PROJECT MONITORING: A GUIDE FOR SPONSORS IN THE UPPER COLUMBIA BASIN

First Edition

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Prepared by:
Tracy W. Hillman
BioAnalysts, Inc.
Boise, Idaho

Prepared for:
Chelan County Natural Resource Department
Wenatchee, Washington

TABLE OF CONTENTS

PREFACE

This document was prepared at the request of Chelan County and the Upper Columbia Regional Technical Team (RTT) to help guide project sponsors in developing simple, cost-effective monitoring plans for assessing the effectiveness of restoration projects funded by the Salmon Recovery Funding Board (SRFB) and the Habitat Conservation Plans (HCPs) Tributary Funds. Both programs require some level of effectiveness monitoring; however, as stated in the HCPs Tributary Assessment Program, "[i]t is not the intent of the tributary assessment program to measure whether the Plan Species Account has provided a 2% increase in survival for Plan Species. Instead, the program has been established to ensure that the dollars allocated to the Plan Species Account are utilized in an effective and efficient manner." Therefore, although some level of effectiveness monitoring is required, it is not the responsibility of the sponsor to measure changes in fish survival.

With this in mind, this guidance document was prepared to assist sponsors in developing monitoring plans for evaluating the effectiveness of restoration actions in the Upper Columbia Basin. This document describes the <u>minimum</u> amount of monitoring needed to demonstrate the effectiveness of stream restoration actions. If a sponsor so desires, they can propose a more "intensive" monitoring plan, but they must understand that other monitoring programs designed to assess population responses to restoration actions may already be implemented. Thus, if a sponsor intends to implement a more intensive monitoring plan, they will need to demonstrate how it is coordinated with and linked to the other intensive programs.

It is important to note that there is no single monitoring design or plan that satisfies all restoration projects. Every project is unique and has specific goals and objectives. Therefore, each monitoring plan will be unique, because it must be tailored to fit the goals and objectives of the restoration action. This makes it a bit challenging for project sponsors, because there is no easy-to-follow recipe that directs exactly how to monitor diverse restoration efforts. The good news, however, is that there are logical steps that can be followed that should result in the development of cost-effective monitoring plans. In this document I describe the steps needed to develop an effectiveness monitoring plan and provide several examples that hopefully will aid sponsors in designing valid monitoring plans.

I thank Chelan County Natural Resource Department (CCNRD) for funding this work. I appreciate the helpful discussions and comments from Mike Kaputa, Joy Juelson, Julie Pyper, John Arterburn, Charlie Paulsen, Jim Geiselman, Chuck Peven, Kate Terrell, Mike Ward, Casey Baldwin, Ken MacDonald, Bob Bugert, Brian Cates, and Joe Kelly. This work was greatly informed by the work of Philip Roni, who recently edited an excellent book on monitoring stream and watershed restoration projects (Roni 2005). His book provides sponsors, managers, and scientists with a detailed description of effectiveness monitoring.

SECTION 1: INTRODUCTION

The loss of habitat complexity and diversity, connectivity, water quantity and quality, and riparian function in some stream reaches in the Upper Columbia Basin has led to efforts to restore aquatic habitats for economic, cultural, and environmental reasons. As a result, each year millions of dollars are invested in restoring or improving habitat to increase both resident and anadromous fish populations. Although much effort goes into restoration work, relatively little goes into monitoring the effectiveness of restoration actions. Given the debate among scientists about the effectiveness of various restoration techniques and the financial investment in restoration, it is unfortunate that monitoring has not been an essential component of designing restoration projects.

Many funding entities (e.g., Habitat Conservation Plans Tributary Fund, Salmon Recovery Funding Board, Bonneville Power Administration, etc.) now require sponsors to include some level of monitoring within the design of their restoration projects. Although this may significantly improve our understanding of the effectiveness of restoration work, there remains the question of how much monitoring is needed to demonstrate a restoration effect. This is complicated by the fact that the intent of most restoration projects is to improve the abundance, distribution, and/or diversity of fish populations, even though population parameters are often difficult and expensive to measure. Few sponsors have the expertise or resources to monitor fish populations at the spatial and temporal scales necessary to demonstrate positive restoration effects. In addition, large-scale monitoring programs (e.g., the Integrated Status and Effectiveness Monitoring Program, the Okanogan Basin Monitoring and Evaluation Program, and the Washington Salmon Recovery Funding Board Monitoring Program) are already measuring population characteristics in many locations and it is assumed that these programs will monitor the effectiveness of restoration projects at the population scale. Thus, it has not been clear how much monitoring and what type of monitoring should be included in project proposals.

The purpose of this report is to provide project sponsors with a comprehensive resource for developing cost-effective[1] monitoring and evaluation programs for restoration projects at the habitat unit (site) or reach scale. This report describes the level and type of monitoring that is needed to assess project effectiveness and which parameters (environmental and/or biological) should be measured. It is important to understand that no single monitoring approach fits all project types or scenarios. This report provides useful guidance and information on several different types of restoration monitoring, but it does not address all possible restoration projects. The general information provided in Section 1.4 and the many examples described throughout the report should provide sponsors with enough information to design a valid effectiveness monitoring plan for a specific type of restoration project.

Although I strive to provide descriptions and examples that can be understood by a broad spectrum of sponsors, I assume that most readers have some knowledge of aquatic and watershed ecology, restoration ecology, and basic principles of experimental design. It is important to recognize that restoration actions are, in essence, experiments, and as such they require valid experimental

1 The type of monitoring described in this document should in most cases constitute no more than about 5% of the proposed budget.

approaches with monitoring and evaluation so that funding entities and managers can determine which techniques are effective and worthwhile investments. For those who lack knowledge in these areas, I suggest they consult with the Washington Department of Fish and Wildlife Watershed Steward Program or with the Lead Entity. I also encourage sponsors to read the Upper Columbia Monitoring Strategy (Hillman 2004) and the excellent work by Roni (2005). These documents provide a detailed treatment on monitoring. Much of what is presented here was greatly informed by the work of Roni (2005) and Crawford (2004).

1.1 What is Restoration?

Before launching into a discussion on how to monitor and evaluate restoration projects, it is necessary to provide some background on restoration terminology and the importance of understanding ecological processes in designing appropriate restoration actions and monitoring activities. This will help the sponsor better understand the necessary components of project monitoring and the reason for measuring certain parameters (environmental and/or biological variables).

Restoration has many definitions and is therefore often misunderstood and misapplied. Within most scientific circles, restoration means returning an ecosystem to a close approximation of its undisturbed condition. Accomplishing restoration means ensuring that ecosystem structure and function are recreated or repaired, and that natural dynamic ecosystem processes are operating effectively again. Implicit in this definition is some knowledge of the undisturbed or natural state of the ecosystem. Restoration therefore depends on two assumptions. The first is that all ecosystems (streams or watersheds) should meet an “idealized” standard, quantified in terms of presently undisturbed “reference” areas. The second assumption is that in the absence of suitable reference conditions, a definition of restoration can be established through extrapolation of laboratory testing results (e.g., temperature criteria established through laboratory testing).

Under this definition, restoration is no longer possible in some locations. Some streams and rivers have been so altered that it may be impossible to ascertain the original reference condition. The process by which the environment arrived at its current condition may not be reversible. Because of the degree of anthropogenic impacts and ongoing socioeconomic constraints, it may not be possible to return some streams and rivers to a specific “pristine” or reference condition. Thus, a more general definition of restoration should include activities such as “rehabilitation,” “enhancement,” “improvement,” “reclamation,” and “creation.”

Cairns (1988) proposed three levels of restoration that capture various types of activities. He identified *full restoration* (to the original, undisturbed state), *partial restoration* (enhancement, rehabilitation, and improvement), and *habitat creation* (creating new habitat where none existed). For the purposes of this report, the term restoration covers all three levels, including many activities that restore, improve, or create habitat.

Understanding Ecological Processes

Many restoration projects fail because natural processes operating at different spatial and temporal scales and how human activities affect these processes are not well understood or considered. Implementation of successful restoration projects requires an understanding of these natural processes and the factors that control them. Because these factors and processes operate at different spatial and temporal scales, restoration ecologists need to view the river holistically as a continuous “riverscape.” The idea is that ecosystem processes operating at different scales form a nested, interdependent system where one level influences other levels. Thus, an understanding of one level is greatly informed by those levels above and below it. Furthermore, many processes that create habitat operate on time scales of decades or longer (e.g., channel migration and the formation of off-channel habitat). Interrupting natural ecosystem processes can result in the loss of fish habitat over the long term.

In simple terms, one can view the riverscape at three interconnected spatial scales: the geographic scale, the watershed scale, and the habitat/reach scale. At the geographic scale, factors such as geology, soils, vegetation, and climate serve as ultimate controls. These factors operate over large areas, are stable over long time periods, and act to shape the overall character and attainable conditions within a watershed or basin. Factors at the watershed scale are a function of geographic-scale factors and refer to more local conditions of geology, landform, and biotic processes that operate over smaller areas and shorter time periods. These factors include processes such as stream flows, temperature, sediment input, and channel migration. Factors operating at both the geographic and watershed scales help to define flow (water and sediment) characteristics, which in turn help shape habitat/reach-scale characteristics within broadly predictable ranges. Habitat/reach-scale factors include pool-riffle ratios, channel size, riparian vegetation, substrate composition, large woody debris, and bank stability. This is the scale at which fish species exploit resources and reproduce. This is also the scale at which most restoration occurs (Fausch et al. 2002).

Human activities that disrupt natural watersheds tend to act on processes that form suitable habitat conditions at the habitat/reach scale (Figure 1.1). For example, human activities can alter connectivity and the delivery of woody debris, water, sediment, and nutrients to a stream. Interruption of these processes reduces habitat quality and quantity at the habitat/reach scale by decreasing spawning and rearing space, food, and migration corridors. Likewise, restoration actions can focus on watershed processes or on habitats themselves (Figure 1.1). For example, some restoration techniques, such as re-vegetation, road removal, and establishing normative stream flows focus on restoring natural processes at the watershed scale. These techniques affect sediment supply, delivery of organic material, and channel migration. In contrast, other techniques focus on manipulating or enhancing habitat directly. Examples include wood and boulder placement, nutrient enrichment, and creating new habitat. Unless well planned, with an in-depth understanding of ultimate controls and processes across different spatial and temporal scales, most habitat-enhancement techniques tend to be relatively short lived if the underlying process that has been disrupted is not corrected.

In summary, successful restoration requires a holistic approach that considers processes operating at different spatial and temporal scales. A watershed or ecosystem assessment of current and historical conditions and disrupted processes is necessary to identify restoration opportunities that are consistent with reestablishing the natural processes and functions that create habitat. The Entiat Watershed Plan and the Upper Columbia Biological Strategy are two examples of assessments that incorporate a holistic approach. It is also essential to determine what restoration actions to implement first and how to prioritize actions. In general, restoration of watershed processes should precede or be conducted in conjunction with habitat enhancement. This is not to say that habitat enhancement techniques are inappropriate, but rather to emphasize the importance of coupling enhancement efforts with restoration of watershed processes. Clearly, in some locations (e.g., heavily urbanized areas) restoration of watershed processes may not be feasible. Habitat-enhancement techniques may be the only solution in these areas. In other areas, for example the lower Entiat River, habitat enhancement techniques fall within the context of watershed processes and therefore are appropriate restoration measures. Saldi-Caromile et al. (2004) provide useful guidelines for restoring stream habitat in Washington State.

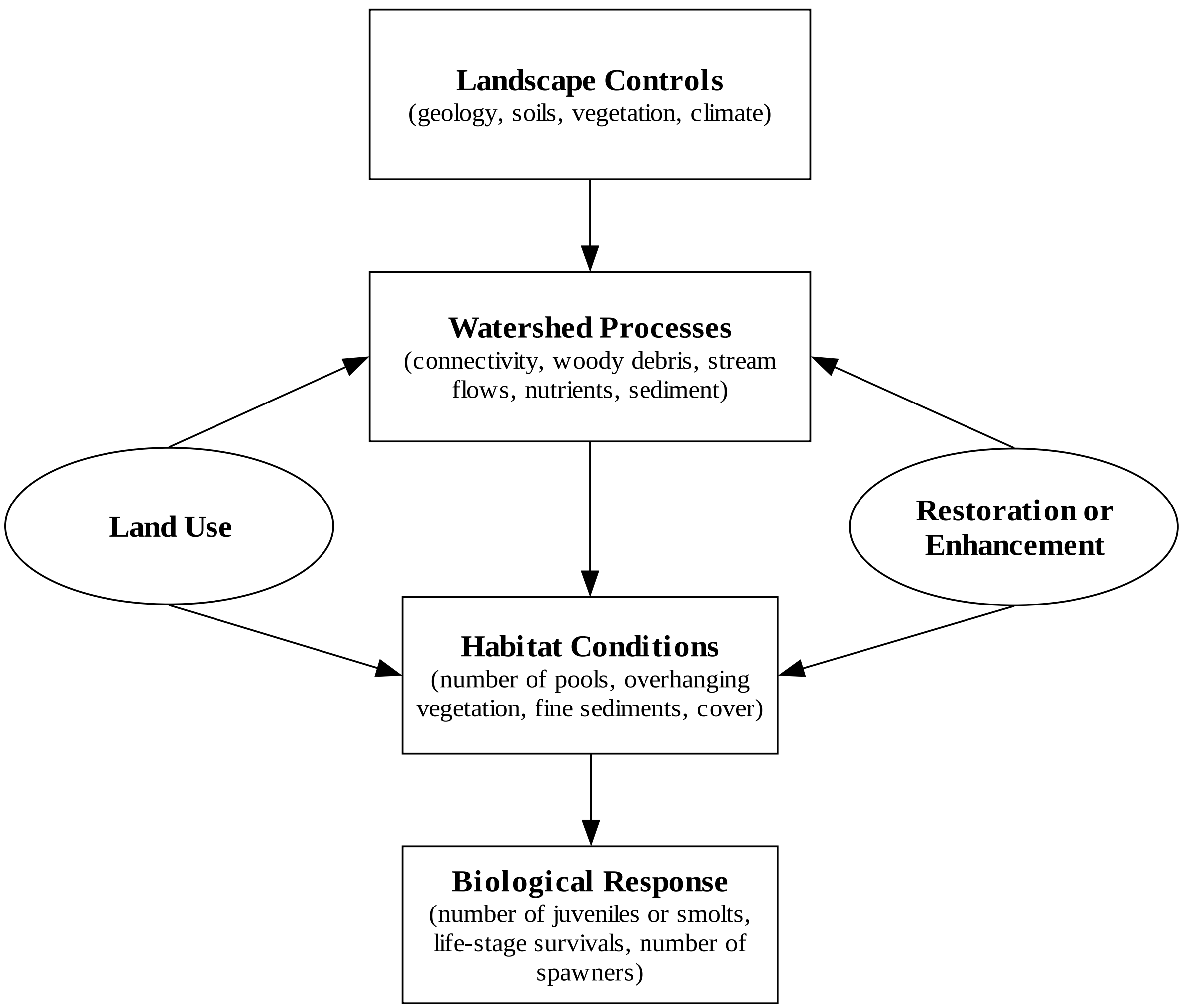

Figure 1.1. Simple model showing linkages between landscape controls and watershed processes, and how land use and restoration or enhancement can influence habitat and biota (modified from Roni 2005).

1.2 Types of Monitoring

Monitoring can be defined as a series of observations or measurements over time (MacDonald et al. 1991). Generally the purpose of monitoring is to document changes associated with the implementation of some management or restoration action. In this case, monitoring is essentially an experiment. For example, one might measure water temperatures in treatment and control sites several times before and after the planting of riparian vegetation (planting riparian vegetation is the restoration action). Here, monitoring is used to demonstrate an improvement in water quality (i.e., temperature) caused by the planting of vegetation along the stream. Importantly, monitoring is not limited to measuring temporal variability, but should describe both temporal and spatial variability. As a result, several different types of monitoring have been described. Identified below are the most common types of monitoring, following the definitions provided in MacDonald et al. (1991).

Status or Baseline Monitoring**—**Status or baseline monitoring is used to characterize existing or undisturbed conditions, and to establish a database for future comparisons. The intent of baseline monitoring is to capture temporal and spatial variability in the parameters of interest.

Trend Monitoring**—**Trend monitoring involves measurements taken at regular time intervals in order to assess the long-term trend in a particular parameter. Usually, the measurements are not taken specifically to evaluate management practices. Rather, they serve to describe changes in the parameter over time.

Implementation Monitoring**—**Implementation monitoring determines whether activities were carried out as planned. This is generally carried out as an administrative review and does not require any parameter measurements. This type of monitoring cannot directly link restoration actions to physical, chemical, or biological responses, as none of these parameters are measured.

Effectiveness Monitoring**—**Effectiveness monitoring evaluates whether the restoration activities achieved the desired effect or goal. Success may be measured against "reference areas," "baseline conditions," or "desired future conditions." *Project monitoring*, a type of effectiveness monitoring, addresses the effectiveness of a particular project.

Validation Monitoring**—**Validation monitoring has more of a research focus and verifies the basic assumptions behind effectiveness monitoring and models. For example, validation monitoring is used to assess the validity of assumptions within EDT. It is a research tool with which to examine the basic scientific understanding of how aquatic ecosystems work.

Compliance Monitoring**—**Compliance monitoring determines whether specified criteria are being met. The criteria can be numeric or descriptive. Generally, regulations associated with individual criterion specify the location, frequency, and method of measurement.

Two types are particularly useful for monitoring restoration actions in the Upper Columbia Basin: *implementation monitoring* and *effectiveness monitoring*. Both of these should (1) indicate whether the restoration actions were designed and implemented properly, (2) determine whether the restoration met the objectives, and (3) give new insights into ecosystem structure and function.

Implementation monitoring should be part of every restoration project and is normally performed during or shortly after restoration. Implementation monitoring documents the type of restoration action, the location, and whether the action was implemented properly or complies with established standards. Indicators for implementation monitoring include visual inspections, photographs, and field notes on numbers, location, quality, and area affected by the action. It does not require collection of environmental or biological data. Success is determined by comparing field notes with what was specified in the plans or proposals (detailed descriptions of engineering and design criteria). Thus, design plans and/or proposals serve as the benchmark for implementation monitoring. Any deviations from specified engineering and design criteria should be described in detail. Implementation monitoring sets the stage for other types of monitoring by demonstrating that the restoration treatments were implemented correctly and followed the design.

Effectiveness monitoring, which focuses on determining whether a recovery action had the desired physical and/or biological effect, is more complex, more difficult, and longer term than implementation monitoring. This is in part because effectiveness monitoring can occur across many different spatial scales and may involve the measurement of several different environmental and biological parameters over long periods of time. For example, if the objective is to use nutrient enrichment techniques to increase egg-smolt survival of spring Chinook in the Chiwawa Basin (a sub-population of the Wenatchee spring Chinook population), then the spatial scale covered by the monitoring study must include the entire area inhabited by the eggs, fry, parr, and smolts. If, on the other hand, the objective is to use sediment reduction techniques to increase egg-fry survival of a local group of bull trout (i.e., bull trout within a specific reach of stream), then the study area would only encompass the reach of stream used by spawners of that local group. Clearly, the objectives and hence the parameters measured dictate the spatial scale at which effectiveness monitoring is conducted. As a general rule, as the spatial scale for monitoring increases, a more complex program and a longer period of time are needed to detect a treatment effect (Figure 1.2).

Deciding how much monitoring is needed to demonstrate a restoration or treatment effect is often quite difficult. For convenience, I identify three levels of effectiveness monitoring, based on spatial scale and the parameters measured. *Level 1 effectiveness monitoring* is the minimum amount of monitoring needed to demonstrate that the restoration action has at least affected the environmental parameters that were the target of restoration. Measuring changes in biological parameters (e.g., fish abundance and survival) is not emphasized at this level of monitoring. Level 1 monitoring (also called "project monitoring" in this report) primarily relies on photographs, counts, and presence/absence surveys and is therefore inexpensive and does not require a high level of scientific expertise.

