR data was collected (2004). Once calibrated, future vegetation, channel morphology, and flow scenarios will be simulated in order to quantify potential improvements in stream temperature and effective shade. The Heat Source model has been used in several TMDL analyses throughout Oregon. For example, the Heat Source model was used in the Walla Walla River to describe thermal longitudinal profiles under several scenarios (Figure 88).

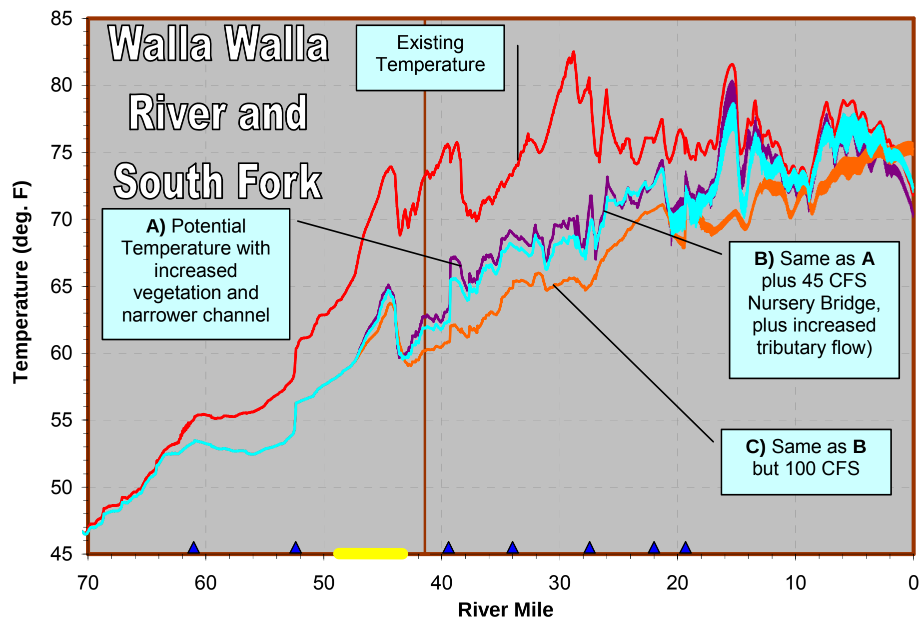

Figure 88. Heat Source estimates of the existing temperature profiles of the Walla Walla River and under different scenarios. Scenario A includes vegetation restoration and expected natural channel restructuring with increased vegetation. Scenario B includes this restoration plus increase tributary flows and 45 CFS at Nursery Bridge. Scenario C is the same as Scenario B but includes 100 CFS at Nursery Bridge rather than 45 CFS.

The bioenergetics model will be incorporated with Heat Source, either by embedding the algorithms within the Heat Source model, or by tailoring Heat Source outputs for direct use within a separate bioenergetics model.

The following images exemplify the high resolution stream temperature modeling nodes, 1-meter LiDAR data, and TIR stream temperature profile. Figure 89 shows the area that LiDAR was collected (yellow) and the sub-area used for Figure 90, Figure 91, and Figure 92 (red).