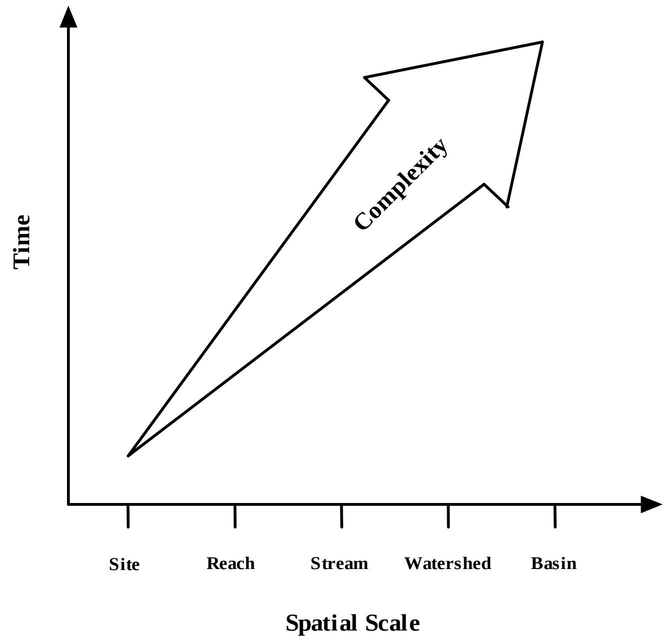

Figure 1.2. A simple, theoretical relationship among spatial scale and the complexity of the monitoring program and the time needed to detect a treatment effect.

The logic behind Level 1 effectiveness monitoring is based on the fact that restoration actions rarely affect biological parameters directly (save hatchery programs). The usual approach is to manipulate the environment (add wood, rock, vegetation, nutrients, passage, etc.) in the hope that the change in the environment will result in a desired change in the population (biological parameters). For example, one may add woody debris to a stream to increase the abundance and survival of juvenile Chinook in a stream reach. In the chain-of-causation, the "cause" is the addition of wood (treatment), which directly "affects" the stream environment (presence of woody debris is the first link in the chain). The presence of woody debris should then "affect" the abundance and survival of juvenile Chinook (biological response is the second link). Note that abundance and survival of Chinook (biological response) is more than one link from the treatment (Figure 1.3). As a general rule, the more links between the treatment (cause) and the desired effect, the more difficult it will be to detect a treatment effect. This is because several other factors may have a greater effect on the desired outcome than the treatment. Therefore, Level 1 effectiveness monitoring, as described in this report, will focus on measuring environmental responses (first link in chain-of-causation) and place less emphasis on measuring biological responses (second or higher links), which will be the focus of other monitoring programs.

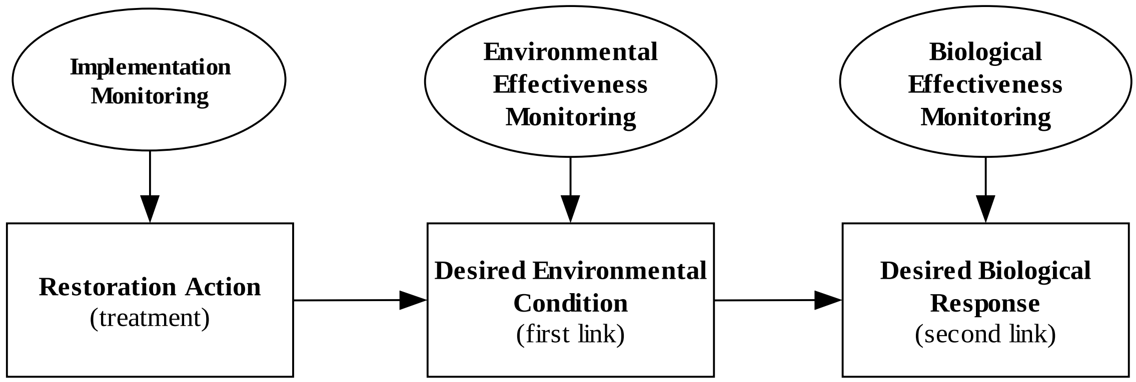

Figure 1.3. Conceptual model showing the chain-of-causation from the restoration action (treatment) to the environmental and biological responses. The type of monitoring associated with each link is also shown.

Level 2 effectiveness monitoring is similar to Level 1 but is more intensive, i.e., requires more detailed information on changes in environmental and biological parameters. This approach is also referred to as the "Bottom-Up" approach (Jordan et al. 2003) and focuses efforts on measuring desired environmental and biological effects at small spatial scales (reach or habitat scale). It is designed to assess the effects of specific projects in isolation of other restoration actions. That is, results from this type of effectiveness monitoring would not be confounded by actions occurring elsewhere in the basin. This level of effectiveness monitoring is the focus of the Washington Salmon Recovery Funding Board Monitoring Program. Some of the restoration actions implemented in the Upper Columbia Basin will be monitored by the State under their program.

Finally, *Level 3 effectiveness monitoring* is an "intensive" approach that addresses the cumulative effects of restoration actions at larger spatial scales (e.g., watershed or subbasin) over longer periods of time (decade or more). This approach is also referred to as the "Top-Down" Approach (Jordan et al. 2003). The WSRFB (2003) refers to it as "Intensive (Validation) Monitoring." This approach requires intensive and extensive sampling of several environmental and biological parameters within the watershed or basin. Although the effects of individual projects on fish populations may not be assessed unequivocally, their cumulative effects can be measured. Programs such as the Integrated Status and Effectiveness Monitoring Program and the Okanogan Basin Monitoring and Evaluation Program are designed to monitor effectiveness of restoration projects at larger spatial and temporal scales.

Both Level 2 and 3 effectiveness monitoring are beyond the scope of project sponsors. Sponsors will only be required to implement Level 1 effectiveness monitoring. The next section and the remainder of this report will provide sponsors with information that can be used to develop Level 1 effectiveness monitoring plans.

1.3 Steps for Designing Project Effectiveness Monitoring

Because restoration projects, like many management actions, are experiments, they should be implemented according to standard rules of experimental design. There are several logical steps that should be taken when designing any monitoring program. These include establishing project goals and objectives; identifying key questions and specific hypotheses; selecting the appropriate monitoring design; selecting monitoring parameters; identifying appropriate spatial and temporal scales; selecting a sampling scheme for collecting parameters; implementing the monitoring program; and analyzing and communicating results (Figure 1.4). Each of these steps is described briefly below.

Define Goals and Objectives

Before initiating a study to evaluate a restoration action, the overall goal of the project and the monitoring objectives must be identified clearly. Goals are typically broad and strategic, while objectives are more specific and quantifiable. For example, the goal of a stream restoration project may be to increase habitat diversity and improve overwinter survival of juvenile steelhead. In contrast, the objectives would be to (1) determine if the addition of three rock cross vanes increase pool frequency and quality (depth) and (2) assess if the rock structures increased overwinter survival of juvenile steelhead by 20%.[2] It is critical that the sponsors identify the restoration goals and monitoring objectives. The goals and objectives help to determine the monitoring design, monitoring parameters, and the sampling scheme.

Define Key Questions and Hypotheses

The monitoring objectives need to be refined into key monitoring questions and hypotheses. If the monitoring objectives have been well defined, they can be easily translated into questions and then redefined more specifically into testable hypotheses. Following the example above, the key questions and hypotheses are:

Key Question 1: Does the addition of three rock cross vanes increase the number of high-quality (>1 m deep) pools within the stream?

Hypothesis 1: The addition of three rock cross vanes has no effect on the number of high-quality pools within the stream.[3]

Key Question 2: Does the presence of high-quality pools (>1 m deep) increase overwinter survival of juvenile steelhead by 20% in the stream?

Hypothesis 2: The presence of high-quality pools has no effect on the overwinter survival of juvenile steelhead within the stream.

Key questions and hypotheses will differ among projects and will depend on the overall objectives of the project and monitoring program.

[2] The later objective is beyond the scope of the project sponsors. This objective would be addressed under Level 2 or 3 monitoring programs.

[3] The hypothesis to be tested is stated as no difference. This is referred to as the “null” hypothesis.

Effectiveness Monitoring Logic Path

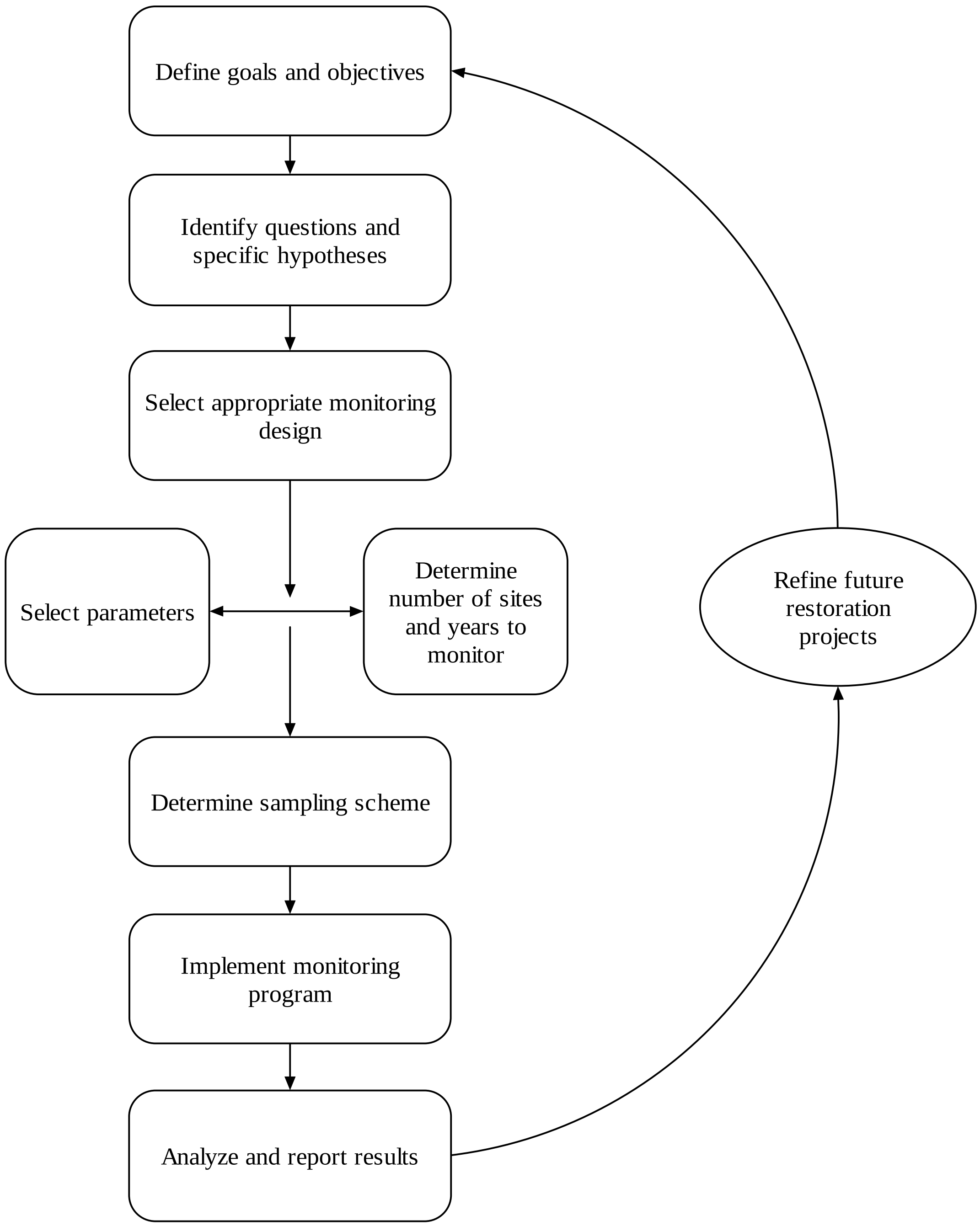

Figure 1.4. Basic steps for setting up an effectiveness monitoring program for stream restoration (modified from Roni et al. 2005).

Select Monitoring Design

There are many potential study designs for monitoring restoration actions. Although none is ideal for all situations, "before-after" study designs can be used for level 1 effectiveness monitoring. A before-after study refers to a design where data are collected both before and after treatment. Data collected before treatment serve as pre-treatment or reference data (temporal control), while data collected after treatment serve as post-treatment data. If there is a treatment effect, then the post-treatment score should be more desirable than the pre-treatment score (e.g., number of high quality pools within the stream increased from 2 to 5 after the addition of rock cross vanes). For project effectiveness monitoring, these data are collected within a site, reach, or stream.

By simply adding a spatial control site, the before-after study becomes a "Before-After Control-Impact" (BACI) study, which, if implemented correctly, is a better monitoring design than the before-after study design. Under the BACI study design, a control site (actually a reference site)[4] is evaluated over the same time period as the treatment (impact) site. The addition of a reference site to the before-after study design is meant to account for environmental variability and temporal trends found in both the reference and treatment areas and, thus, increase the ability to differentiate treatment effects from natural variability. Adding more than one reference site further increases the probability of detecting a treatment effect. The BACI study design is the preferred design for project monitoring and to the extent possible sponsors should use this design.

Select Monitoring Parameters

Identifying which environmental and/or biological parameters to monitor depends on the goals and objectives, key questions and hypotheses, selection of a monitoring design, and the availability of monitoring tools and protocols. Monitoring parameters should be relevant to the questions asked, strongly associated with the restoration action, ecologically and socially significant, and efficient to measure. Moreover, parameters must change in a measurable way in response to treatment, must be directly related to the resource of concern, and must have limited variability and not likely to be confounded by temporal or spatial factors. Continuing with the example above, the appropriate parameters to monitor would be number of pools (addresses pool frequency), residual pool depths (addresses pool quality), and the number of juvenile steelhead before and after winter—adjusted for the number of steelhead entering and leaving the area during the winter (addresses overwinter survival).

In addition to measuring various environmental and/or biological parameters, all sponsors should establish photo points to document changes within treatment and reference sites. Annual photographs taken at the same locations within treatment and reference areas both before and after treatment provide an excellent tool for demonstrating project effectiveness. Hall (2001) describes methods for documenting environmental change using photo points.

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4 Reference sites need to be as similar as possible to the treatment sites. The design does not require exact pairing; parameters simply need to "track" each other. Reference sites can represent either the degraded condition or the preferred condition.

Identify Number of Sites and Years to Monitor

Estimating the number of sites and years to monitor can be a difficult and involved process for most monitoring programs. It usually requires an understanding of spatial and temporal variability of the parameter of interest, statistical decision rules (i.e., Type I and II errors), and effect sizes. Many sponsors lack the expertise to conduct "power analysis," which is needed to determine the number of sites and years to monitor. Therefore, it is recommended that sponsors monitor <u>all</u> treatment sites (and their corresponding control sites) at least once before treatment and once every year for five years after treatment.[5] For example, if there are two stream reaches, one that will be treated with three rock cross vanes and the other with no treatments (reference reach), then the number of pools and pool depths within both reaches will be measured once before treatment and once every year for five years following treatment (Table 1.1). The sampling of all treatments and their corresponding reference areas constitutes a census. It is assumed that all restoration projects will last for at least five years, therefore monitoring for a period of at least six years (one year before treatment and five years after treatment) is appropriate.[6]

Table 1.1. The form of results from a BACI study with one observation before and five observations after the treatment. Observations are indicated by X.

Reach	**Pre-treatment measurements**	**Post-treatment measurements (years)**				
	1	**1**	**2**	**3**	**4**	**5**
Treatment	X	X	X	X	X	X
Reference	X	X	X	X	X	X

Determine Sampling Scheme

Before initiating monitoring, one needs to determine the methods and spatial allocation of sampling within a site or study reach. As noted above, for project monitoring, it is recommended that all treatment sites and their corresponding reference sites be sampled (census). However, in some situations, it may not be feasible to sample the entire treatment reach. For example, restoration projects such as nutrient enrichment and large conservation easements may extend for several stream kilometers, making a complete census impossible or expensive. In this case, a sampling strategy (scheme) that reduces effort but provides unbiased estimates of treatment effects is necessary. Although no one sampling design is best for all situations, the preferred approach is a simple random sample or stratified random sample. The optimal sampling design will depend on the spatial arrangement of the parameters of interest and the logistics of moving between locations and collecting samples.

Data Management, Analysis, and Reporting

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5 Some restoration actions my take more than one year to implement. In these cases, monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

6 The five-year, post-treatment, monitoring period is consistent with provisions in the PUD's Habitat Conservation Plans. In some cases, e.g., riparian restoration actions and acquisitions and conservation easements, a longer period of post-treatment monitoring may be useful or necessary.

Data acquisition, management, and analysis are key parts of any monitoring program. This includes determining how the data will be entered and stored in a database[7] and making sure the database is consistent with the field forms. Because observer error can be quite large, it is important that field crews understand how data are to be collected. Tools such as data loggers and computer clipboards can simplify entering data into a database but may be expensive and complicate field data collection.

Before collecting data, it is important to consider how the data will be analyzed and what statistical methods should be used. Before-after and BACI designs are well suited to t-tests, analysis of variance, regression, and time series methods. It is also important to use graphical methods to analyze data. If the sponsors are not familiar with statistics, statistical analyses, or statistical design considerations, they should consult a statistician early in the design process. The local Watershed Steward or Lead Entity can direct sponsors to statistical resources.

If the sponsors, managers, and funding entities are to learn from restoration activities, monitoring results should be reported to both the scientific community and the general public. Regardless if a restoration project is a success or failure, it is important to report the findings. Often failures go unreported. This is unfortunate given the money spent on restoration. To avoid making the same mistakes in the future, it is probably just as important to report failed efforts as successes.

1.4 Summary

The purpose of this report is to provide sponsors with a practical resource for developing cost-effective monitoring and evaluation programs for restoration projects at the habitat unit (site) or reach scale. Well designed restoration and monitoring require an understanding of the natural watershed and ecological processes that create habitat. The focus of restoration should be on watershed processes rather than habitat enhancement. However, there are situations were habitat enhancement is the only feasible means of restoring habitat. In some cases, habitat enhancement within the framework of watershed processes is a valuable means of restoring stream habitat (e.g., lower Entiat River).

While there are many types of monitoring, the focus here is on implementation monitoring and project effectiveness monitoring. These types of monitoring should indicate whether the restoration actions were designed and implemented properly and determine whether restoration met the objectives. Project monitoring conducted by sponsors should determine the effects of individual projects on environmental characteristics and to a lesser degree on biological characteristics. It is not the goal of level 1 effectiveness monitoring to assess large-scale population (biological) effects. Identifying biological responses will not be the responsibility of sponsors but may be included within other large-scale, intensive monitoring programs (e.g., the Integrated Status and Effectiveness Monitoring Program, the Okanogan Basin Monitoring and Evaluation Program, and the Washington Salmon Recovery Funding Board Monitoring Program). However, it is important that sponsors document how their monitoring will be coordinated with other large-scale monitoring programs.

[7] The Upper Columbia Basin is currently working to develop a data management system through the ISEMP program. It is recommended that all monitoring data collected in the Upper Columbia Basin be stored in this system once it is available. In the meantime, sponsors will need to manage data within their own systems.

Because restoration projects are experiments, they should be implemented according to rules of experimental design. Outlined in this report are the key steps and issues that need to be followed when designing programs to monitor the effectiveness of individual restoration projects. These include determining goals and objectives; defining key questions and hypotheses; selecting a monitoring design and project scale; selecting monitoring parameters; determining number of sites, years to monitor, and sampling schemes; and analyzing data and reporting results. It is important to remember that there is no ideal design, sampling scheme, set of parameters, or method of analysis for all projects. These factors will depend upon the goals and objectives of the project. The local Watershed Steward or Lead Entity can direct sponsors to additional monitoring resources.

What follows are more specific guidelines for developing monitoring programs for different types of restoration activities. The guidelines and hypothetical examples are for riparian restoration, floodplain restoration, instream habitat restoration, restoration of connectivity, instream diversion restoration, and acquisitions and conservation easements.

SECTION 2: RIPARIAN RESTORATION

Riparian forests provide several important benefits to stream habitat, including transport of large wood, organic material, nutrients, sediment, water, and thermal energy. These benefits ultimately affect stream productivity and abundance of desirable fish species. Riparian areas also are a necessary habitat component for many wildlife species. Despite the importance of riparian vegetation to streams, fish, and wildlife, riparian systems have a long history of being degraded by land-use activities such as diking, logging, grazing, agriculture, road building, and residential and industrial development. This is largely because riparian areas, and especially floodplains, are usually the most productive portions of the landscape and offer relatively easy access for human use. Restoration or enhancement of degraded or impaired riparian areas is an effective way to restore natural watershed processes. Monitoring the effectiveness of riparian restoration actions requires measuring the response of vegetation in riparian areas, as well as measuring certain physical responses (e.g., bank stability, shading, etc.).

Monitoring riparian restoration actions can be challenging because riparian areas are often restored or enhanced to meet different management objectives. For example, the objective of riparian restoration may be to improve commercial harvest opportunities, improve stream habitat conditions, or to improve riparian habitat (species diversity, multiple canopy layers, etc.). In some cases, riparian restoration may address multiple objectives. In this section, I provide guidelines for monitoring riparian restoration actions designed to improve stream and riparian habitat. As such, the goals addressed in this section generally include such things as increasing the amount of wood, leaves, and shade to the stream; improving bank stability; minimizing erosion (reducing fine sediment recruitment to the stream); increasing riparian vegetation; or removing agents of disturbance (e.g., livestock or roads) from riparian areas.

2.1 Riparian Restoration Techniques

In general, there are two common forms of riparian restoration techniques: silviculture techniques, which include both planting vegetation and removal of competing vegetation; and removal of a disturbance that suppresses vegetation establishment. In most cases, the latter is the preferred approach. Silviculture techniques may have little effect on riparian restoration if the primary source of disturbance is not removed. As a general rule, riparian restoration plans should first address potential sources or disturbance, and then, if necessary, consider silviculture techniques.

Plantings

Many riparian restoration actions involve planting trees or other vegetation. Planting techniques may include direct seeding, natural seeding, coppicing[8], staking and layering[9], and planting seedlings or older trees. There are advantages and disadvantages to each technique. Which one is used is based

8 Coppicing is regeneration from vegetative sprouts (e.g., from stumps or limbs).

9 Staking is the vertical insertion of live stems or branches partially into the ground. Layering is the complete or partial horizontal burial of live stems that then take root.

on site conditions, cost, and management objectives. If used in the appropriate situation, they greatly increase initial tree growth and survival.

Removal of Invasive Species

Riparian disturbances may create conditions suitable for rapid colonization by invasive exotic species. Many invasive species are aggressive and often form monocultures or become the most abundant species if left unchecked. In riparian areas dominated by non-native species, the restoration techniques involve removing the species. Some of the more common invasive exotics include Japanese knotweed, salt cedar, reed canary grass, and leafy spurge.

Removal of a Disturbance

Many riparian areas have been altered because of diking, road construction, logging, development, extensive livestock grazing, and other agricultural activities. Where feasible, the appropriate restoration technique is to remove the disturbance. This may include relocating the disturbance outside the riparian area or preventing the disturbance from entering the riparian zone. For example, using fencing to exclude livestock from riparian areas is a common method of reducing livestock impacts to stream and riparian habitat. After the source of disturbance is removed, the riparian area can be enhanced passively (letting natural processes take their course) or actively (plantings).

2.2 Riparian Restoration Monitoring Plan

Because riparian restoration projects focus on direct manipulations of habitat, they represent excellent opportunities to test hypotheses. Testing these hypotheses is important for guiding future restoration efforts. Developing an adequate monitoring study to test hypotheses is challenging because of the wide variety of riparian restoration techniques. However, as noted in Section 1, there are several logical steps that should be taken to set up a valid Level 1 monitoring program. These steps are discussed below.

Goals and Objectives

As described in Section 1, identifying goals and objectives of a proposed restoration action is the first step in developing a monitoring plan. Generating goals and objectives up front has the advantage of clearly specifying what the purpose of the restoration project is and helps to guide the restoration design to achieve the goals. The following are examples of goals and objectives.

Goals:

- Increase riparian vegetation by excluding cattle grazing within the riparian area.
- Increase riparian habitat conditions by planting willows.
- Increase streambank stability by planting riparian vegetation along the stream.
- Increase native riparian vegetation by removing invasive exotic species.
- Increase instream woody debris by planting deciduous trees along the stream.
- Reduce sediment recruitment to the stream by planting riparian vegetation.

Objectives:

- Place 350 m of fencing 75 m from the channel to exclude livestock grazing from the riparian area of the lower Stillwater River.
- Plant willow stakes at a density of 2,000 stakes/ha in a 10-m-wide zone adjacent to Miller Creek.
- Plant 60 Douglas-fir trees taller than 6 feet along 350 m of the Boulder River to increase bank stability.
- Remove leafy spurge from riparian habitat along 400 m of Douglas Creek.
- Increase instream woody debris by planting 60 cottonwood trees taller than 6 feet along 600 m of lower Ruby Creek.
- Plant native grass seed within a 10-m wide zone along 500 m of Dry Creek to reduce soil erosion.

Note that the objectives are more specific than the goals.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All riparian restoration projects have working hypotheses. When a project is initiated, it is based on the general assumption that the restoration action is going to lead to an improvement in riparian or stream habitat conditions. Specific predictions can be made as to how the habitat will improve in response to the restorative action. Example questions and hypotheses for riparian restoration include:

Key Questions:

- Will the exclusion of cattle grazing increase the survival and abundance of cottonwoods and willows along 350 m of the lower Stillwater River?
- Will the plantings of 2,000 willow stakes/ha increase abundance of woody vegetation in a 10-m-wide zone adjacent to Miller Creek?
- Will the plantings of 60 Douglas-fir trees taller than 6 feet increase bank stability along 350 m of the Boulder River?
- Will the removal of leafy spurge from 400 m of riparian habitat increase the abundance of native grasses along Douglas Creek?
- Will the plantings of 60 cottonwoods taller than 6 feet increase instream woody debris by at least 20% along 600 m of lower Ruby Creek?
- Will the planting of native grasses reduce soil erosion within a 10-m wide zone along 500 m of Dry Creek?

Hypotheses:

- The exclusion of cattle will have no effect on the survival and abundance of cottonwoods and willows along 350 m of the lower Stillwater River.
- Planting willow stakes at a density of 2,000 stakes/ha will not increase the abundance of woody vegetation within a 10-m-wide zone adjacent to Miller Creek.
- Planting 60 Douglas-fir trees taller than 6 feet will have no effect on bank stability along 350 m of the Boulder River.

- Removing leafy spurge from 400 m of riparian habitat will not increase the abundance of native grasses along Douglas Creek.
- The planting of 60 cottonwoods taller than 6 feet will not increase the amount of woody debris along 600 m of lower Ruby Creek.
- The planting of native grasses within a 10-m-wide zone along 500 m of Dry Creek will not reduce soil erosion.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

Once the goals, objectives, key questions, and hypotheses are determined, the treatment needs to be implemented in such a way that the hypotheses can be tested. As indicated in Section 1, an appropriate monitoring design is to survey the restoration site before and after treatment (Before-After design). If possible, the sponsor should identify a similar site(s) that will not be treated and will serve as a spatial reference. Measurements are then taken at both the treatment and reference sites before and after restoration (BACI design). This allows one to compare restoration effects with both a spatial and temporal reference condition.

Parameters

For project monitoring, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 2.1 identifies possible parameters and sampling methods for monitoring riparian restoration actions.

In addition to measuring various channel and riparian parameters, all sponsors should establish photo points (see Hall 2001) to document changes within treatment and reference sites for all riparian restoration projects. Annual photographs of riparian areas taken at the same locations within treatment and reference areas both before and after treatment provide an excellent tool for illustrating project effectiveness.

Table 2.1. Possible parameters and sampling methods for monitoring riparian restoration actions.

Monitoring parameter	Sampling method
Presence of vegetation (native and/or exotic)	Document the presence of target plants by surveying entire treatment and reference areas or by surveying within at least three randomly selected 10 m x 10 m riparian plots in each of the treatment and reference sites.
Survival of vegetation (native and/or exotic)	Count the number of target plants that survive from one year to the next within entire treatment and reference areas or within at least three randomly selected 10 m x 10 m riparian plots in each of the treatment and reference sites.

Monitoring parameter	Sampling method
Density of vegetation (native and/or exotic)	Estimate the density (#/100 m^2) of target plants within entire treatment and reference areas or within at least three randomly selected 10 m x 10 m riparian plots in each of the treatment and reference sites.
Presence of disturbance (human and natural)	Determine the presence of disturbances (bare soil, roads, fires, signs of grazing, etc.) by surveying entire treatment and reference areas or by surveying within at least three randomly selected 10 m x 10 m riparian plots in each of the treatment and reference sites.
Area of disturbance (human and natural)	Estimate the area of disturbance (m^2) by surveying entire treatment and reference areas or by surveying within at least three randomly selected 10 m x 10 m riparian plots in each of the treatment and reference sites.
Number of pieces of woody debris	Count the number of pieces of woody debris (diameter >10 cm and a length >1 m) within the entire reach of stream within the treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in the treatment and reference areas.
Bank stability	Assess bank stability[10] (on the treatment side of the stream) along the entire reach of stream within the treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in the treatment and reference areas.

Sampling Scheme

For all riparian restoration projects, data (including photographs) will be collected at least once before implementation of the restoration action and then annually for five years following completion of the restoration action.[11] If a spatial reference area is used (BACI design), data and photographs will be collected in the reference area at the same time data are collected within the treatment area. Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer low flow, than sampling should occur during summer low flow every year thereafter. In addition, if sampling occurs within three randomly selected 10 m x 10 m riparian plots within each of the reference and treatment areas, then the same plots must be sampled each year. Sampling different plots annually may increase variability and make it more difficult to demonstrate a treatment effect. It is therefore important to monument each

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[10] Bank stability is visually estimated as the percent (%) of the lineal distance that is actively eroding at the active channel height on the side of the channel that is treated (see Hillman 2004). If both sides of the channel are treated, then percent erosion is estimated along both banks. Active erosion is defined as recently eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability. Bank stability is estimated throughout the entire treatment and reference reaches or along the 150-m long survey sites.

[11] Riparian restoration may require more than five years of post-treatment monitoring in order to identify treatment effects. A 20-year post-treatment monitoring period with sampling once every four years may be more appropriate. In addition, some restoration actions my take more than one year to implement, in which case monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

riparian survey plot, stream reach, and photo-point location with permanent markers (e.g., rebar), GPS, drawings, markings on topographic maps, and photographs.

Whenever possible, surveys should be conducted throughout the entire treatment and reference areas. If treatment and reference areas are too large to census, measurements can be taken within at least three randomly selected 10 m x 10 m riparian plots (for measuring riparian parameters) or within at least three randomly selected 150-m long stream reaches (for measuring stream and channel parameters). The same sampling scheme should be used in both the treatment and reference areas.

Data Analysis and Reporting

When riparian and channel data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis (e.g., see Figures 2.1 and 2.2). Measurements for both the reference and treatment areas can be shown on the same graph. In many cases, figures, tables, and photographs may be all that are needed to demonstrate riparian restoration effects. Additional analysis could include testing trends using time series analysis or regression techniques. Other statistics such as t-tests and analysis of variance can be used to test for significant differences between treatment and reference conditions. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

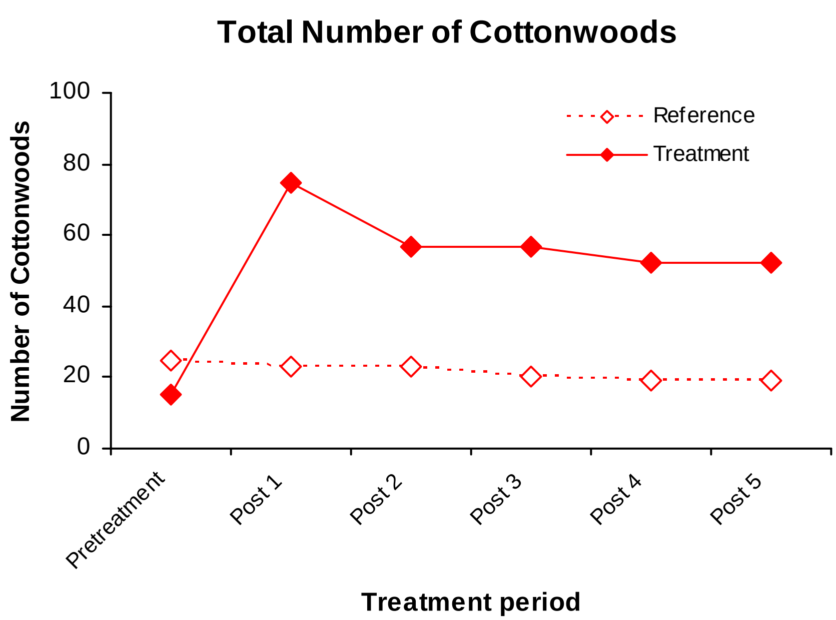

Figure 2.1. An example of data analysis using graphing methods for a BACI study. The figure shows the total number of cottonwoods in treatment and reference areas before (pretreatment) and after (post) treatment. These data are from a complete census. Note that the reference area represents the degraded condition.

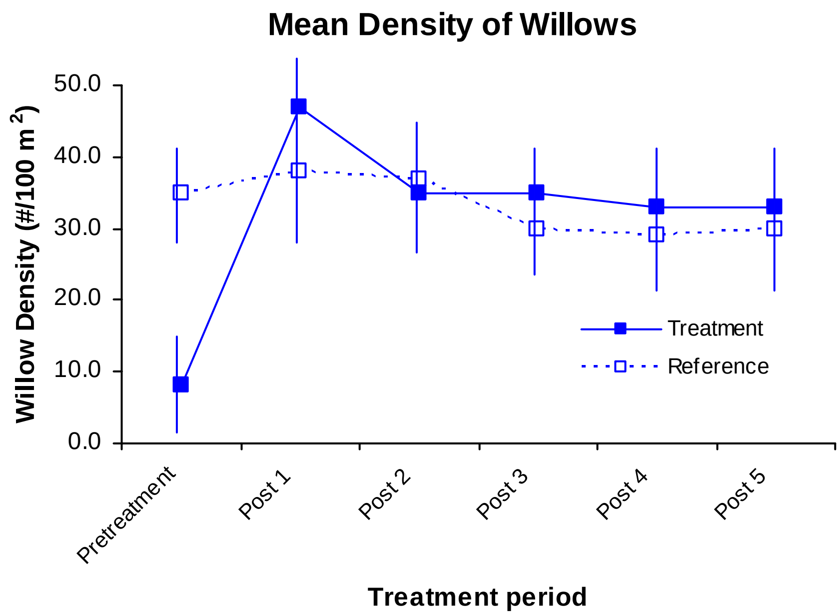

Figure 2.2. An example of data analysis using graphing methods for a BACI study. The figure shows the mean density of willows (number/100 m^2) within 10 m x 10 m riparian plots in treatment and reference areas before (pretreatment) and after (post) treatment. Vertical bars represent 95% CI. Note that the reference area represents the desired condition.

2.3 Riparian Restoration Example

A sponsor is interested in restoring channel stability and riparian habitat (willows and cottonwoods) along one mile (1.6 km) of lower Willow Creek. Both sides of the channel have been severely degraded by livestock grazing and the landowner is concerned about the loss of pasture land during high-flow events. The landowner has agreed to the restoration of a 10-m-wide zone on both sides of the stream, provided that the restoration work will reduce bank erosion and increase the abundance of adult steelhead. The landowner also wants off-channel watering provided for his livestock. The sponsor proposes the following work.

Goals and Objectives

Goal: Restore riparian vegetation and streambank stability along 1.6 km of lower Willow Creek.

Objective 1: Place 1,600 m of fencing on both sides of the stream 10 m from the channel to exclude cattle from grazing within the riparian area on lower Willow Creek.

Objective 2: Plant a 1:4 mix of cottonwood:willow stakes at a density of 200 stakes/ha in a 10-m-wide zone on both sides of lower Willow Creek to increase riparian vegetation and streambank stability.[12]

Key Questions and Hypotheses

[12] Note that the sequence of actions is to first address the riparian disturbance (cattle grazing) and second to restore riparian vegetation and bank stability.

Key Question 1: Will the exclusion of cattle from a 10-m-wide zone of riparian habitat along both sides of 1.6 km of lower Willow Creek increase regeneration of riparian vegetation and decrease bank instability?

Hypothesis 1: Excluding cattle from grazing within a 10-m-wide zone along both sides of 1.6 km of lower Willow Creek will have no effect on plant regeneration or bank stability.

Key Question 2: Will the plantings of cottonwood/willow stakes increase bank stability and the abundance of riparian vegetation within a 10-m-wide zone on both sides of lower Willow Creek?

Hypothesis 2: The plantings of cottonwood/willow stakes will have no effect on bank stability and the abundance of riparian vegetation within a 10-m-wide zone on both sides of lower Willow Creek.

Implementation Monitoring

- Were 3,200 m of fencing (1,600 m on both sides of the stream) installed correctly?
- Were 640 cottonwood/willow stakes (200 stakes/ha) planted along 1.6 km of lower Willow Creek?

Measurements: Length and location of fencing installed; number of cottonwood and willow stakes planted.

Level 1 Effectiveness Monitoring

Was the restoration action effective in restoring riparian vegetation and increasing streambank stability?

Monitoring design: BACI design with one measurement taken before treatment and five measurements taken annually after treatment in both treatment and reference areas.

Treatment area(s): The one treatment area is located between Rkm 3.6 and 5.2 on Willow Creek and lies entirely on the Mountain View Ranch property. The entire 1.6 km reach will be treated with fencing and cottonwood/willow plantings.

Reference area(s): About 3.4 km upstream from the treatment area is a 450-m-long section of Willow Creek that is grazed and has similar channel and riparian characteristics to the 1.6-km-long treatment area. This 450-m-long segment of Willow Creek is part of the Smith Property and will serve as a single spatial reference. The landowners indicated that grazing will continue in this area for at least the life of the study. They have also granted access for monitoring the site for five years.

Monitoring Parameters: Signs of livestock within the riparian zone (presence/absence data); number of cottonwoods and willows; survival of cottonwood and willow plantings; percent bank stability.

Sampling Scheme: Three 10 m x 10 m riparian plots will be selected randomly on both sides of the stream in both the treatment and reference areas (total of 12 riparian plots). Photographs will be taken within each plot, as well as documenting the presence of any livestock use[13] and counting the number of cottonwoods and willows alive within each plot. The entire fence line on both sides of the stream will be walked to look for breaks in the fence and/or evidence of livestock passing under, over, or through the fence.

Three 150-m long stream reaches will be selected randomly within the treatment area for assessing percent bank stability. Percent stability will be visually estimated for both banks, and photographs will be taken at established photo-points within each reach (one photo-point per site). Bank stability along the entire 450-m-long reach of the reference area will be estimated visually. Three bank-stability photo-points will be established within the reference area.

Sampling within riparian plots and stream reaches will occur in August once before treatment and for five years after treatment.

Data Analysis: Mean scores and 95% CI of numbers of cottonwoods and willows, survival of cottonwoods and willows, and percent bank stability within treatment and reference areas will be analyzed graphically. Large changes in bank stability are not expected within the first five years after treatment, because the root structure of cottonwoods and willows will probably not have developed to the point that they stabilize banks. However, if survival of willows and cottonwoods is high, increased bank stability should occur within 5-15 years after planting. Photographs will also be used to show changes in riparian vegetation and streambank stability.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the restoration action and will offer recommendations.

2.4 Summary

This section focused on methods for monitoring common riparian restoration actions. There is no easy-to-follow recipe for monitoring all types of riparian restoration projects. Nevertheless, if the goals and objectives are specific, monitoring plans can be developed to address any kind of riparian project. This section provides sponsors with a “toolbox” that can be used to develop Level 1 effectiveness monitoring plans for riparian restoration projects. Designing a monitoring program for riparian restoration projects is similar to designing monitoring for other restoration projects and includes (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with spatial and temporal reference sites, if possible; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the restoration action resulted in the desired outcome. This information can be used by funding entities and managers to adaptively manage riparian and aquatic resources.

[13] Evidence of livestock use includes presence of livestock tracks, hair, droppings, or signs of grazing. Care must be taken to distinguish between deer, elk, and other wildlife signs and domestic livestock.