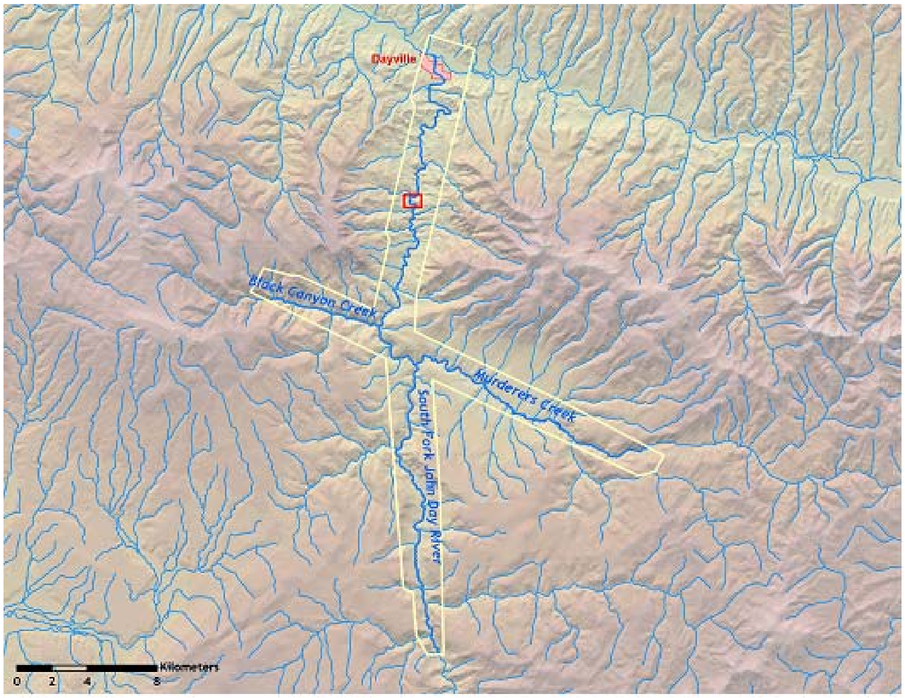

Figure 89. South Fork John Day LiDAR Coverage (Yellow) and Example Area (Red).

Figure 90. True Color Photo - South Fork John Day River near Tunnel Creek.

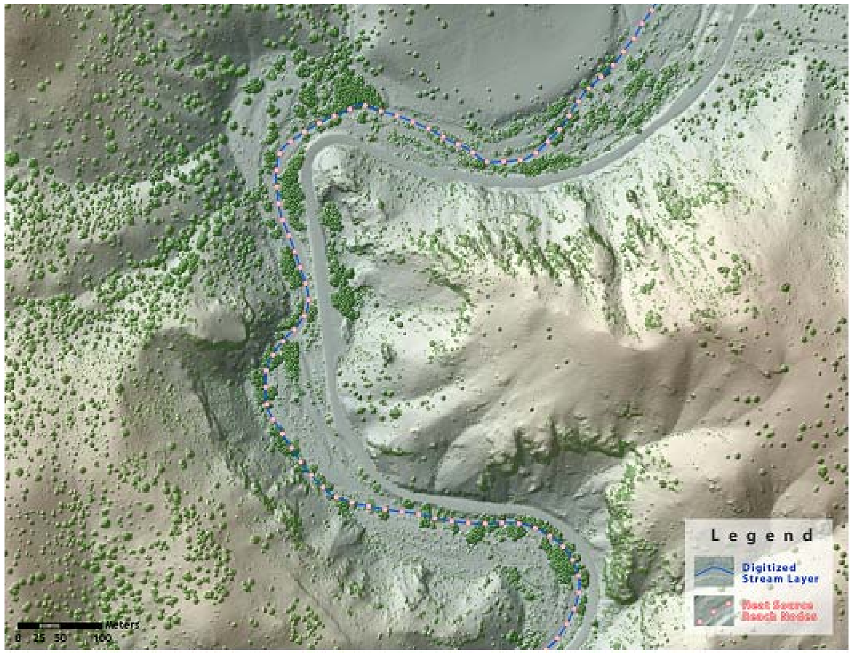

Figure 91. Vegetation LiDAR Raster with stream path and Heat Source input nodes

Figure 92. Bare Earth LiDAR Raster with stream path and Heat Source input nodes.

Figure 92 shows the TIR stream temperature profile of the SFJD River. Tributaries and springs/seeps were identified and their surface temperatures were also measured. This stream temperature profile is representative of Heat Source simulation output resolution.