SECTION 3: FLOODPLAIN RESTORATION

An important feature within river corridors is the floodplain. The floodplain is the flat depositional feature of the river valley adjoining the river channel. It is the land near the channel that is subject to periodic flooding (at least by the 100-year flood event). Some of the more common features of the floodplain include oxbow lakes, floodplain channels, side channels, natural levees, wetlands, and off-channel ponds. These features are often altered or destroyed because of various land uses. For example, disturbances such as dams, levees, and the development of floodplains for agriculture, industry, and residential use have disrupted the natural connection between the river and its floodplain. These disruptions may reduce and alter the frequency, extent, and duration of floodplain inundation; truncate the input of sediments, nutrients, and wood into and out of the floodplain; and reduce the total amount of habitat for fish and other aquatic organisms. A consequence of this is the loss of fish and other aquatic organism productivity.

The purpose of this section is to describe how to monitor the effectiveness of floodplain restoration projects. First I describe some common restoration techniques that are used to reconnect floodplain habitat with the river channel. Next I discuss how to develop a monitoring plan to assess the effectiveness of floodplain restoration projects. Finally, I provide an example of a Level 1 monitoring plan that will assess the effects of a hypothetical floodplain restoration project.

3.1 Floodplain Restoration Techniques

The reconnection of floodplains and their associated habitats has become an important component of river ecosystem restoration. As such, many techniques have been developed to restore floodplain habitats. The most common techniques include levee removal or setback, direct reconnection of floodplain channels, and the creation of "new" floodplain channels and ponds. Culvert replacement or removal is another method for reconnecting isolated floodplain habitat.[14] Removing large dams that form reservoirs and inundate floodplain habitats is a large-scale restoration technique that is beyond the scope of this report.

Levee Removal or Setback

A levee setback project, whether full or partial, allows a river to migrate and to create and maintain different floodplain habitat types. Because of land constraints, many projects are a combination of full and partial levee removal. One method is the "beaded approach," where small sections of the full floodplain width are allowed to function, alternating with leveed sections of the river. This technique allows portions of the floodplain to be inundated and encourages scour, erosion, and deposition in those areas.

14 Monitoring the effects of culvert replacement or removal is discussed in Section 5, Restoration of Connectivity.

Reconnection of Floodplain Channels

Removal of small dams, weirs, culverts, or levees to reconnect a relic channel or larger floodplain water bodies (e.g., off-channel ponds, oxbow lakes, etc.) is a common technique for restoring floodplain habitat. This method can also be used to reconnect a section of a cutoff meander or channel and often results in a backwater environment for rearing fish. Elevation differences between the relic channels and the river channel must be considered, as well as water quality. If the river has a high sediment supply, reconnected floodplain habitats may fill with fine sediments and be useless to fish.

Creation of Floodplain Channels and Ponds

The creation of new floodplain habitats is a form of floodplain enhancement that involves active construction of new floodplain channels and ponds. These projects are often designed for a specific species or species life stage (e.g., juvenile coho salmon). Floodplain habitat creation projects offer an alternative to mainstem restoration projects, which can be difficult to construct and maintain due to unstable flow and channel-bed conditions.

3.2 Floodplain Restoration Monitoring Plan

Because floodplain restoration projects focus on direct manipulations of habitat, they represent excellent opportunities to test hypotheses. Testing these hypotheses is important for guiding future restoration efforts. Developing an adequate monitoring study to test hypotheses is challenging because of the wide variety of floodplain restoration techniques. However, as noted in Section 1, there are several logical steps that should be taken to set up a valid Level 1 monitoring program. These steps are discussed below.

Goals and Objectives

The first and most important step in developing a monitoring plan for assessing the effectiveness of floodplain restoration projects is to clearly identify the overall goals and specific objectives of the project. The following are examples of floodplain restoration goals and objectives.

Goals:

- Increase floodplain connectivity by opening existing relic channels.
- Increase floodplain connectivity by removing a small side-channel diversion.
- Increase floodplain habitat diversity by removing a levee.
- Increase floodplain habitat diversity by connecting an off-channel pond with the river.
- Increase off-channel rearing habitat for juvenile salmon by creating off-channel ponds.
- Reduce summer water temperatures by reconnecting off-channel springs with the river.
- Increase floodplain diversity by increasing the flow of water from Lucky Peak Reservoir.

Objectives:

- Remove four small levees to open 540 m of side channels along the Judith River.

- Remove a small, defunct concrete diversion to open 1.6 km of floodplain channels along the Wood River.
- Remove three sections of a 4-km-long levee to reconnect 9.2 ha of floodplain habitat along the Okanogan River.
- Create a 74-m-long channel that connects an off-channel pond with the main Crooked River.
- Create a 0.3 ha off-channel pond connected to the lower Wenatchee River to increase overwinter survival of juvenile Chinook salmon and steelhead.[15]
- Construct two channels that reconnect three cold-water springs to the lower Burns River.
- Maintain flows in six side channels by releasing an additional 17 cfs from Lucky Peak Reservoir.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All floodplain restoration projects have working hypotheses. When a project is initiated, it is based on the general assumption that the restoration action is going to lead to an improvement in floodplain condition. Specific predictions can be made as to how the habitat will improve in response to the restorative action. Example questions and hypotheses for floodplain restoration include:

Key Questions:

- Will the removal of four small levees increase floodplain connectivity by opening 540 m of side channel habitat along the Judith River?
- Will the removal of a small, defunct diversion dam on the Wood River increase floodplain connectivity by opening 1.6 km of floodplain channels?
- Will the removal of three sections of a 4-km-long levee reconnect 2.2 ha of floodplain habitat along the Okanogan River?
- Will the creation of a 74-m-long channel increase floodplain habitat diversity by connecting an off-channel pond with the Crooked River?
- Will the creation of a 0.3 ha off-channel pond along the lower Wenatchee River increase overwinter survival of juvenile Chinook salmon and steelhead?
- Will creating two channels that reconnect three cold-water springs with the river reduce summer water temperatures in the lower Burns River?
- Will the release of an additional 17 cfs from Luck Peak Reservoir re-water six side channels downstream from the reservoir?

Hypotheses:

- The removal of four small levees will have no effect on floodplain connectivity along the Judith River.
- The removal of a small, defunct concrete diversion dam on the Wood River will have no effect on floodplain connectivity.

[15] Monitoring overwinter survival is beyond the scope of Level 1, effectiveness monitoring described in this report. However, presence/absence surveys for specific species or species life stages are appropriate.

- The removal of three sections of a 4-km-long levee will not reconnect 2.2 ha of floodplain habitat along the Okanogan River.
- The creation of a 74-m-long channel will not increase floodplain habitat diversity along the Crooked River.
- The creation of a 0.3 ha off-channel pond along the lower Wenatchee River will not increase overwinter survival of juvenile Chinook salmon and steelhead.
- Creating two channels that reconnect three cold-water springs with the river will have no effect on summer water temperatures in the lower Burns River?
- The release of an additional 17 cfs from Luck Peak Reservoir will not re-water six side channels downstream from the reservoir.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

Once the goals, objectives, key questions, and hypotheses are determined, the treatment needs to be implemented in such a way that the hypotheses can be tested. As indicated in Section 1, an appropriate monitoring design is to survey the restoration site before and after treatment (Before-After design). If possible, the sponsor should identify a similar site that will not be treated and will serve as a spatial reference site. Measurements are then taken at both the treatment and reference sites before and after restoration (BACI design). This allows one to compare restoration effects with both a spatial and temporal reference condition.

Parameters

For project monitoring, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 3.1 identifies possible parameters and sampling methods for monitoring floodplain restoration actions.

In addition to selecting specific habitat parameters, all sponsors should establish photo points (see Hall 2001) to document changes within treatment and reference sites for all floodplain restoration projects. Annual photographs of floodplain areas taken at the same locations within treatment and reference areas both before and after treatment provide an excellent tool for illustrating project effectiveness.

Table 3.1. Possible parameters and sampling methods for monitoring floodplain restoration actions.

Monitoring parameter	Sampling method
Connection between mainstem and floodplain	Identify the presence of flow connection between the floodplain and mainstem. Identify and photograph any obstructions that prevent surface water from flowing between the mainstem and floodplain.
Length of side channels and/or floodplain channels	Measure the length (to nearest 0.1 m) of side channels and floodplain channels. Length measurements are made down the center of the channel.
Size of off-channel ponds	Calculate the area of off-channel ponds by measuring lengths and widths, or radius (to the nearest 0.1 m) of ponds. Aerial photos or satellite imagery can also be used.
Presence of levees	Document the presence of levees using site diagrams and photographs.
Streamflows	Document the presence of surface flow in side channels and floodplain channels using photographs.
Number of pools	Count the number of pools within all side channels and floodplain channels or within at least three randomly selected reaches that are no less than 100 m long. To be counted, a pool must span more than half the wetted width, include the thalweg[16], be longer than it is wide, and be at least 1.5 times the crest depth. Plunge pools[17] should be included even if they are not as long as they are wide.
Residual pool depth	Calculate the residual pool depth for all pools within side-channels and floodplain channels or within three randomly selected reaches that are no less than 100 m long. Residual pool depth is calculated as the maximum pool depth minus the maximum pool-outlet depth (Hillman 2004). Depths are measured (to the nearest 0.01 m) with a meter stick or surveyor's rod.
Residual pond depth	Calculate the residual pond depth within each off-channel pond using a meter stick or surveyor's rod (to the nearest 0.01 m). Residual pond depth is calculated as the maximum pond depth minus the maximum pond-outlet depth.
Number of pieces of woody debris	Count the number of pieces of woody debris (diameter >10 cm and a length >1 m) within side channels and floodplain channels or within at least three randomly selected reaches that are no less than 100 m long.
Bank stability	Assess bank stability[18] along both sides of side channels and floodplain channels or within at least three randomly selected reaches that are no less than 100 m long.

[16] Thalweg is the deepest part of the channel.

[17] A plunge pools is defined as a pool created by water passing over or through a channel obstruction and dropping into the streambed scouring out a basin in the substrate.

[18] Bank stability is visually estimated as the percent (%) of the lineal distance that is actively eroding at the active channel height on both sides of the channel (see Hillman 2004). Active erosion is defined as recently eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension

Monitoring parameter	Sampling method
Water temperature	Use data loggers to record temperatures to the nearest 0.1°C at hourly intervals throughout the period of interest.
Presence/absence of target fish and life stage	Use underwater observations (snorkeling) or visual observations from the bank to document the presence of target fish and life stages.

Sampling Scheme

For all floodplain restoration projects, data (including photographs) will be collected at least once before implementation of the restoration action and then annually for five years following the completion of the restoration action.[19] If a spatial reference area is used (BACI design), data and photographs will be collected in the reference area at the same time data are collected within the treatment area. Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer low flow, than sampling should occur during summer low flow every year thereafter. In addition, if sampling occurs within three randomly selected 100-m-long sites within each of the reference and treatment areas, then the same sites must be sampled each year. Sampling different sites annually may increase variability and make it more difficult to demonstrate a treatment effect. It is therefore important to monument each sampling site and photo-point location with permanent markers (e.g., rebar), GPS, drawings, markings on topographic maps, and photographs.

Whenever possible, surveys should be conducted throughout the entire treatment and reference areas. If treatment and reference areas are too large to census, measurements can be taken within at least three randomly selected 150-m-long stream reaches (for measuring numbers of pools, depths of pools, number of pieces of woody debris, bank stability, and/or presence of fish). The same sampling scheme should be used in both the treatment and reference areas.

Data Analysis and Reporting

When floodplain and channel data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis (e.g., see Figures 3.1 and 3.2). Measurements for both the reference and treatment areas can be shown on the same graph. In many cases, figures, tables, and photographs may be all that are needed to demonstrate floodplain restoration effects. Additional analysis could include testing trends using time series analysis or regression techniques. Other statistics such as t-tests and analysis of variance can be used to test for significant differences between treatment and reference conditions. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

cracks, active sloughing, or superficial vegetation that does not contribute to bank stability. Bank stability is estimated throughout the entire treatment and reference reaches or along the 100-m long survey sites.

[19] Some restoration actions my take more than one year to implement. In these cases, monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

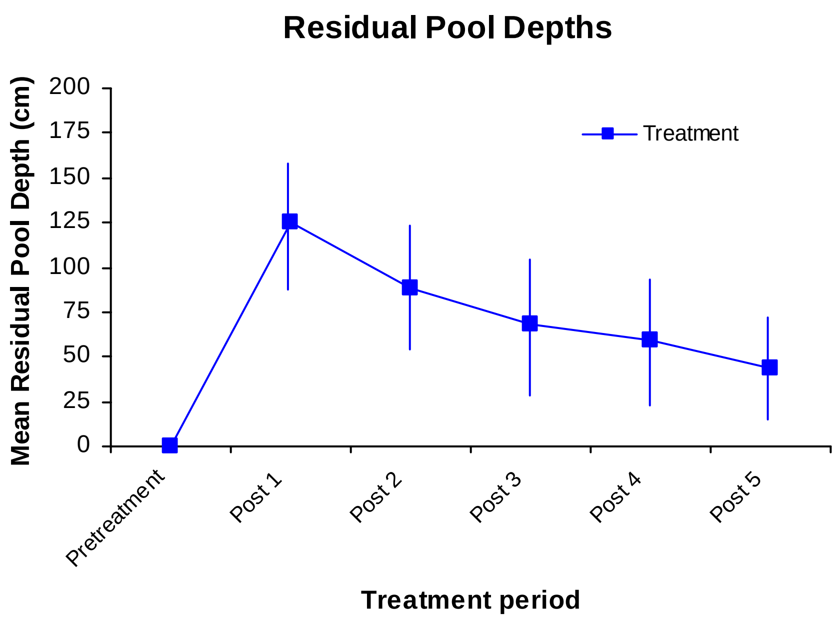

Figure 3.1. An example of data analysis using graphing methods for a Before-After study (there is no spatial reference site). The figure shows the mean residual pool depths and 95% CI for eight pools created within side channels before (pretreatment) and after (post) treatment. Note that there were no pools before treatment (residual pool depth of 0). Fine sediment deposition within pools during spring high-flow events caused the mean residual pool depths to decrease following floodplain restoration.

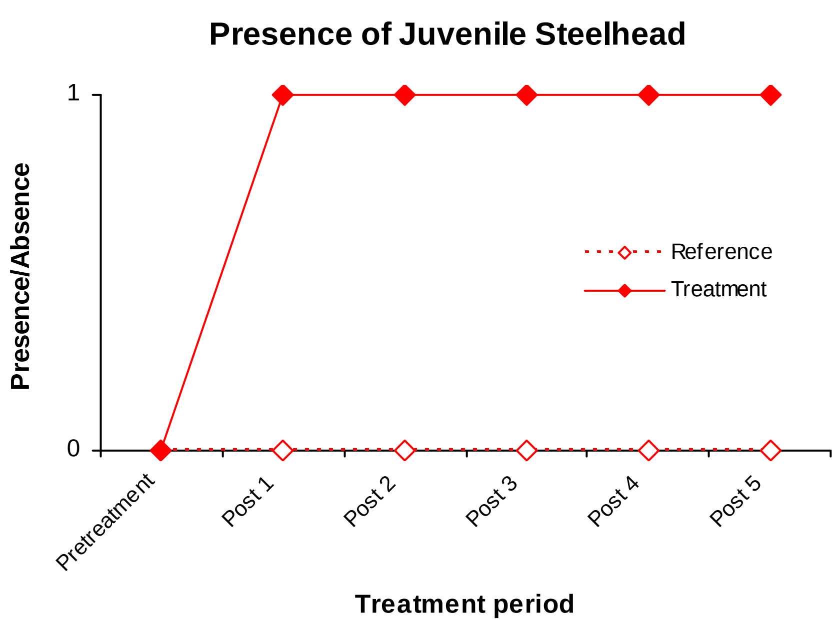

Figure 3.2. An example of data analysis using graphing methods for a BACI study. The figure shows the presence (1) and absence (0) of juvenile steelhead within off-channel ponds during winter in a treatment and reference area before (pretreatment) and after (post) treatment. The restoration project involved connecting an off-channel pond to the mainstem. An off-channel pond not directly connected to the mainstem served as the reference site. The figure demonstrates that juvenile steelhead used the off-channel pond during winter.

3.3 Floodplain Restoration Example

A sponsor is interested in increasing overwinter survival of juvenile Chinook salmon in the CeeCee River by reconnecting an off-channel pond (old gravel barrow pit) with the river. Restoration work will involve opening a 240-m-long relic channel (currently dry) that will connect the pond to the mainstem. In addition, the sponsor will create eleven pools in the channel and placing woody debris in the channel and pond. Opening the channel will require the removal of a dike that has prevented the river from flowing into the side channel and pond for more than ten years. Although the off-channel pond is not directly connected to the mainstem, a shallow aquifer maintains the water level within the pond. The sponsor believes the moderating effect of the aquifer on winter water temperatures and the presence of quiet-water habitat with concealment cover will increase the overwinter survival of juvenile Chinook.[20] The sponsor proposes the following work.

Goals and Objectives

Goal: Increase overwinter survival of juvenile Chinook salmon by restoring floodplain connectivity with the CeeCee River.

- ***Objective 1:*** Remove a dike that currently blocks the flow of water into a 240-m-long side channel that is connected to an off-channel pond.
- ***Objective 2:*** Create eleven pools, each 50-cm deep, at outside bends within the side channel.
- ***Objective 3:*** Place 26 pieces of large woody debris randomly throughout the side channel and five brush bundles along the margins of the off-channel pond.[21]

Key Questions and Hypotheses

Key Question 1: Will the removal of a 1.6-m-high dike allow water to flow into a 240-m-long relic channel during all times of the year?

- ***Hypothesis 1:*** Removal of a 1.6-m-high dike will not increase floodplain connectivity between an off-channel pond and the mainstem.

Key Question 2: Will the creation of eleven pools, each 50-cm deep, increase habitat diversity within the relic side channel?

- ***Hypothesis 2:*** The creation of eleven pools, each 50-cm deep, will not increase habitat diversity within the relic side channel.

Key Question 3: Will the addition of 26 pieces of large woody debris in the side channel and five brush bundles in the pond increase habitat complexity and concealment cover for juvenile Chinook salmon?

- ***Hypothesis 3:*** The addition of 26 pieces of large woody debris to the side channel and five brush bundles in the pond will not increase habitat complexity or provide concealment cover for juvenile Chinook salmon.

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20 Monitoring the overwinter survival of juvenile Chinook is beyond the scope of level 1 effectiveness monitoring.

21 Note that the sequence of actions is to first address the primary threat (dike) and then to restore/create habitat complexity.

Implementation Monitoring

- Was the 1.6-m-high dike removed according to engineering plans?
- Were eleven pools, each 50-cm deep, constructed along the outside bends of the relic channel?
- Were 26 pieces of large woody debris[22] placed within the relic channel and five brush bundles placed along the margin of the off-channel pond?

Measurements: Presence/absence of levee; number, location, and depths of pools created in side channel; number and locations of pieces of woody debris placed in side channel; number and locations of brush bundles placed in the off-channel pond.

Level 1 Effectiveness Monitoring

Was the restoration action effective in restoring floodplain connectivity and increasing overwinter survival of juvenile Chinook salmon?[23]

Monitoring design: Before-after design with one measurement taken before treatment and five measurements taken annually after treatment.

Treatment area(s): The one treatment area is located at Rkm 15.4 on CeeCee River and lies entirely on State lands. The 0.32 ha off-channel pond is located on the north side of the river. A 240-m-long relic channel will be used to reconnect the pond with the mainstem.

Reference area(s): No suitable reference area was found that could be compared with the treatment area.

Monitoring Parameters: Presence/absence of obstruction (levee); presence of surface flow during all seasons; length of side channel; area of off-channel pond; number of pools per kilometer in side channel; residual pool depths; residual pond depth; number and location of pieces of woody debris and brush bundles; water temperatures of the pond; presence/absence of juvenile Chinook in the pond and in woody debris during winter.

Sampling Scheme: The entire 240-m-long side channel and the off-channel pond will be surveyed once before treatment (removal of levee, creation of pools, and addition of woody debris) and annually for five years following treatment. Photographs will be taken of the levee before and after removal, at four points along the length of the channel to document presence of stream flow, at each pool site, and of the off-channel pond. Photos documenting the presence of surface flow will be taken during spring high flow, summer/fall low flow, and during winter. Photos of the levee and pools will be taken during summer/fall low flow. Photos of the off-channel pond will be taken during summer/fall low flow and during winter.

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[22] All woody debris placed in a stream or pond should be marked with a metal tag, each with a unique number or code (e.g., CC001, which stands for Chelan County piece #1). This will allow the sponsor to track individual pieces of wood placed in the stream.

[23] Monitoring the overwinter survival of juvenile Chinook salmon is beyond the scope of Level 1 effectiveness monitoring. However, the sponsor should document the presence of juvenile Chinook in the pond during winter and their use of woody debris.

The length of the side channel and the area of the off-channel pond will be measured annually during summer/fall low flow. Numbers of pools, pieces of woody debris in the side channel, and brush bundles in the pond will be counted annually during summer/fall low flow. The locations of pools and woody debris will be noted on drawings or maps of the restoration site. Residual pool depths and residual pond depth will be measured annually during summer/fall low flow. A data logger placed in the pond will record water temperatures at hourly intervals throughout winter (end of November to end of March).

Presence/absence of juvenile Chinook salmon in the pond will be documented during each winter using underwater observation methods. Presence of juvenile Chinook in woody debris will also be documented during winter. Winter sampling will occur at night when juvenile Chinook are more active and easier to see.

Data Analysis: Mean scores and 95% CI of residual pool depths will be analyzed graphically before and after treatment. Presence/absence data (levee, seasonal surface flows, juvenile Chinook) will be analyzed graphically and with photos before and after treatment. Count data (numbers of pools, pieces of woody debris, and brush bundles) will also be analyzed graphically before and after treatment. Daily mean, minimum, and maximum water temperatures in the pond will be plotted over the winter period. Finally, changes in the length of side channel, area of the pond, and residual pond depth will be analyzed graphically. Because of generally high sediment loads during spring snowmelt, there will likely be some reduction in the number of pools, residual pool depths, residual pond depth, and area of the pond over the five-year monitoring period.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the restoration action and will offer recommendations.

3.4 Summary

As with all projects, monitoring must be tailored for each specific restoration action. There is no easy-to-follow recipe for monitoring all types of restoration projects. However, if the goals and objectives are specific, monitoring programs can be developed to address any kind of restoration action. Because floodplain restoration is a relatively young science, monitoring the effectiveness of floodplain restoration projects is needed to better understand successful restoration techniques. This section provides sponsors with a "toolbox" that can be used to develop Level 1 effectiveness monitoring plans for floodplain restoration projects. The steps involved in setting up a monitoring program for floodplain restoration projects include (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with spatial and temporal reference sites, if possible; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the restoration action resulted in the desired outcome.

This information can be used by funding entities and managers to adaptively manage aquatic resources.

SECTION 4: INSTREAM HABITAT RESTORATION

The placement of physical structures into streams is one of the most common and widespread restoration methods in regular use. Many different configurations of instream structures and methods have been used to improve habitat, but they are all generally composed of rocks, boulders, trees, and brush bundles. The structures are usually placed in streams to create pools, to alter channel morphology, and to provide cover and habitat for fish (primarily salmonids) and other aquatic organisms. Because these activities seek to enhance habitat rather than restore a deficient watershed process (e.g., riparian habitat, hydrology, etc.) or return a stream to some pre-disturbed state, they are technically habitat enhancement projects.

As noted in the introduction, there is considerable debate about the use of instream enhancement projects. This is because these actions are often taken without an assessment of what factors caused the lack of habitat complexity, what processes in the watershed might be disrupted and need to be corrected, and what factors might be limiting the physical and biological production of a system. For example, the failure of instream wood and boulder structures to increase fish abundance and survival may be related to delivery of fine sediments from an upstream area where logging and roads have removed riparian vegetation. Thus, in some cases, if the underlying cause of the problem is not addressed, instream enhancement may represent only a short-term improvement in habitat. On the other hand, instream enhancement may be needed to protect rare fishes or to provide benefits where some watershed process cannot be restored. They are particularly relevant when coupled with restoration activities that restore natural processes, such as riparian restoration, floodplain restoration, or road improvements.

The purpose of this section is to describe how to monitor the effectiveness of instream enhancement projects. First I describe some common restoration techniques that are used to increase habitat diversity within a stream channel. Next I discuss how to develop a monitoring plan to assess the effectiveness of the instream enhancement action. Finally, I provide an example of a Level 1 monitoring plan that will assess the effects of a hypothetical instream enhancement project.

4.1 Instream Habitat Restoration Techniques

There are many different configurations of instream structures and methods that have been used to improve habitat. In general, they can be categorized by material (rock or wood) and purpose (e.g., create pools, trap gravels) and may include structures such as boulder or log weirs, dams and deflectors, cover structures, rootwads and brush bundles, gabions, and logjams. Identified below are common instream enhancement types based on materials used.

Rock

Rocks and boulders are often used to alter channel structure, morphology, and habitat. There are two general types of rock structures: boulders and gravel additions. Boulder enhancement structures include boulder weirs, boulder clusters, single boulders, drop structures, and boulder deflectors. These structures are placed in the wetted channel to create pools and cover for fish, trap gravel, confine the channel, or create spawning habitat. Gravel additions include the placement of spawning gravels or creation of riffles. These are intended to increase spawning habitat for fish.

Wood

Wood is added to channels to increase habitat diversity and alter channel structure and morphology. There are three general types of wood structures: log structures, logjams, and brush bundles/rootwads. Log structures, including weirs, sills, deflectors, single logs, wing deflectors, and k-dams are placed in the active channel to create pools and cover for fish, trap gravels, confine the channel, or create spawning habitat. Log jams (multiple log structures or engineered logjams) are placed in the active channel to form a debris dam that creates pools and holding and rearing areas for fish, traps sediment, prevent channel migration, or restore floodplain and side channels. Brush bundles and rootwads are placed in pools or slow-water areas to provide cover for juvenile and adult fish, refuge from high flows, or substrate for macroinvertebrates.

Others

Other types of instream enhancement activities include creation of cover structures, sediment traps, and channel reconstruction and realignment. Cover structures can be made of wood, metal, or rock and generally are embedded in the stream bank. They provide overhead cover for fish and prevent bank erosion. Sediment traps are excavated depressions or ponds within the active channel. These depressions trap fine sediments, which improves channel condition and morphology. Channel reconstruction or realignment involves the excavation of new channels to restore meander patterns or to return the stream to the historic channel. This technique restores meander patterns, increases habitat complexity and pool:riffle ratios, and reduces channel width.

4.2 Instream Habitat Restoration Monitoring Plan

Because instream enhancement projects focus on direct manipulations of habitat, they represent excellent opportunities to test hypotheses. Testing these hypotheses is important for guiding future habitat enhancement efforts. Developing an adequate monitoring study to test hypotheses is challenging because of the wide variety of instream enhancement techniques. However, as noted in Section 1, there are several logical steps that should be taken to set up a valid Level 1 monitoring program. These steps are discussed below.

Goals and Objectives

The first and most important step in developing a monitoring plan for assessing the effectiveness of instream enhancement projects is to clearly identify the overall goals and specific objectives of the project. The following are examples of goals and objectives.

Goals:

- Increase habitat diversity in Gold Creek.
- Increase habitat diversity and survival of juvenile Chinook in Silver Creek.
- Increase pool:riffle ratios on Little Smith Creek.

- Increase stream length and sinuosity of Rainbow Creek.
- Increase steelhead spawning habitat in Marsh Creek.
- Increase habitat diversity, floodplain connectivity, and salmonid rearing habitat in the lower Wenatchee River.
- Provide high-flow refugia for spring Chinook in Deep Creek.
- Increase the abundance of woody debris in Alder Creek.
- Reduce bank erosion along a meander bend on Juniper Creek.

Objectives:

- Increase habitat diversity in Gold Creek by installing three boulder weirs in a long riffle reach.
- Increase habitat diversity and survival of juvenile Chinook by adding three brush bundles into each of five pools in Silver Creek.
- Increase pool:riffle ratios by adding five log weirs in a kilometer-long reach of riffle on Little Smith Creek.
- Install four boulder deflectors and two log wing deflectors to increase stream length and sinuosity of Rainbow Creek.
- Add 0.15 ha of spawning gravel in Marsh Creek to increase spawning habitat for steelhead.
- Increase the number of pools, floodplain connectivity, and salmonid cover by adding an engineered logjam to the lower Wenatchee River.
- Increase high-flow refugia for spring Chinook by anchoring 12 rootwads to the banks of Deep Creek.
- Increase the abundance of woody debris in Alder Creek by dropping 14 Douglas fir into the stream.
- Reduce bank erosion along a meander bend of Juniper Creek by placing six boulder deflectors along the outside bend of the stream.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All instream enhancement projects have working hypotheses. When a project is initiated, it is based on the general assumption that the enhancement action is going to lead to an improvement in some physical and/or biological condition. Specific predictions can be made as to how the habitat will improve in response to the action. Example questions and hypotheses for instream enhancement projects include:

Key Questions:

- Will the addition of three boulder weirs in a riffle section of Gold Creek increase the number of pools in the stream?
- Will the addition of three brush bundles within each of five pools increase woody debris and the survival of juvenile Chinook in Silver Creek?
- Will the addition of five log weirs in a kilometer-long riffle increase the pool:riffle ratio on Little Smith Creek?

- Can the total length and sinuosity of Rainbow Creek be increased by adding four boulder deflectors and two log wing deflectors?
- Will the area of steelhead spawning habitat increase by adding 0.15 ha of spawning gravel to Marsh Creek?
- Will the installation of an engineered logjam increase the number of pools, floodplain connectivity, and salmonid cover in the lower Wenatchee River?
- Will the placement of 12 rootwads into the banks of Deep Creek increase high-flow refugia for spring Chinook salmon?
- Will dropping 14 Douglas fir trees into Alder Creek increase the abundance of large woody debris in the stream?
- Will the placement of six boulder deflectors reduce bank erosion along a meander bend on Juniper Creek?

Hypotheses:

- The addition of three boulder weirs in a riffle section of Gold Creek will not increase the number of pools in the stream.
- The addition of three brush bundles within each of five pools will have no effect on woody debris and the survival of juvenile Chinook in Silver Creek.
- The addition of five log weirs in a kilometer-long riffle will have no effect on pool:riffle ratios on Little Smith Creek.
- The addition of four boulder deflectors and two log wing deflectors will have no effect on total length and sinuosity of Rainbow Creek.
- Adding 0.15 ha of spawning gravel will have no effect on steelhead spawning habitat in Marsh Creek.
- The installation of an engineered logjam will have no effect on the number of pools, floodplain connectivity, and salmonid cover in the lower Wenatchee River.
- The anchoring of 12 rootwads into the banks of Deep Creek will not increase high-flow refugia for spring Chinook salmon.
- Dropping 14 Douglas fir trees into Alder Creek will have no effect on the abundance of large woody debris in the stream.
- The placement of six boulder deflectors will not prevent bank erosion along a meander bend on Juniper Creek.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

Once the goals, objectives, key questions, and hypotheses are determined, the treatment needs to be implemented in such a way that the hypotheses can be tested. As indicated in Section 1, an appropriate monitoring design is to survey the enhancement site before and after treatment (Before-After design). If possible, the sponsor should identify a similar site that will not be treated and will serve as a spatial reference site. Measurements are then taken at both the treatment and reference sites before and after enhancement (BACI design). This allows one to compare enhancement effects with both a spatial and temporal reference condition.

Parameters

For project monitoring, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 4.1 identifies possible parameters and sampling methods for monitoring instream enhancement projects.

In addition to measuring various channel and flow parameters, all sponsors should establish photo points (see Hall 2001) to document changes within treatment and reference sites for all enhancement projects. Annual photographs of enhancement areas taken at the same locations within treatment and reference areas both before and after treatment provide an excellent tool for illustrating project effectiveness.

Table 4.1. Possible parameters and sampling methods for monitoring instream enhancement actions.

Monitoring parameter	Sampling method
Length of stream channel	Measure the length (to nearest 0.1 m) of stream channel by measuring down the center of the channel.
Number of boulders	Count the number of boulders within the treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in the treatment and reference areas. To be counted, a boulder must be the size of a basketball or larger (>25 cm).
Number of pools	Count the number of pools within treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas. To be counted, a pool must span more than half the wetted width, include the thalweg[24], be longer than it is wide, and be at least 1.5 times the crest depth. Plunge pools should be included even if they are not as long as they are wide.
Residual pool depth	Calculate the residual pool depth for all pools within treatment and reference areas or within three randomly selected reaches that are no less than 150 m long in treatment and reference areas. Residual pool depth is calculated as the maximum pool depth minus the maximum pool-outlet depth (Hillman 2004). Depths are measured (to the nearest 0.01 m) with a meter stick or surveyor's rod.
Number of pieces of woody debris	Count the number of pieces of woody debris (diameter >10 cm and a length >1 m)[25] within treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas.

[24] Thalweg is the deepest part of the channel.

[25] The definition for large woody debris differs widely among institutions. The definition provided here comes from Armantrout (1998). Sponsors are encouraged to follow the definition of the managing agency within their geographic area.

Monitoring parameter	Sampling method
Number of logjams	Count the number of logjams within treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas. To be counted, a logjam must consist of a cluster of at least 2 pieces of large wood (diameter >10 cm and a length >1 m).
Bank stability	Assess bank stability[26] along both sides of treatment and reference channels or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas.
Area of spawning gravels	Measure the surface area of suitable spawning gravels within the treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas. The size of suitable gravel is based on the specific species of interest. Smaller fish species (e.g., resident bull trout) spawn in smaller gravels than larger fish species (e.g., Chinook salmon).
Presence/absence of target fish and life stage	Document the presence of target fish and life stages using snorkeling or visual observations from the bank. Observation are made in treatment and reference areas or within at least three randomly selected reaches that are no less than 150 m long in treatment and reference areas.

[26] Bank stability is visually estimated as the percent (%) of the lineal distance that is actively eroding at the active channel height on both sides of the channel (see Hillman 2004). Active erosion is defined as recently eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability. Bank stability is estimated throughout the entire treatment and reference reaches or along the 150-m long survey sites.

Sampling Scheme

For all instream enhancement projects, data (including photographs) will be collected at least once before implementation of the enhancement action and then annually for five years following treatment.[27] If a spatial reference area is used (BACI design), data and photographs will be collected in the reference area at the same time data are collected within the treatment area. Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer low flow, than sampling should occur during summer low flow every year thereafter. In addition, if sampling occurs within three randomly selected 150-m-long sites within each of the reference and treatment areas, then the same sites must be sampled each year. Sampling different sites annually may increase variability and make it more difficult to demonstrate a treatment effect. It is therefore important to monument each sampling site and photo-point location with permanent markers (e.g., rebar), GPS, drawings, markings on topographic maps, and photographs.

Whenever possible, surveys should be conducted throughout the entire treatment and reference areas. If treatment and reference areas are too large to census, measurements can be taken within at least three randomly selected 150-m-long stream reaches (for measuring numbers of pools and boulders, depths of pools, number of pieces of woody debris and log jams, bank stability, area of suitable spawning gravel, and/or presence of fish). The same sampling scheme should be used in both the treatment and reference areas.

Data Analysis and Reporting

When habitat and channel data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis (e.g., see Figures 4.1 and 4.2). Measurements for both the reference and treatment areas can be shown on the same graph. In many cases, figures, tables, and photographs may be all that are needed to demonstrate treatment effects. Additional analysis could include testing trends using time series analysis or regression techniques. Other statistics such as t-tests and analysis of variance can be used to test for significant differences between treatment and reference conditions. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

[27] Some restoration actions my take more than one year to implement. In these cases, monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

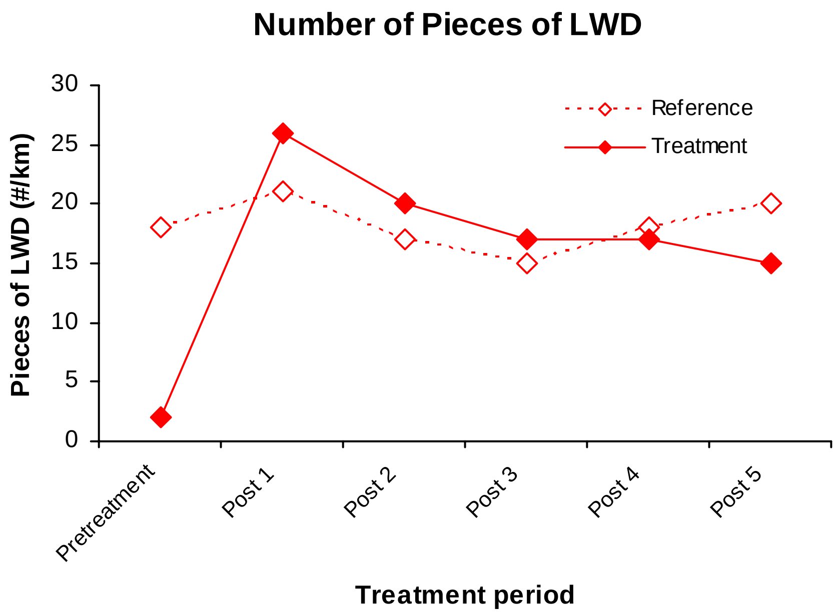

Figure 4.1. An example of data analysis using graphing methods for a BACI study. The figure shows the number of pieces of large woody debris (pieces/km) for a treatment and reference reach before (pretreatment) and after (post) treatment. Note that the reference reach represents the desired condition.

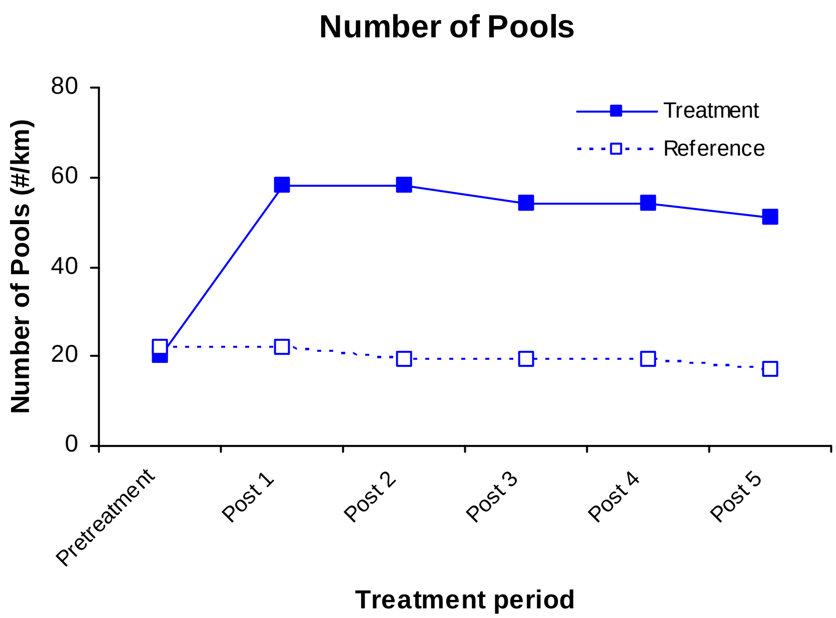

Figure 4.2. An example of data analysis using graphing methods for a BACI study. The figure shows the number of pools (pools/km) in the treatment and reference areas before (pretreatment) and after (post) treatment. Note that the reference reach represents the degraded condition.

4.3 Instream Habitat Restoration Example

A sponsor is interested in increasing habitat diversity and the abundance of juvenile bull trout within a 0.7-km-long segment of Stump Creek that is artificially confined by a highway on one side and the railroad on the other side. Because the railway and the highway cannot be moved, the sponsor intends to increase habitat diversity by adding large wood, boulder clusters and weirs, and brush bundles to the confined, homogenous riffle. Enhancement work will involve anchoring five large pine trees to the bank, placing four boulder clusters near the middle of the channel, installing three boulder weirs, and anchoring six brush bundles to the banks upstream from each rock weir (for a total of 18 brush bundles). The sponsor believes that by adding structure (pools and cover) to the confined riffle reach, juvenile bull trout abundance will increase in the reach, thereby benefiting the Stump Creek bull trout population. The sponsor proposes the following work.

Goals and Objectives

Goal: Increase habitat diversity and abundance of juvenile bull trout within a 0.7-km-long confined reach of Stump Creek.

Objective 1: Increase habitat diversity and abundance of juvenile bull trout within the 0.7-km-long confined reach of Stump Creek by anchoring five large pine trees to the bank, placing four boulder clusters near the middle of the channel, installing three V-shaped boulder weirs, and anchoring six brush bundles to the banks upstream from each rock weir (for a total of 18 brush bundles).