Results

The relative growth profile was created from the TIR collected in August 2004 (Figure 93). Anadromous red band trout are limited in the upstream extent by the impassable Izee Falls (labeled SF falls) at approximately river mile 27. On this date in several reaches where temperature exceeded 23.5 °C, growth rates were negative and would likely lead to mortality if fish were to stay in this reach for longer periods of time. However, several sections of stream were suitable for fish to attain 80-90% of the maximum growth rate at this P-value (0.4), with 100% of maximum growth observed at 14.7 °C.

The influence of altering the P-value, which is another expression of altering consumption or perhaps invertebrate abundance, was also explored. We changed P-value to 0.9, 0.6, 0.33 in Figure 94, Figure 95, and Figure 96, respectively. Increasing the amount of food that is consumed resulted in an increase in the thermal optima and the amount of available energy for growth. At a P-value = 0.9 in nearly all reaches of the South Fork growth was near 100% of maximum growth (Figure 94). Only in reaches greater than 23˚C did growth drop to approximately 50%. A similar result was observed with a P-value = 0.6 (Figure 95); however, absolute growth was less than at P-value = 0.9. However, when P-value was lowered to 0.33 very few reaches below the falls were available for growth (Figure 96). At P-value ≤ 0.31 growth was not possible anywhere in the SFJD.

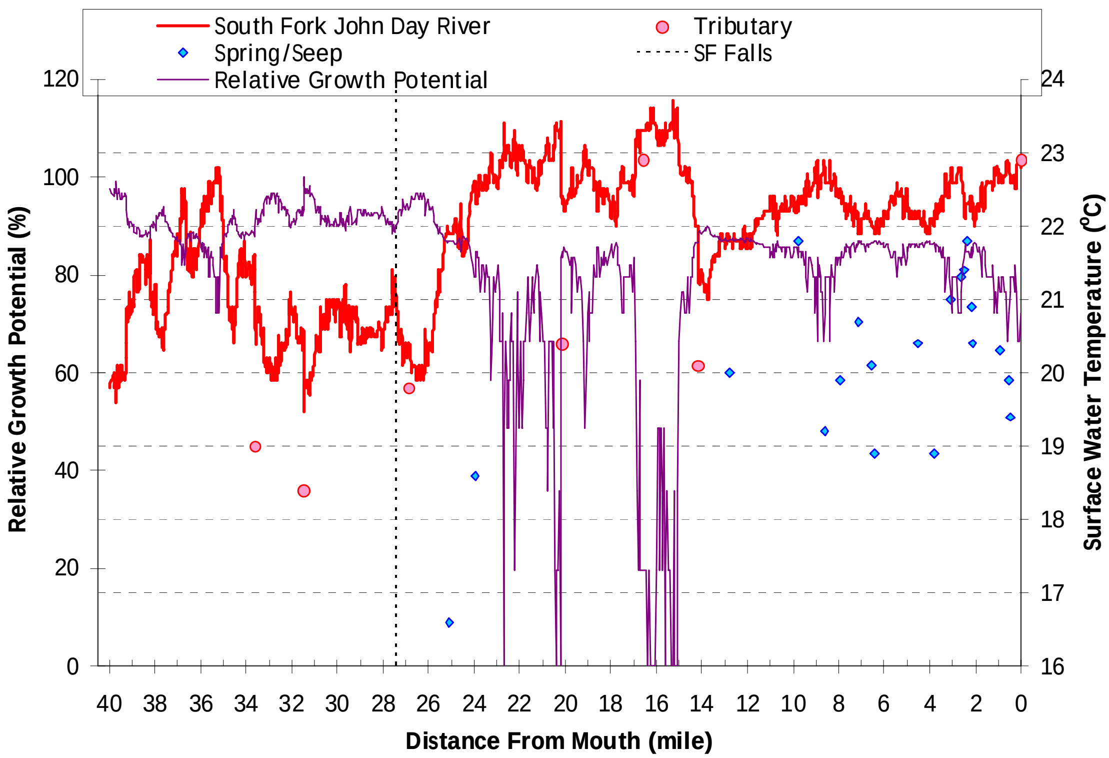

Figure 93. The relative growth potential of a 10 g juvenile red band trout assuming a P-value=0.4, along the South Fork John Day River, with TIR stream temperatures on collected on 8/19/2004, 15:47-17:06 as reference.