Key Questions and Hypotheses

Key Question 1: Will the addition of five large pine trees, four boulder clusters, and three V-shaped boulder weirs increase the number of pools within a 0.7-km reach of Stump Creek?

Hypothesis 1: The addition of five large pine trees, four boulder clusters, and three V-shaped boulder weirs will have no effect on the number of pools within a 0.7-km reach of Stump Creek.

Key Question 2: Will the addition of three large pine trees and 18 brush bundles increase the number of pieces of large woody debris within a 0.7-km reach of Stump Creek?

Hypothesis 2: The addition of three large pine trees and 18 brush bundles will not increase the number of pieces of large woody debris within a 0.7-km reach of Stump Creek.

Key Question 3: Will the addition of five large pine trees, four boulder clusters, three V-shaped weirs, and 18 brush bundles increase the abundance of juvenile bull trout within a 0.7-km-long confined reach of Stump Creek?

Hypothesis 3: The addition of five large pine trees, four boulder clusters, three V-shaped weirs, and 18 brush bundles will have no effect on the abundance of juvenile bull trout within a 0.7-km-long confined reach of Stump Creek.[28]

[28] Although this is a testable hypothesis, it is beyond the scope of Level 1 effectiveness monitoring. Abundance of juvenile bull trout would be assessed under other monitoring programs.

Implementation Monitoring

- Were five large (>15 m) pine trees anchored to the banks in the locations specified in the engineering plans?
- Were four boulder clusters (with three large boulders per cluster) placed mid-channel in locations specified in the engineering plans?
- Were three V-shaped boulder weirs installed in locations specified in engineering plans?
- Were 18 brush bundles anchored to the banks in locations specified in the engineering plans?

Measurements: Number and location of large pine trees; number and location of boulder clusters; number and location of V-shaped boulder weirs; number and location of brush bundles.

Level 1 Effectiveness Monitoring

Was the enhancement action effective in increasing habitat diversity and abundance of juvenile bull trout?[29]

Monitoring design: BACI design with one measurement taken before treatment and five measurements taken annually after treatment in both treatment and reference areas.

Treatment area(s): The one treatment area is located between Rkm 19.3 and 20.0 on Stump Creek. Adjacent lands are owned by the railroad and the State. Enhancement actions will be implemented throughout the entire reach.

Reference area(s): A suitable reference area, 280-m long, is located on Bucktail Creek. The entire reach is artificially confined by roads and consists entirely of a low-gradient riffle with no habitat diversity (lacks pools, woody debris, and large boulders). Bull trout exist within the Bucktail Creek watershed.

Monitoring Parameters: Number of boulders per kilometer; number of pools per kilometer; residual pool depth; number of pieces of woody debris per kilometer; number of brush bundles per kilometer; presence/absence of juvenile bull trout.

Sampling Scheme: The entire treatment reach (700-m long)[30] and reference reach (280-m long) will be surveyed once before treatment (addition of wood and boulders) and annually for five years following treatment. During summer low flow, photographs will be taken before and after installation of structures. Each tree and brush bundle installed will be marked with a metal tag. All structures will be photographed and their locations mapped annually during summer low flow. Numbers of pieces of woody debris, brush bundles, pools, and boulders will be counted annually during summer low flow in both treatment and reference reaches. At the same time, residual pool depths of all pools will be measured within both reaches. Finally, during summer

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29 Monitoring the abundance of juvenile bull trout is beyond the scope of Level 1 effectiveness monitoring. However, the sponsor should document the presence of juvenile bull trout in the enhancement reach.

30 Although the reach is long enough to select three 150-m-long sampling sites, the sponsor elected to survey the entire reach.

low flow, snorkeling will be used to document the presence of juvenile bull trout within the treatment and reference reaches.

Data Analysis: Mean scores and 95% CI of residual pool depths will be analyzed graphically before and after treatment and between treatment and reference reaches. Numbers of pieces of woody debris, brush bundles, pools, and boulders (reported as #/km) will be analyzed graphically before and after treatment and between treatment and reference reaches. Changes in locations of wood and boulders will be determined by examining maps and photographs. Presence of juvenile bull trout will be analyzed graphically. Scour pools will likely form after the first high-flow event following installation of the structures.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and Level 1 effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the enhancement project and will offer recommendations.

4.4 Summary

The monitoring of instream enhancement projects has been more intensive than most other restoration techniques. However, there is still much to learn about the effects of instream enhancement structures. As with all projects, monitoring must be tailored for each specific enhancement project. There is no easy-to-follow recipe for monitoring all types of enhancement projects. Nevertheless, if the goals and objectives are specific, monitoring programs can be developed to address any kind of instream enhancement action. This section provides sponsors with a "toolbox" that can be used to develop Level 1 effectiveness monitoring plans for instream enhancement projects. The steps involved in setting up a monitoring program for instream enhancement projects include (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with spatial and temporal reference sites, if possible; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the restoration action resulted in the desired outcome. This information can be used by funding entities and managers to adaptively manage aquatic resources.

SECTION 5: RESTORATION OF CONNECTIVITY

The loss of connectivity among historic aquatic habitats has reduced the abundance, spatial structure, and diversity of fish species in the Columbia Basin. In Washington State alone, more than 7,700 km of historical salmon habitat is inaccessible to fishes because of impassable man-made structures (culverts and road crossings) (Pess et al. 2005). In many cases, connectivity among habitats has been reduced because of roads, culverts, levees, dams, pipeline crossings, and other man-made structures. These structures not only block access for migratory fishes, they can compromise delivery of materials, including sediment, wood, organics, and marine-derived nutrients.

Inventories to assess isolation of stream habitats by man-made barriers should be conducted using physical criteria for fish migration (e.g., WDFW 2000). These inventories can be used to assess the amount of habitat affected or isolated upstream from barriers, and whether a stream crossing is a complete (all species at all life stages or seasons) or partial (certain species at specific life stages or seasons) barrier to fish movements within the watershed. The State of Washington has developed fish passage criteria for juvenile and adult salmonids that can be the basis for identifying fish blockages (WDFW 2000; WDFW 2003).

The purpose of this section is to describe how to monitor the effectiveness of reconnection projects. First I describe some common restoration techniques that are used to reconnect aquatic habitats within watersheds. Next I discuss how to develop a monitoring plan to assess the effectiveness of the restoration actions. Finally, I provide an example of a Level 1 monitoring plan that will assess the effects of a hypothetical reconnection project.

5.1 Connectivity Restoration Techniques

The reconnection of freshwater habitats is an important restoration method that is commonly used to aid in the recovery of salmonid populations. As such, many techniques have been developed to restore connectivity, based on the type of obstruction. The most common techniques include bridge projects, culvert improvements, dam removals, diversion dam passage, fishway construction, and water management projects. These can be grouped into three general categories: water crossings; dams and diversions; and water management.

Water Crossings

Many reconnection projects include replacing or removing culverts that completely or partially block fish passage and the delivery of wood, sediment, and nutrients. In most cases, improperly functioning culverts are replaced with "fish-friendly" culverts or bridges. WDFW (2003) provides guidelines for designing road culverts for fish passage.

Dams and Diversions

Dams and water diversions can impede or block fish passage within a stream system. Restoration techniques generally consist of removing the structures or providing a fishway. WDFW (2000) provides guidelines for designing fishways, including considerations for fishway entrances, auxiliary water systems, fish ladders, and fishway exits.

Water Management

In some cases fish passage is reduced by critically low flows, high stream temperatures, or the presence of toxicants and pollutants. Restoration techniques may include methods to restore stream flows (e.g., implementing water conservation measures), reduce water temperatures (e.g., through riparian restoration techniques), and the removal or reduction of point-source and non-point-source pollutants. These restoration techniques can be quite involved and expensive.

5.2 Connectivity Restoration Monitoring Plan

Because restoring connectivity focuses on direct manipulations of habitat, it represents an excellent opportunity to test hypotheses. Testing these hypotheses is important for guiding future restoration efforts. Developing an adequate monitoring study to test hypotheses is challenging because of the many different types of restoration techniques. However, as noted in Section 1, there are several logical steps that should be taken to set up a valid Level 1 monitoring program. These steps are discussed below.

Goals and Objectives

The first and most important step in developing a monitoring plan for assessing the effectiveness of reconnection projects is to clearly identify the overall goals and specific objectives of the project. The following are examples of goals and objectives.

Goals:

- Increase fish passage into Goose Creek.
- Increase connectivity within Poorman Creek.
- Reconnect 18 km of spawning and rearing habitat in Timber Creek.
- Reconnect historic habitat in Pilsner Creek.
- Increase steelhead rearing and spawning habitat in Chamberlain Creek.

Objectives:

- Increase fish passage in Goose Creek by installing a vertical-slot fishway in Goose Creek Diversion.
- Increase connectivity within Poorman Creek by replacing three undersized culverts located downstream from Rkm 2.5 with bottomless culverts.
- Open 18 km of salmonid spawning and rearing habitat in Timber Creek by replacing an undersized culvert at Rkm 4.1 with a bridge.
- Reconnect 12.4 Rkm of historic salmon spawning and rearing habitat in Pilsner Creek by returning 16 cfs of unused diverted water back into lower Pilsner Creek.

- Reconnect 5.7 km of steelhead rearing and spawning habitat in Chamberlain Creek by replacing the culvert at Rkm 0.3 with a larger squash culvert.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All reconnection projects have working hypotheses. When a project is initiated, it is based on the general assumption that the restoration action is going to lead to an improvement in some physical and/or biological condition. Specific predictions can be made as to how the habitat will improve in response to the action. Example key questions and hypotheses for reconnection projects include:

Key Questions:

- Will the installation of a vertical-slot fishway at Goose Creek Diversion increase the upstream passage of juvenile and adult fishes in Goose Creek?
- Will the replacement of three culverts located downstream from Rkm 2.5 with bottomless culverts increase the upstream passage of fishes within Poorman Creek?
- Will the replacement of a culvert at Rkm 4.1 with a bridge increase the distribution of adult and juvenile steelhead in Timber Creek?
- Will the addition of 16 cfs of water into a dewatered section of lower Pilsner Creek increase the passage, abundance, and distribution of Chinook and coho salmon in the Pilsner Creek drainage?
- Will the replacement of a culvert at Rkm 0.3 with a larger squash culvert increase the passage, abundance, and distribution of steelhead in Chamberlain Creek?

Hypotheses:

- The installation of a vertical-slot fishway at Goose Creek Diversion will not increase the upstream passage of juvenile and adult fishes in Goose Creek.
- The replacement of three culverts downstream from Rkm 2.5 with bottomless culverts will not increase the upstream passage of fishes within Poorman Creek.
- The replacement of a culvert at Rkm 4.1 with a bridge will not increase the distribution of adult and juvenile steelhead in Timber Creek.
- The addition of 16 cfs of water into a dewatered section of lower Pilsner Creek will have no effect on the passage, abundance, and distribution of Chinook and coho salmon in the Pilsner Creek drainage.
- The replacement of a culvert at Rkm 0.3 with a larger squash culvert will not increase the passage, abundance, and distribution of steelhead in Chamberlain Creek.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

Once the goals, objectives, key questions, and hypotheses are determined, the fish barrier removal project needs to be implemented in such a way that the hypotheses can be tested. An appropriate monitoring design is to survey a site upstream and downstream from the barrier before and after treatment. Measurements are taken at the upstream and downstream sites and at the location of the barrier before and after restoration. This allows one to compare restoration effects with both a spatial and temporal reference condition.

Parameters

For project monitoring, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 5.1 identifies possible parameters and sampling methods for monitoring reconnection (passage) projects.

In addition to measuring various habitat parameters, all sponsors should establish photo points (see Hall 2001) to document changes in connectivity for all barrier removal projects. Annual photographs of restoration areas taken at the same locations both before and after treatment provide an excellent tool for illustrating project effectiveness.

Table 5.1. Possible parameters and sampling methods for monitoring fish barrier removal projects.

Monitoring parameter	Sampling method
Water velocity within fishway (e.g., culvert)	Using a calibrated water-velocity meter, measure the maximum water velocity within the culvert at the downstream end of the culvert. Measurement should be taken away from the influence of outlet conditions and measured to the nearest 0.01 m/s.
Water depth within fishway (e.g., culvert)	Measure the depth within the culvert at the downstream end of the culvert away from the influence of outlet conditions. Measured to the nearest 0.01 m.
Outfall drop	Measure outfall drop as the distance from the water surface at the downstream end of the culvert to the water surface of the plunge pool. Measured to the nearest 0.01 m.
Stream flows (measured only for restoration projects that increase connectivity by increasing stream flows)	Use USGS or WDOE flow data where available. If these are unavailable, measure stream flows using the velocity-area method described in Peck et al. (2001). Water velocities should be measured to the nearest 0.01 m/s with a calibrated water-velocity meter. Wetted width and depth should be measured to the nearest 0.01 m.
Presence/absence of redds (nests)	Document the presence of target fish redds using visual observations from the bank. At least 300 m of stream should be surveyed both upstream and downstream of the barrier for fish redds.
Presence/absence of target fish and life stage	Document the presence of target fish and life stages using snorkeling or visual observations from the bank. At least 300 m of stream should be surveyed for fish both upstream and downstream of the barrier.

Water depths and velocities within fishways (culverts) are compared to standards based on species and size of fish. WDFW (2003) has established the following standards for velocity and depths (Table 5.2).

Table 5.2. Fish-passage design criteria for culvert installations (WDFW 2003).

Culvert length	Adult trout >6 inches (150 mm)	Adult Chinook, coho, sockeye, or steelhead
Maximum velocity (feet/sec)		
10-60 feet	4.0	6.0
60-100 feet	4.0	5.0
100-200 feet	3.0	4.0
>200 feet	2.0	3.0
Minimum water depth (feet)		
All lengths	0.8	1.0

Sampling Scheme

For all fish passage projects, data (including photographs) will be collected at least once before implementation of the reconnection project and then annually for five years following treatment.[31] Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer low flow, than sampling should occur during summer low flow every year thereafter. Sampling at different times of the year may be necessary depending on the objectives of the project. If the objective is to provide passage during both high and low flow conditions, then measurements need to be collected during both flow periods each year. It is important to monument sampling areas and photo-point locations with permanent markers (e.g., rebar), GPS, drawings, markings on topographic maps, and photographs.

Presence/absence surveys for fish should be conducted within 300 m reaches upstream and downstream from the barrier. Surveys should be conducted at times when the target species and life stages would most likely be present. For example, steelhead redd surveys should be conducted in the spring, while salmon redd surveys would be conducted during the fall. Presence/absence surveys of most juvenile and adult life stages of resident fish (e.g., westslope cutthroat trout) can be conducted during summer low flow periods.

Data Analysis and Reporting

When data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis (e.g., see Figures 5.1 and 5.2). Measurements for both the reference (downstream of barrier) and treatment (upstream of barrier) areas can be shown on the same graph, or actual field measurements can be compared with standard criteria on a graph. In many cases, figures, tables, and photographs may be all that are needed to

[31] Some restoration actions my take more than one year to implement. In these cases, monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

demonstrate treatment effects. Additional analysis could include testing trends using time series analysis or regression techniques. Other statistics such as t-tests and analysis of variance can be used to test for significant differences between before and after treatment conditions. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

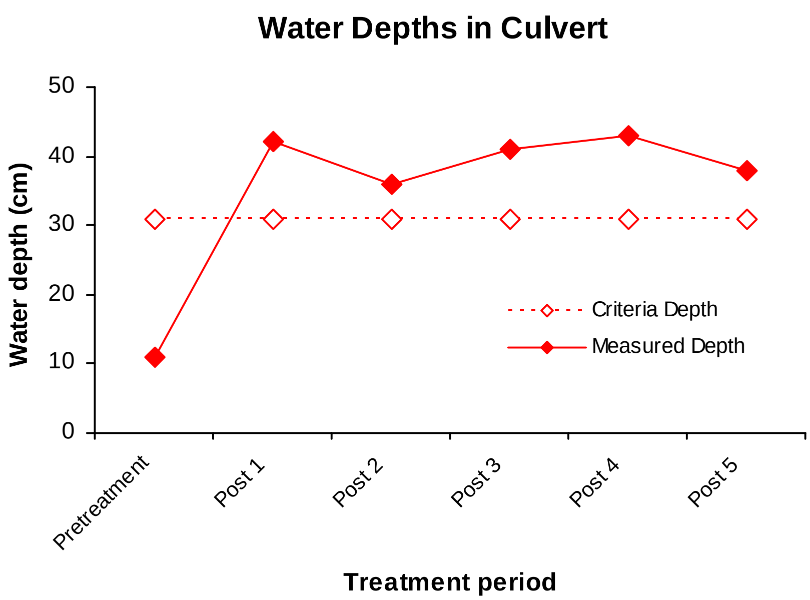

Figure 5.1. An example of data analysis using graphing methods for a culvert replacement study. The figure shows water depths measured during low flow conditions within a culvert before (Pretreatment) and after (Post) replacement. The depths are compared to the standard criteria of 31 cm for adult steelhead in a 100-ft long culvert. Note that the depths within the improved culvert are greater than the criteria (a beneficial condition).

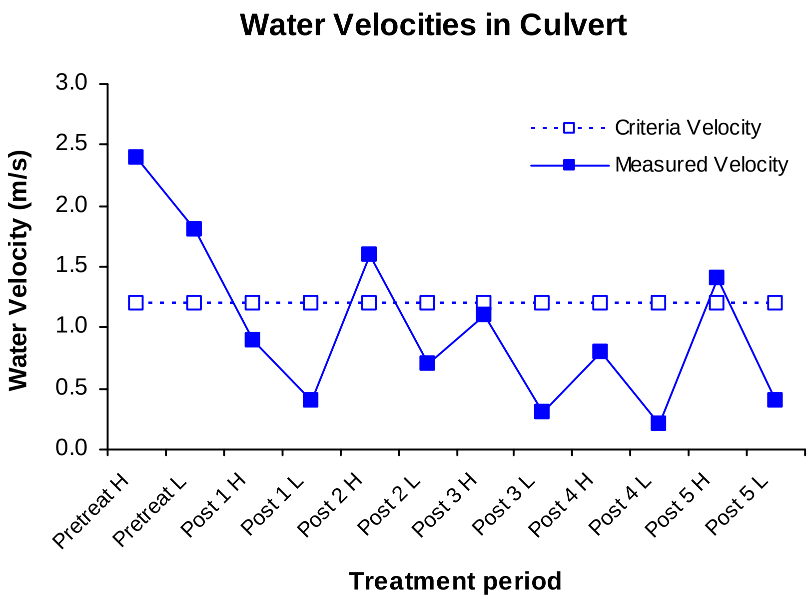

Figure 5.2. An example of data analysis using graphing methods for a culvert replacement study. The figure shows water velocities in a culvert during high (H) and low flow (L) periods before (Pretreat) and after (Post) replacement. The velocities are compared to the standard criteria of 1.2 m/s for adult cutthroat trout in a 75-ft long culvert. Note that the velocities exceed criteria during two high-flow periods after replacement (Post 2 H and Post 5 H).

5.3 Connectivity Restoration Example

A sponsor is interested in reconnecting historical steelhead spawning and rearing habitat within East Fork Rosebud Creek by replacing two culverts along County Road 16 at Rkms 0.8 and 1.9. Both culverts block access of steelhead into upper reaches of the East Fork during all times of the year. Existing culverts are undersized and have a large outfall drop that prevents adult and juvenile steelhead from ascending them. The sponsor estimates that about 19.3 km of steelhead spawning and rearing habitat is available upstream from the lower-most passage barrier. The sponsor proposes to replace the two round culverts with 4-ft-wide (span) x 3-ft-high (rise) x 70-ft-long squash culverts. These dimensions were determined by conducting WDFW (2000) fish passage barrier assessments. The following work is proposed.

Goals and Objectives

Goal: Increase connectivity and the distribution and abundance of steelhead within East Fork Rosebud Creek.

Objective 1: Increase connectivity and the abundance and distribution of steelhead in East Fork Rosebud Creek by replacing two undersized round culverts at Rkms 0.8 and 1.9 with larger squash culverts that allow steelhead passage at all times of the year.

Key Questions and Hypotheses

Key Question 1: Will the replacement of two undersized round culverts with larger squash culverts allow steelhead passage at all times of the year in East Fork Rosebud Creek?

Hypothesis 1: The replacement of two undersized round culverts with larger squash culverts will not provide steelhead passage into East Fork Rosebud Creek during all times of the years.

Key Question 2: Will the replacement of two undersized round culverts with larger squash culverts increase the distribution and abundance of steelhead in the Rosebud watershed?

Hypothesis 2: The replacement of two undersized round culverts with larger squash culverts will have no effect on the distribution and abundance of steelhead in the Rosebud watershed. [32]

Implementation Monitoring

- Were two round culverts under County Road 16 at Rkm 0.8 and 1.9 removed and replaced with two 4-ft-wide (span) x 3-ft-high (rise) x 70-ft-long squash culverts?
- Were the culverts installed according to specifications in "Design of Road Culverts for Fish Passage" (WDFW 2003)?

Measurements: Number and location of squash culverts installed; Engineering specifications (e.g., rise, span, and length of culvert; culvert slope; presence of apron; outfall depth; water depths and velocities in culvert; culvert span to streambed width ratio; and fill depth).

Level 1 Effectiveness Monitoring

Was the restoration action effective in increasing connectivity and the abundance and distribution of steelhead in East Fork Rosebud Creek?

Monitoring design: BACI design with measurements taken one year before treatment and annually for five years after treatment both upstream and downstream from the fish passage barriers.

Treatment area(s): The treatment area consists of the two culvert replacement sites (Rkm 0.8 and 1.9) and the 19.3 km of the East Fork upstream from the culvert replacement sites.

Reference area(s): The reference area is the 0.8-km-long reach of the East Fork downstream from the first fish passage barrier (Rkm 0.8).

Monitoring Parameters: Maximum water velocity within culverts; maximum water depth within culverts; outfall drop; presence/absence of steelhead redds; presence/absence of juvenile or adult steelhead.

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32 Measuring changes in the abundance and distribution of steelhead goes beyond Level 1 monitoring. However, the sponsor will document the presence/absence of steelhead upstream from the barrier. Abundance and distribution will be measured under a more intensive monitoring program.

Sampling Scheme: Physical measurements (velocities, depths, and outfall drop) will be collected at each barrier during high flow (spring) and low flow (late summer) one year before barrier replacement and each year for five years after replacement. Thus, physical measurements will be collected twice per year for the six-year period. Photographs of each culvert (taken upstream, downstream, and within each culvert) will be collected during high-flow and low-flow periods before and after installation of the squash culverts. Photographs will be taken from the same locations during each survey period.

Because suitable spawning and rearing habitat exists immediately upstream and downstream of each culvert, a 300-m reach of stream downstream from each barrier and a 300-m reach upstream from the upper barrier will be surveyed by walking the streambank and looking for the presence of steelhead. Foot surveys will be conducted twice per year; once during the spring to find steelhead redds and again during the low-flow period to find juvenile steelhead. Snorkeling will be used when a positive identification of a juvenile fish cannot be made from the bank.

Data Analysis: Physical measurements collected before and after treatment will be analyzed graphically and compared to standard criteria in WDFW (2003). Presence of juvenile steelhead and steelhead redds will be reported in tables. If available, data collected by the State or other entities on the spatial range and abundance of steelhead within the Rosebud watershed will also be presented. These data will be presented graphically (e.g., maps showing the distribution of redds before and after barrier removal and figures showing the abundance of juveniles before and after barrier removal) and in tables.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and Level 1 effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the enhancement project and will offer recommendations.

5.4 Summary

This section provides an overview of barrier removal and reconnection of isolated habitats and summarized steps for monitoring the effectiveness of these actions. As with all projects, monitoring must be tailored for each specific project. There is no easy-to-follow recipe for monitoring all types of restoration projects. Nevertheless, if the goals and objectives are specific, monitoring programs can be developed to address any kind of fish passage project. This section provides sponsors with a “toolbox” that can be used to develop Level 1 effectiveness monitoring plans for fish passage projects. The steps involved in setting up a monitoring program include (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with spatial and temporal reference sites, if possible; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the restoration action resulted in the desired outcome. This information can be used by funding entities and managers to adaptively manage aquatic resources.

SECTION 6: INSTREAM DIVERSION RESTORATION

Unscreened (or improperly screened) water diversions can affect the abundance and spatial structure of fishes in several ways. For example, unscreened diversions may constitute a migration blockage if downstream-migrating juvenile salmon and trout are entrained in diverted water. Fish can be lost if they end in irrigated fields or are killed or injured on screens. In addition, water withdrawals potentially affect available spawning and rearing habitat for fish. This can lead to a host of negative effects, including increased competition and predation, stranding, redd dewatering, and migration blockages.

Washington State laws require that all diversions be screened to protect fish. The goal of screening water diversions is to provide complete protection (near 100% of the individuals in a population) from mortality, injury, and delay for all life stages and species of concern. Monitoring is therefore needed to determine that water diversions are adequately protecting fish of all life stages. This section describes how to monitor the effectiveness of screening projects. First I describe some common screen types and applications. Next I discuss how to develop a monitoring plan to assess the effectiveness of screening projects. Finally, I provide an example of a Level 1 monitoring plan that will assess the effects of a hypothetical screening project.

6.1 Instream Diversion Restoration Techniques

Fish protection screens are devices installed at surface water diversions to prevent entrainment[33] and impingement[34] on screens. There are many types of fish screens, designed for varying water withdrawal situations. However, they all share common design objectives: to allow the passage of water and to provide safe and relatively unimpeded movement of fish. WDFW (2000) has set specific screen design criteria to protect juvenile salmonids. The following are the most common types of fish screens and their typical applications and limitations.

Rotary Drum Screens

The rotary drum screen is a common type of fish screen used in open channels, such as irrigation ditches. Water passes through the screen mesh that covers a cylinder. Rotation is achieved by an electric motor, paddlewheel, solar drive, or hydraulic motor. The greatest advantage of the drum screen is that it continually removes debris. The disadvantage of the drum screen is that the seals can fail and result in fish impingement. For this reason, these screens must be monitored closely and generally require more maintenance than other screen types.

Vertical, Fixed-Plate Screens

A vertical, fixed-plate screen is simply a flat plate mesh placed vertically into a diversion. It is most often used for industrial, domestic water supply, and irrigation intakes for both pump and gravity

33 Entrainment is the passage of fish through, around, or under a screen or barrier.

34 Impingement is the involuntary contact and immobilization of fish on the screen surface.

diversions. The vertical, fixed-plate screen is easy to seal, mechanically simple because of no moving parts, and requires a smaller civil works. A disadvantage is that it requires a mechanical cleaning system for debris removal.

Non-vertical, Fixed-Plate Screens

Non-vertical, fixed-plate screens are simply fixed-plate screens placed either upward or downward in the direction of flow. Advantages of these types of screens include no moving parts and no additional in-river diversion structures. A disadvantage is that debris removal may not be reliable. In addition, during low flow, fish are passed over shallow depth (or no depth) on the downstream end of the screen potentially causing injury or impingement.

Vertical Traveling Screens

Similar to the rotary drum screens, the mesh of vertical traveling screens rotates to remove debris. The two types, panel-type screens and belt-type screens, are driven by electric motors. These are generally used for pump diversions and can be installed in deep water. They can also be installed on a river bank without a bypass system. A potential problem with vertical traveling screens is that the seals can fail and result in fish impingement. As with rotary drum screens, vertical traveling screens must be monitored closely.

Pump Screens and End-of-Pipe, Fixed-Drum, Tee Screens

This is a group of screen styles built as a chamber attached to the end of a pipe. They can be box-shaped or cylindrical. The walls are screen mesh and a suction pipe is attached to one wall. They range in size from one-cfs screens attached to small irrigation pumps to large tee-screen installations for 50 cfs or more. These screens can be used for deep intakes and may be equipped with air-burst or water-jet cleaning systems. Keeping these screens clean of debris can be a potential problem.

Infiltration Galleries

Infiltration galleries are perforated-pipe manifolds or single pipes buried in a streambed or bank. Water is drawn through the streambed or bank and into the pipe. The streambed or bank prevents entrainment of fish. They are installed in steeper sections of a channel, such as riffles, and stream hydraulics should keep the intake free of debris and fine sediments. Infiltration galleries are generally used for pump diversions, but can be used for gravity diversions in steep channels. When successful, the major advantage of infiltration galleries is that no mechanical cleaning device is needed to remove debris and sediment. The primary disadvantage is that the diversion can still become plugged with debris and sediments.

6.2 Instream Diversion Restoration Monitoring Plan

Although there are many different types and applications of diversion screens, they are relatively easy to monitor for effectiveness. This is because they all have a similar goal: to prevent entrainment of fish into the diversion. Therefore, it is relatively easy to design a monitoring plan to assess the effectiveness of diversion screens. The following steps should help the sponsor set up a valid Level 1 monitoring program to assess the effectiveness of diversion screens.

Goals and Objectives

The first and most important step in developing a monitoring plan for assessing the effectiveness of diversion screens is to clearly identify the overall goals and specific objectives of the project. The following are examples of goals and objectives.

Goals:

- Prevent the entrainment of juvenile summer Chinook into a small irrigation pump.
- Eliminate the entrainment of juvenile and adult steelhead and bull trout into the New York Canal.
- Protect juvenile salmon and trout from being diverted into the City of Chester aqueduct.
- Prevent the entrainment of fish into the Reed Point Hatchery water supply.

Objectives:

- Install a pump intake screen (vertical configuration) on a small irrigation pump in Pine Creek to prevent the entrainment of juvenile summer Chinook.
- Eliminate the entrainment of juvenile and adult steelhead and bull trout into the New York Canal by installing a rotary drum screen with a bypass system.
- Prevent entrainment of salmon and trout by installing a vertical, fixed-plate screen with trolley brush into the City of Chester aqueduct.
- Install end-of-pipe, fixed-drum, tee screens to the Reed Point Hatchery intake pump to prevent entrainment of fish into the hatchery water supply.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All screening projects have working hypotheses. When a project is initiated, it is based on the general assumption that the action is going to lead to some physical and/or biological condition. Specific predictions can be made as to how the habitat or biota will respond to the action. Example key questions and hypotheses for diversion screening projects include:

Key Questions:

- Will the installation of a pump intake screen (vertical configuration) on a small irrigation pump in Pine Creek prevent the entrainment of juvenile summer Chinook into the irrigation system?
- Will the installation of a rotary drum screen with a bypass system eliminate the entrainment of juvenile and adult steelhead and bull trout into the New York Canal?
- Will the installation of a vertical, fixed-plate screen with trolley brush prevent entrainment of salmon and trout into the City of Chester aqueduct?
- Will the installation of end-of-pipe, fixed-drum, tee screens to the intake pump for the Reed Point Hatchery prevent entrainment of fish into the hatchery water supply?

Hypotheses:

- The installation of a pump intake screen (vertical configuration) on a small irrigation pump in Pine Creek will not prevent the entrainment of juvenile summer Chinook into the irrigation system.
- The installation of a rotary drum screen with a bypass system will not eliminate the entrainment of juvenile and adult steelhead and bull trout into the New York Canal.
- The installation of a vertical, fixed-plate screen with trolley brush will not prevent entrainment of salmon and trout into the City of Chester aqueduct.
- The installation of end-of-pipe, fixed-drum, tee screens to the intake pump for the Reed Point Hatchery will not prevent entrainment of fish into the hatchery water supply.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

An appropriate design for monitoring the effectiveness of screening projects is to survey the site before and after installation of screens (Before-After design).

Parameters

For monitoring screening projects, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 6.1 identifies possible parameters and sampling methods for monitoring screening projects.

In addition to measuring various physical and biological parameters, all sponsors should establish photo points (see Hall 2001) to document changes at the diversion. Annual photographs taken at the same locations before and after screening provide an excellent tool for illustrating project effectiveness.

Table 6.1. Possible parameters and sampling methods for monitoring screening projects.

Monitoring parameter	Sampling method
Presence/absence of fish screen	Document the presence of a fish screen of appropriate mesh size, shape, material, and location at the point of diversion (see WDFW 2000).
Presence/absence of large holes or dents in the screen	Document the presence of large holes (greater than the allowed opening) or dents in the screen or frame.
Presence/absence of corrosion on screen	Document the presence of corrosion on the screen and frame.
Presence/absence of debris on screen	Document the presence of debris on the screen.
Presence of broken seals around screen	Document the presence of gaps or spaces (>2.4 mm) between the screen structural frame and the ditch bottom or screen civil works structure.

Monitoring parameter	Sampling method
Water velocity at the screen face (approach velocity)	Using a calibrated water-velocity meter, measure the water velocity immediately in front of the screen (within 3 inches or 7.6 cm of the screen face). A series of measurements should be taken along the face of the screen (at about every 2 ft or 61 cm).
Water velocity at bypass entrance	Using a calibrated water-velocity meter, measure the water velocity at the entrance to the fish bypass (if present).
Presence/absence of flow in bypass	Document the presence of flow in the fish bypass system (if present).
Presence/absence of debris in bypass	Document the presence of debris in the fish bypass system (if present).
Presence/absence of fish impinged on the screen	Document the presence of fish immobilized on the screen surface.
Presence/absence of target fish and life stage	Document the presence of target fish and life stages downstream from the fish screens using snorkeling or visual observations from the bank. Observations are made in the canal or ditch in at least a 100-m-long segment just downstream from the fish screen.

Sampling Scheme

For all screening projects, data (including photographs) will be collected at least once before installation of fish screens and then annually for five years following screening.[35] Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer withdrawal, than sampling should occur during summer withdrawal every year thereafter. It is therefore important to monument each sampling and photo-point location with GPS, drawings, markings on topographic maps and engineering plans, and photographs.

Sampling for the presence of fish downstream from fish screens is only necessary for screens placed in ditches and canals (e.g., rotary drum screens, vertical and non-vertical fixed-plate screens, and vertical traveling screens). For obvious reasons, fish cannot be surveyed in pump diversions (i.e., water diverted into pipes). However, sampling should include the presence of fish impinged on pump screens.

Data Analysis and Reporting

When data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis. For example, actual field measurements can be compared with standard criteria on a graph (Figures 6.1). In many cases, figures, tables, and photographs may be all that are needed to demonstrate beneficial effects. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

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35 Some restoration actions my take more than one year to implement. In these cases, monitoring should occur before implementation, during implementation, and for at least five years after implementation of the treatment.

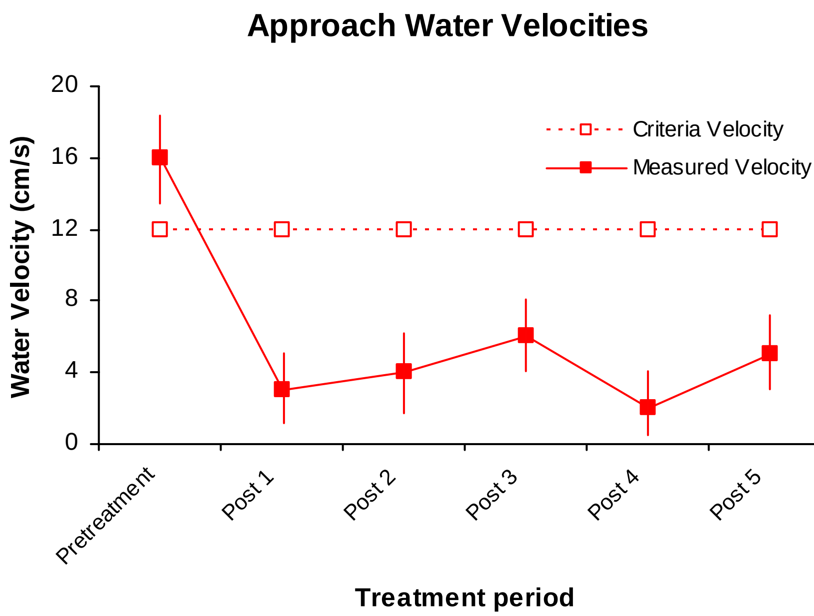

Figure 6.1. An example of data analysis using graphing methods for a Before-After study. The figure shows the mean and 95% CI approach velocities (cm/s) immediately in front of a screen before (pretreatment) and after (post) diversion restoration. The approach velocities are compared to the standard criteria of 12 cm/s. To be compliant, approach velocities should not exceed the criteria of 12 cm/s.

6.3 Instream Diversion Restoration Example

A sponsor is interested in replacing a leaky, vertical fixed-plate screen in the Jefferson Canal with a rotary drum screen. The existing vertical, fixed-plate screen allows small fry to pass through enlarged holes in the screen (damaged by debris buildup) and between the screen and frame, and the current fish bypass system frequently plugs with debris, creating a potential barrier to fish diverted back to the river. The sponsor is also interested in screening a small pump diversion located in the Jefferson Canal about 31 m upstream from the vertical, fixed-plate screen. The pump diversion currently entrains Pacific lamprey ammocoetes that periodically plug the landowner's sprinkler system. The sponsor proposes the following work.

Goals and Objectives

Goal 1: Eliminate the entrainment of fish, especially steelhead and Chinook salmon, within the Jefferson Canal.

- ***Objective 1:*** Eliminate the entrainment of fish, especially juvenile steelhead and Chinook salmon, by replacing the leaky, vertical fixed-plate screen in the Jefferson Canal with a rotary drum screen.
- ***Objective 2:*** Safely pass diverted fish back into the river by replacing the undersized fish bypass system with a larger system that meets WDFW criteria.

Goal 2: Prevent the entrainment of Pacific lamprey ammocoetes into a small pump diversion.

Objective 3: Install a cylindrical screen to the intake of the pump diversion located in the Jefferson Canal 31 m upstream from the vertical, fixed-plate screens to prevent the entrainment of Pacific Lamprey ammocoetes into the irrigation system.

Key Questions and Hypotheses

Key Question 1: Will the installation of a rotary drum screen prevent the entrainment of fish (especially juvenile steelhead and Chinook salmon) into the Jefferson Canal?

Hypothesis 1: The installation of a rotary drum screen will not prevent the entrainment of fish (especially juvenile steelhead and Chinook salmon) into the Jefferson Canal.

Key Question 2: Will the installation of a fish bypass system safely pass diverted fish back into the river?

Hypothesis 2: The installation of a fish bypass system will not safely pass diverted fish back into the river.

Key Question 3: Will the installation of a cylindrical screen to the intake of a pump diversion prevent the entrainment of Pacific lamprey ammocoetes into the irrigation system?

Hypothesis 3: The installation of a cylindrical screen to the intake of a pump diversion will not prevent the entrainment of Pacific lamprey ammocoetes into the irrigation system.

Implementation Monitoring

- Was the rotary drum screen installed according to engineering plans and WDFW criteria?
- Was the fish bypass system installed according to engineering plans and WDFW criteria?
- Was the cylindrical screen installed according to engineering plans and WDFW criteria?

Measurements: Location and orientation of fish screens; approach and sweep velocities; screen areas; screen mesh size, shape, and material; bypass entrance geometry; bypass entrance velocity and flow; bypass conduit and drop structure; location of bypass outfall.

Level 1 Effectiveness Monitoring

Were the screens effective in preventing entrainment of fish into the canal and irrigation system?

Monitoring design: Before-After design with one measurement taken before screening and five measurements taken annually after screening.

Treatment area(s): The rotary drum screen will be installed 87 m downstream from the mouth of the Jefferson Canal at the site of the present vertical, fixed-plate screen. The bypass system will be installed adjacent to the screen. The cylindrical screen will be installed on the small diversion pump, which is located 31 m upstream from the vertical, fixed-plate screen in the Jefferson Canal.

Reference area(s): No reference area is needed for monitoring the effectiveness of fish screens.

Monitoring Parameters: Presence of fish screens; presence of large holes and dents in the screens; presence of corrosion on the screens; presence of debris on the screens; presence of broken seals or leaks around the screens; water velocities at the face of the screens; water velocity at the bypass entrance; presence of flow in the bypass; presence of debris in the bypass; presence of fish impinged on screens; presence of fish in the canal downstream from the rotary drum screen.