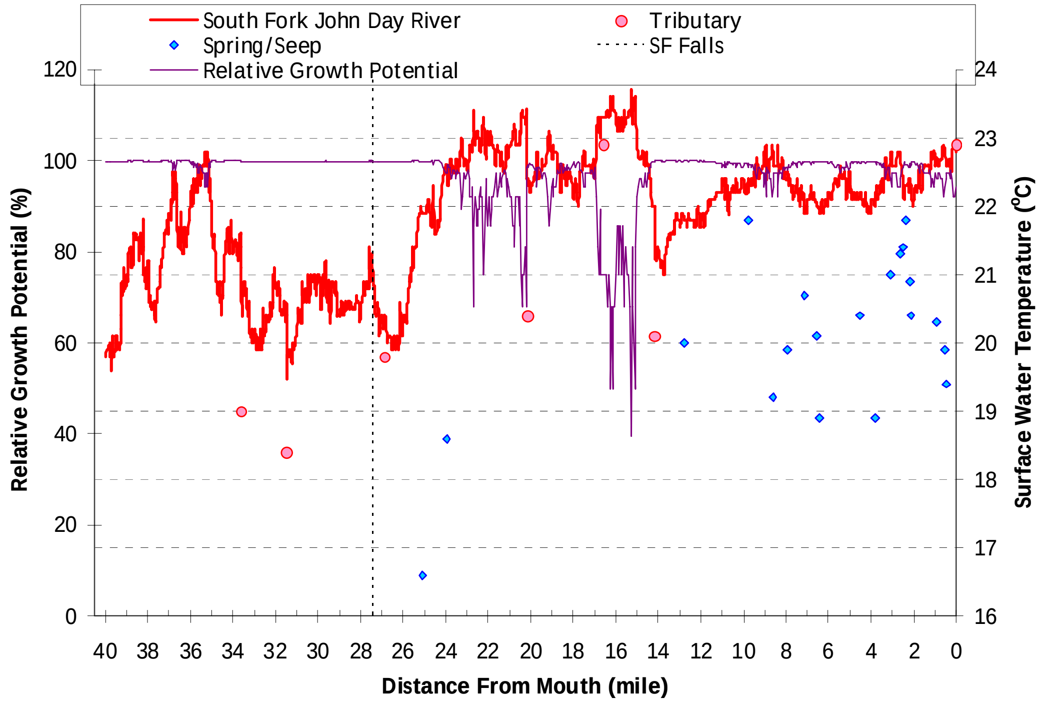

Figure 94. The relative growth potential of a 10 g juvenile red band trout assuming a *P*-value=0.9, along the South Fork John Day River, with TIR stream temperatures on collected on 8/19/2004, 15:47-17:06 as reference.

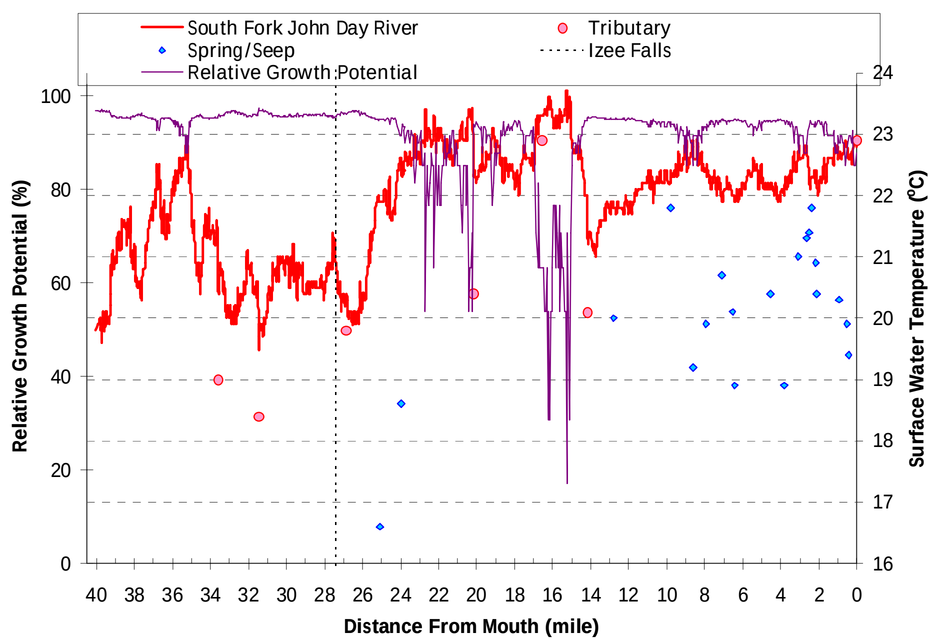

Figure 95. The relative growth potential of a 10 g juvenile red band trout assuming a *P*-value=0.6, along the South Fork John Day River, with TIR stream temperatures on collected on 8/19/2004, 15:47-17:06 as reference.

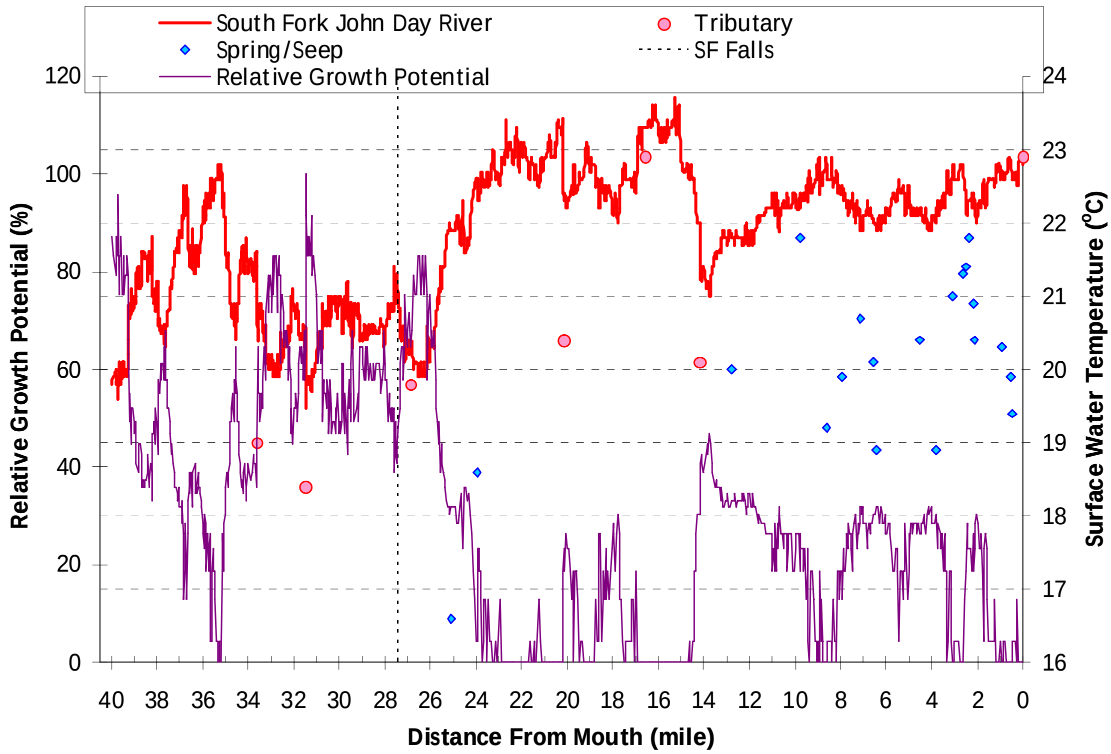

Figure 96. The relative growth potential of a 10 g juvenile red band trout assuming a P-value = 0.33, along the South Fork John Day River, with TIR stream temperatures on collected on 8/19/2004, 15:47-17:06 as reference.