Sampling Scheme: Surveys will be conducted once before installation of new screens and annually for five years following installation of new screens to document changes at the diversions. The primary parameter measured at the rotary drum site will be the presence or absence of fish in the canal downstream from the screen. A 100 m reach of the canal immediately downstream from the screen will be surveyed by snorkeling or walking the banks and looking for fish. The absence of fish in the canal downstream from the screen does not necessarily mean that the screen was effective at diverting fish out of the canal. Therefore, inspection of the screen and bypass system, velocity measurements, and presence of fish and debris impinged on the screen will also be conducted at the same time fish surveys are conducted. Photographs will be taken of the screen before and after installation. Sampling will occur during the summer when the diversion is operating.

Sampling at the small pump diversion will occur before and after implementation of the cylindrical screen. Presence or absence of fish within the irrigation system will not be surveyed directly; however, the landowner will be contacted throughout the monitoring period to document if ammocoetes have plugged his irrigation system. In addition, the screen will be inspected annually for leaks, holes, and corrosion, as well as documenting the presence of fish and debris impinged on the screen. Photographs will be taken of the screen before and after installation. Sampling will occur during the summer when the diversion is operating.

Data Analysis: Mean water velocities and 95% CI will be compared to WDFW velocity criteria and will be analyzed graphically before and after installation of the screens. Presence/absence data will be presented in tables. Fish will be reported to species if possible.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and Level 1 effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the screening project and will offer recommendations.

6.4 Summary

Fish screening projects are probably the easiest projects to monitor. This is because they all have a similar objective: to avoid impingement and entrainment of fish at the diversion. This section provides sponsors with guidelines for developing Level 1 effectiveness monitoring plans for fish screening projects. As with all projects, the steps involved in setting up a monitoring program for screening projects include (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with a temporal reference site, if necessary; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the screening project resulted in the desired outcome. This information can be used by funding entities and managers to adaptively manage aquatic resources.

SECTION 7: ACQUISITIONS AND CONSERVATION EASEMENTS

Previous sections of this document described how to monitor "active" restoration techniques, which require some level of habitat manipulation or alteration. In this section, the focus is on monitoring "passive" restoration methods that do not require habitat manipulation or alteration, but rather protect critical habitats or important ecological processes. Passive restoration techniques are valuable and in some cases essential tools in stream and watershed restoration. Acquisitions and conservation easements are two means used to protect important habitats and ecological processes.

There are two general reasons for using acquisitions and conservations easements to protect habitat. The first is to preserve unique or valuable habitat or to acquire an area that has high natural potential for restoration. Examples include high-quality stream reaches, springs, and side channels that provide valuable spawning and rearing functions. The second reason is to establish buffers from human impacts. Examples include protecting upland forests that serve important hydrological, chemical, and biological functions (e.g., protection of natural flow regimes, nutrient cycling, and woody debris recruitment).

Despite the value of protecting habitats and ecological processes, little attention has been given to monitoring their effectiveness in meeting habitat and species protection and restoration goals. The purpose of this section is to describe how to monitor the effectiveness of acquisitions and conservation easements. First I describe some common types of acquisitions and conservation easements. Next I discuss how to develop a monitoring plan to assess the effectiveness of acquisitions and conservation easements. Finally, I provide an example of a Level 1 monitoring plan that will assess the effects of a hypothetical conservation easement.

7.1 Types of Acquisitions and Conservation Easements

An acquisition is defined as the result of purchasing all rights an existing owner may have to the land, including that of "quiet enjoyment" in perpetuity. A conservation easement is defined as a non-possessory interest granted in the lands of another owner to obtain certain limited rights that often are in perpetuity but sometimes for only set periods of time (Lucchetti et al. 2005). Conservation easements are usually obtained when acquisition is prohibitively expensive or is unacceptable to the landowner.

There are three basic ways conservation easements are obtained (Lucchetti et al 2005):

1. Selected property rights are bought outright when a private landowner has lands of special value (e.g., riparian areas) for natural resource protection or restoration goals.

2. Conservation easements are established as a regulatory condition of land development or to mitigate land-use impacts (e.g., protect riparian areas from urban and residential development).

3. Conservation easements obtained through tax incentives or the transfer of development rights, in which landowners commit to certain land uses that reduce the highest and best-use basis for taxation.

7.2 Acquisitions and Conservation Easement Monitoring Plan

Because acquisitions and conservation easements protect important habitat and ecological processes, they can be more challenging to monitor than active restoration projects. Nevertheless, they represent excellent opportunities to test hypotheses. Testing these hypotheses is important for guiding future passive restoration efforts. Developing an adequate monitoring study to test hypotheses should follow the steps described below. These steps should help the sponsor set up a valid Level 1 monitoring program to assess the effectiveness of acquisitions and conservation easements.

Goals and Objectives

The first and most important step in developing a monitoring plan for assessing the effectiveness of acquisitions and conservation easements is to clearly identify the overall goals and specific objectives of the project. The following are examples of goals and objectives.

Goals:

- Preserve and protect riparian habitat along upper Morgan Creek.
- Protect a major bull trout spawning area along upper Freezeout Creek.
- Acquire riparian habitat along Woodbine Creek for future restoration work.
- Protect the riparian corridor along Des Moines Creek.
- Protect off-channel habitats along the lower Bridger River.

Objectives:

- Purchase 6 ha of riparian habitat along upper Morgan Creek to protect the mature coniferous forest from residential development and roads.
- Purchase a conservation easement along 4 km of upper Freezeout Creek to protect a major spawning area for bull trout.
- Purchase a conservation easement along 1.3 km of Woodbine Creek to restore ecological function lost because of historic mining activities.
- Purchase a conservation easement along 2.5 km of Des Moines Creek to buffer an important Chinook rearing area from industrial development.
- Purchase 18 ha of bottom lands adjacent to the lower Bridger River to protect existing side channels and four wetlands from urban development.

Questions and Hypotheses

Generating hypotheses and key questions provide the context within which to analyze monitoring data. All protection projects have working hypotheses. When a project is initiated, it is based on the general assumption that the action is going to lead to some physical and/or biological condition.

Specific predictions can be made as to how the habitat will or will not change in response to the action. Example questions and hypotheses for acquisitions and conservation easements include:

Key Questions:

- Will the purchase of 6 ha of riparian habitat along upper Morgan Creek protect the mature coniferous forest from residential development and road building?
- Will the purchase of a conservation easement along 4 km of upper Freezeout Creek protect a major spawning area for bull trout?
- Will the purchase of a conservation easement along 1.3 km of Woodbine Creek lead to restoration of ecological function lost because of historic mining activities?
- Will the purchase of a conservation easement along 2.5 km of Des Moines Creek buffer an important Chinook rearing area from industrial development?
- Will the purchase of 18 ha of bottom lands adjacent to the lower Bridger River protect existing side channels and four wetlands from urban development?

Hypotheses:

- The purchase of 6 ha of riparian habitat along upper Morgan Creek will not protect the mature coniferous forest from residential development and road building.
- The purchase of a conservation easement along 4 km of upper Freezeout Creek will not protect a major spawning area for bull trout.
- The purchase of a conservation easement along 1.3 km of Woodbine Creek will not lead to restoration of ecological function lost because of historic mining activities.
- The purchase of a conservation easement along 2.5 km of Des Moines Creek will not buffer an important Chinook rearing area from industrial development.
- The purchase of 18 ha of bottom lands adjacent to the lower Bridger River will not protect existing side channels and four wetlands from urban development.

Note that the hypotheses are very similar to the key questions. The major difference is that hypotheses are written as no effect or no difference.

Monitoring Design

As with "active" restoration projects, an appropriate design to monitor the effectiveness of acquisitions and conservation easements is to survey the site before and after protection (Before-After design). If possible, the sponsor should identify a similar site that will not be protected and will serve as a spatial reference site. Measurements are then taken at both the treatment and reference sites before and after protection (BACI design). This allows one to compare the effects of protection with both a spatial and temporal reference condition.

Parameters

For monitoring acquisition and conservation easement projects, the sponsor only needs to measure parameters that will ensure that the hypotheses can be tested and the objectives were met. Thus, the hypotheses will indicate which parameters need to be measured. Table 7.1 identifies possible parameters and sampling methods for monitoring acquisitions and conservation easements.

In addition to measuring various environmental parameters, all sponsors should establish photo-points (see Hall 2001) to document changes within protection and reference sites for all acquisition and conservation easement projects. Annual photographs taken at the same locations within protected and reference sites both before and after protection provide an excellent tool for illustrating project effectiveness.

Table 7.1. Possible parameters and sampling methods for monitoring acquisitions and conservation easements.

Monitoring parameter	Sampling method
Presence/absence of human disturbance	Document the presence of human disturbances within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas. Human disturbances include: walls, dikes, revetments, riprap, and dams; buildings; pavement/cleared lots; roads or railroads; inlet or outlet pipes; landfills or trash; parks or maintained lawns; row crops; pastures, rangeland, hay fields, or evidence of livestock; logging; and mining.
Area of human disturbance	Measure the area (m^2) of human disturbance within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas. Human disturbances include: walls, dikes, revetments, riprap, and dams; buildings; pavement/cleared lots; roads or railroads; inlet or outlet pipes; landfills or trash; parks or maintained lawns; row crops; pastures, rangeland, hay fields, or evidence of livestock; logging; and mining.
Presence/absence of natural disturbance	Document the presence of natural disturbances within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas. Natural disturbances include: fires; flood damage; wind damage; drought damage; volcanism; landslides; and erosion.
Area of natural disturbance	Measure the area (m^2) of natural disturbance within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas. Natural disturbances include: fires; flood damage; wind damage; drought damage; volcanism; landslides; and erosion.
Presence/absence of invasive species	Document the presence of invasive species within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas.
Density of invasive species	Estimate the density (#/100 m^2) of each invasive species within the entire protected and reference areas or within at least three 10 m x 10 m plots in each of the protected and reference areas.

Monitoring parameter	Sampling method
Number of off-channel habitats	Count the number of different types of off-channel habitats within the entire protected and reference areas. Off-channel habitats includes: side channels; off-channel ponds; springs; wetlands; and oxbows.
Presence/absence of target fish and life stage	Document the presence of target fish and life stages using snorkeling or visual observations from the bank. Observations are made in protected and reference areas or within at least three randomly selected reaches that are no less than 150 m long in protected and reference areas.

Sampling Scheme

For all acquisition and conservation easement projects, data (including photographs) will be collected at least once before implementation of protection measures and then annually for five years[36] following protection. If a spatial reference area is used (BACI design), data and photographs will be collected in the reference area at the same time data are collected within the protection area. Data must be collected in the same locations and at the same time each year. That is, if the first set of data is collected during summer, than sampling should occur during summer every year thereafter. In addition, if sampling occurs within three randomly selected 10 m x 10 m plots within each of the reference and protection areas, then the same plots must be sampled each year. Sampling different plots annually may increase variability and make it more difficult to demonstrate a beneficial effect. It is therefore important to monument each plot, stream reach, and photo-point location with permanent markers (e.g., rebar), GPS, drawings, markings on topographic maps, and photographs.

Whenever possible, surveys should be conducted throughout the entire protected and reference areas. If protected and reference areas are too large to census, measurements can be taken within at least three randomly selected 10 m x 10 m land plots (for measuring disturbance and vegetation parameters) or within three randomly selected 150-m long stream reaches (for measuring aquatic parameters). The same sampling scheme should be used in both the protected and reference areas.

Data Analysis and Reporting

When data have been collected consistently and repeatedly over several years, the data can be analyzed for trends or patterns. Trends and patterns are easily demonstrated using graphs that show the magnitude of the parameter on the y-axis and time on the x-axis (e.g., see Figures 7.1 and 7.2). Measurements for both the reference and protection areas can be shown on the same graph. In many cases, figures, tables, and photographs may be all that are needed to demonstrate beneficial effects. Additional analysis could include testing trends using time series analysis or regression techniques. Other statistics such as t-tests and analysis of variance can be used to test for significant differences between protection and reference conditions. Progress reports should be submitted annually to the funding entities and management agencies. A final report should be submitted at the end of the five-year, post-treatment monitoring period.

[36] A longer post-treatment monitoring period may be needed to demonstrate benefits of acquisitions and conservation easements. For example, monitoring could occur once every four years for 20 years.

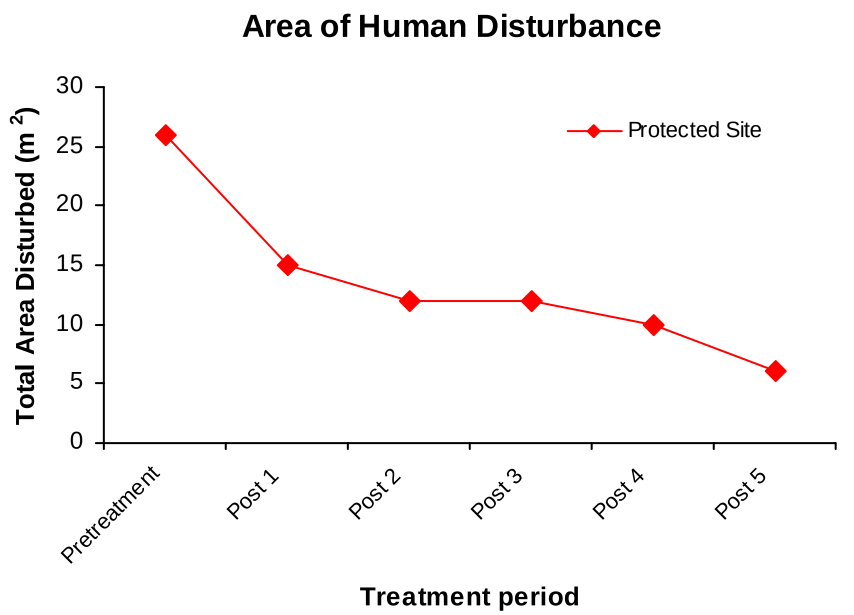

Figure 7.1. An example of data analysis using graphing methods for a Before-After study. The figure shows the total area (m^2) of human disturbance within an acquisition before (pretreatment) and after (post) protection. Disturbance area was based on a complete census of the entire protected area.

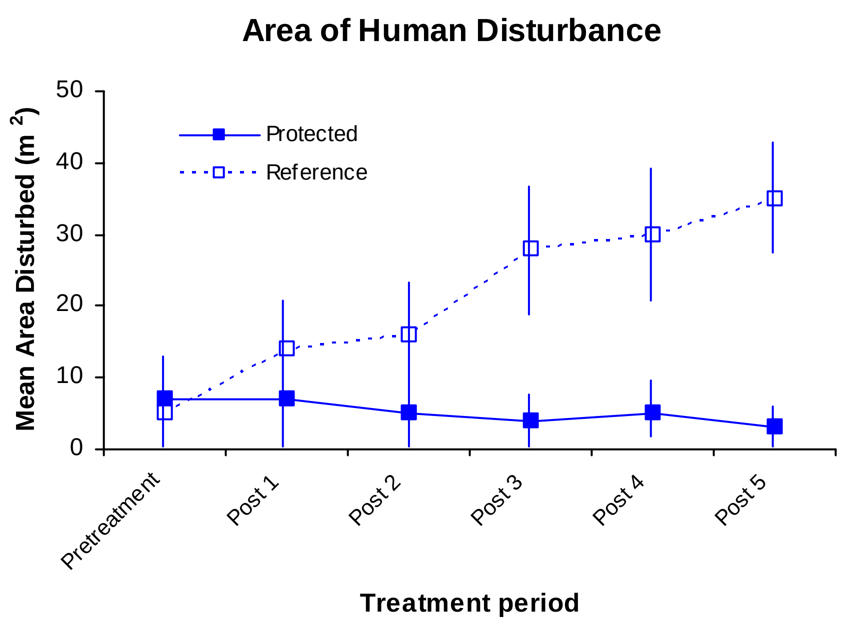

Figure 7.2. An example of data analysis using graphing methods for a BACI study. The figure shows the mean area (m^2) and 95% CI of human disturbance within a reference area and conservation easement before (pretreatment) and after (post) protection. Disturbance was based on sampling within three randomly selected 10 m x 10 m plots in both the reference and protection areas. Note that the reference area experienced significant human disturbance over time, while the protected area experienced a decrease in disturbance over time.

7.3 Conservation Easement Example

A sponsor is interested in purchasing a 15 ha conservation easement from a willing landowner along upper Tanner Creek. The easement would protect critical spawning habitat for sockeye salmon from the potential negative effects of residential development. The easement would also protect two wetlands, four cold-water springs, and several side channels from development. These off-channel features provide habitat for several wildlife species, including birds, amphibians, and mammals. Most of the land adjacent to the easement has been subdivided for residential and commercial development. The sponsor proposes the following work.

Goals and Objectives

Goal: Protect riparian habitat, sockeye spawning habitat, and off-channel habitats along upper Tanner Creek.

Objective 1: Purchase a 15 ha conservation easement to protect riparian habitat, critical spawning habitat for sockeye salmon, two wetlands, four cold-water springs, and 13 side channels along upper Tanner Creek.

Key Questions and Hypotheses

Key Question 1: Will the purchase of a 15 ha conservation easement along upper Tanner Creek protect riparian habitat, critical spawning habitat for sockeye salmon, two wetlands, four cold-water springs, and 13 side channels from human disturbance?

Hypothesis 1: The purchase of a 15 ha conservation easement along upper Tanner Creek will not protect riparian habitat, critical spawning habitat for sockeye salmon, two wetlands, four cold-water springs, and 13 side channels from human disturbance.

Implementation Monitoring

- Were the easement conditions met?
- Are there any illegal encroachments?

Measurements: Location and size of conservation easement; number and location of off-channel habitats included in the conservation easement; presence of illegal encroachments.

Level 1 Effectiveness Monitoring

Was the conservation easement effective in protecting riparian, spawning, and off-channel habitats?

Monitoring design: Before-After design with one measurement taken before protection and five measurements taken annually after protection.

Treatment area(s): The easement is located at Rkm 3.3 on Tanner Creek upstream from Tanner Lake. The 15 ha conservation easement is currently owned by the Smith Properties. The landowners are currently subdividing most of their lands for residential and commercial development. The easement will protect valuable habitat from development.

Reference area(s): No suitable reference area was found. The easement is unique because of off-channel and sockeye spawning habitats.

Monitoring Parameters: Presence and area of human disturbance; presence and area of natural disturbance; number of each type of off-channel habitat; presence of sockeye redds.

Sampling Scheme: Surveys will be conducted once before protection and annually for five years following protection to document changes within the entire conservation easement.[37] A biologist will walk through the entire easement during autumn and document the presence and area (m^2) of human and natural disturbances and count the number of off-channel habitats. The biologist will also survey the portion of Tanner Creek adjacent to the easement for the presence of sockeye redds. All disturbances and off-channel habitats will be photographed and their locations recorded on maps.

Data Analysis: Disturbance area and numbers of off-channel habitats will be analyzed graphically before and after implementation of protection measures. Presence of sockeye redds will be reported in tables and on maps. Any changes in off-channel habitats will also be noted on maps.

Reporting

Annual reports will be submitted to the funding entities and management agencies by December 31 of each year. Annual reports will include up-to-date results of implementation and Level 1 effectiveness monitoring. A final report will be submitted at the end of the five-year monitoring period. The final report will describe results and conclusions of the conservation project and will offer recommendations. Any evidence of illegal activities (e.g., clearing, building, and dumping) will be reported to the proper authorities.

7.4 Summary

Acquisitions and conservation easements are an important strategy for protecting and restoring natural resources but are rarely monitored for effectiveness. Monitoring has generally focused on legal concerns, primarily enforcing terms of easements or detecting illegal activities. This section provides sponsors with guidelines for developing Level 1 effectiveness monitoring plans for acquisitions and conservation easements. As with all projects, monitoring must be tailored for each specific conservation project. There is no easy-to-follow recipe for monitoring all types of acquisition and conservation easement projects. Nevertheless, if the goals and objectives are specific, monitoring programs can be developed to address any kind of protection action. The steps involved in setting up a monitoring program for acquisition and conservation easement projects include (1) determining the goals and objectives; (2) identifying key questions and specific hypotheses to test; (3) identifying a suitable monitoring design with spatial and temporal reference sites, if possible; (4) identifying appropriate parameters to measure; (5) selecting a sampling scheme

[37] Because of the high biological importance and diversity of the entire easement, the sponsor decided to survey the entire conservation area rather than sample within randomly selected plots.

that will answer the key questions; and (6) analyzing the data to test the hypotheses and to determine if the conservation action resulted in the desired outcome. This information can be used by funding entities and managers to adaptively manage aquatic resources.

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