Discussion

The interaction between food and temperature is complex. Both maximum consumption and respiration rates increase as a function of temperature; however, they decrease at different rates. This is further complicated when fish do not consume their maximum consumption rate. When food consumption is low, the rate of increase of energy spent through respiration is greater than energy intake, and thus fish growth is reduced especially as temperature become warmer. However, if consumption rate is sufficient, energy intake will exceed respiration at a faster rate allowing for greater a range of temperature where an increase in growth will be observed.

The above results highlight the need to understand how food resources are distributed across reaches. This conclusion is consistent with Railsback and Rose (1999), who suggested that food resources were as or more important than temperature for influencing growth of juvenile *O. mykiss***.** We hope to gain insight into the availability of food resources from the Invertebrate Production project initiated by the ISEMP project.

As we observed in this exercise, the South Fork temperature range on this date (near maximum observed temperatures for the year) is within the range suitable for red band trout if they are allowed to feed near their maximum consumption rate. However, this condition is rarely observed with stream dwelling salmonids, with consumption rates perhaps limited not only by quantity but also quality of food. We anticipate the incorporation of information pertaining to invertebrate abundance will greatly influence the relative growth profile of the South Fork.

What learn from this example that there is a temperature range where growth is high across a large range of *P*-values. At temperatures observed just above and just below the falls, growth rates were positive across all *P*-values > 0.31 in the South Fork. From a precautionary management perspective, restoration actions that can lower temperatures to approximately 19˚C would allow for >45% positive relative fish growth across a large range of invertebrate densities found in streams. It is in this context that we expect the Heat Source component of this model to be extremely valuable. This model might identify restoration scenarios where this temperature regime is attainable.

Habitat Protocol Comparison Study

Monitoring programs throughout the Pacific Northwest use a variety of protocols to describe the same general metric. Data collected under different protocols are not comparable, preventing an aggregation of data to address larger scale management questions. The ISEMP is testing multiple protocols and sampling designs in a coordinated fashion within the Wenatchee/Entiat subbasins to identify feasible and effective alternatives to legacy monitoring approaches. In the summer of 2005, Upper Columbia Monitoring Strategy protocols for sampling fish habitat were compared with other protocols in use in the Pacific Northwest as part of a "Side-by-Side" protocol comparison experiment organized by the PNAMP.

Funding Agency

Bonneville Power Administration

National Atmospheric and Oceanic Administration-Fisheries

Contractor

BioAnalysts, Inc.

Colville Confederated Tribes/KWA, Inc

Terraqua, Inc.

Time Line

The ISEMP protocols were tested in a PNAMP "Side-by-Side" protocol comparison experiment in 2005. Many of the other protocol comparisons we are conducting require long-term datasets and are scheduled for completion in 2009 after 5 years of ISEMP data collection.

Budget

Contractor	Scope of Work	FY05
Terraqua, Inc.	Environmental Compliance	$372
Terraqua, Inc.	Study design, coordination, data summary	$3,947
Terraqua, Inc.	2 field crew leaders, 1 field technician	$43,448
BioAnalysts, Inc	1 field crew leader	$16,474
CCT/KWA Inc.	2 field technicians	$33,000
	PNAMP Side-by-Side study	$1,385
	Total PNAMP Side-by-Side protocol test budget:	$98,626

What's been accomplished so far

- ✓ A number of habitat protocols comparisons are ongoing since 2004 and require 5 years of data before final analysis (e.g. LWD counts by various size classes; riparian vegetation quantification by visual estimation and densiometer and satellite imagery; pool frequency by visual estimation and longitudinal elevation-profile surveys; etc). Some were tested in individual years (2004 and 2005) and results are yet to be analyzed.
- ✓ Snorkel survey temporal study.

✓ Beginning in 2004, protocol differences between the ISEMP and OBMEP were identified. Currently, a number of comparisons between these protocols are underway using data collected in 2005 by ISEMP habitat crews in the Entiat. Relative levels of variability between the alternate approaches will be compared and we will attempt to develop "cross-walks" that will allow users to compare data from alternate protocols with each other.

✓ In the summer of 2005, Upper Columbia Monitoring Strategy protocols for sampling fish habitat were compared with other protocols in use in the Pacific Northwest as part of a "Side-by-Side" protocol comparison experiment organized by the PNAMP. Habitat surveys were conducted at each of 12 stream sites in the John Day subbasin by three crews each representing survey protocols in use by six different programs. Overall study design was conducted according to the Roper (2005) study design, the ISAB (2004) study design review, and according to the results of the PNAMP coordination meetings. These study design documents specify that survey crews should be hired, trained, and conduct habitat surveys consistent with the protocol being represented. Terraqua, Inc. collected, validated, and collated data collected as part of this study and transmitted it to the PNAMP for statistical analysis. Final data analysis by the PNAMP is anticipated by the end of 2006.

What's ahead

- Data analysis tool development will focus on the creation of a standard process to reduce status and trend monitoring data generated by the pilot project, calculate standard habitat metrics, calculate statistical summary metrics, and develop indicators of habitat metrics relevant to biological populations of interest. The construction of RME data management infrastructure and storage tools will consider the needs, structure, and process of the data reduction process. Both analysis and storage tools will facilitate data sharing, analysis, and management at local and regional scales, encouraging further analysis tool development within the RME program.
- Evaluate protocol comparisons conducted in the Wenatchee and John Day subbasins in 2004-2006, investigate the partitioning of environmental and spatial site variability and develop effective methodologies for determining sample sizes for field sampling efforts with respect to program goals. Analysis and data reduction tools will prepare data for statistical comparisons of data collected within protocol testing scenarios. Further determination of sample size and spatial sampling designs will be tested by comparing data variability at multiple spatial scales, and answering questions related to landscape representation (e.g., What attributes of the landscape are captured with current monitoring sample designs?).
- Modeling and a basic regression approach will be used to determine mechanistic linkages among habitat condition and response variables. Regression analyses will identify habitat and response variables potentially linked through cause and effect at multiple spatial scales. Data generated for RME projects will be used to evaluate mechanistic models used by recovery and subbasin planning efforts (e.g., SHIRAZ, SWAM, HeatSource, EDT) to predict fish distribution based on limiting factors of basins.
- The ISEMP will continue characterizing the inherent fish production potential and human impacts throughout the Columbia River Basin using multiple GIS approaches. The effectiveness of any stream restoration strategy will be heavily dependant on the landscape level context in which the project is implemented. To be able to interpret the effectiveness of a restoration strategy, we need to place restoration sites within the context of the site's inherent fish production potential and human impacts to fish production.
- With the proliferation of geo-spatial data and the increasing complexity of analyses being performed on geo-spatial data, more advanced data structures are needed to manage these data and perform the analyses. We will refine our current geodatabase to include geometric network-based data structures so that we can define the relationship between monitoring points or reaches and their upstream catchments, identify all streams or catchments upstream or downstream of points on the network, and calculate network distance between monitoring points to support the landscape scale analysis of monitoring data.
- The GIS-based landscape classification process will be completed. We will develop test statistics to determine the number of naturally occurring classes within the

process. In addition to completing the multi-dimensional classification of inherent fish production potential, we will perform a similar analysis on human impacts to fish production. This will require developing appropriate data layers representing human population density, road density, forest age, agricultural clearing, and stream reaches influence by dam, barriers, or other hydro modifications.

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