Appendix List for Entiat

Appendix A. Ashley and Stovall. 2004. Columbia Cascade Province Wildlife Assessment. WDFW. Olympia, WA.

Appendix B. Bioanalysts, Inc. 2004. Monitoring Strategy for the Upper Columbia Basin: Draft Report. Prepared for the Upper Columbia Regional Technical Team and Upper Columbia Salmon Recovery Board. Wenatchee, WA.

Appendix C. BioAnalysts, Inc. 2004. Effects of Hydroelectric Dams on Viability of Wild Fish

Appendix D. Summary of Artificial Production in the Entiat Subbasin

Appendix E. Peven, ed. 2004. Hatchery Information for Subbasin Planning. Peven, Consulting, Inc.

Appendix A
Entiat Subbasin Plan

Columbia Cascade Ecoprovince Wildlife Assessment
Paul R. Ashley and Stacey H. Stovall

2004

Recommendation: Hyperlink this 625-page, 25MB document to a location on NPCC web pages. It is now on the Upper Columbia ftp site in the folder Wildlife/Columbia Cascade Province (upload dated 5/7/04).

Appendix B
Entiat Subbasin Plan

MONITORING STRATEGY FOR THE UPPER COLUMBIA BASIN

Draft Report

February 1, 2004

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SECTION 1: INTRODUCTION

Managers often implement actions within tributary streams to improve the status of fish populations and their habitats. Until recently, there was little incentive to monitor such actions to see if they met their desired effects. In cases where actions were monitored, investigators often used inappropriate experimental designs, resulting in failures to assess effects of habitat improvements on fish (Bayley 2002; Currens 2002). Now, however, many programs require that funded actions include valid monitoring efforts, coordinated indicators and measurements to reduce duplication, and a process for standardized reporting and strategic planning. Within the Upper Columbia Basin[1], Washington, several different organizations, including federal, state, tribal, local, and private entities currently implement tributary actions and conduct monitoring studies. Because of different goals and objectives, different entities are using different monitoring approaches and protocols. In some cases, different entities are measuring the same (or similar) things in the same streams with little coordination or awareness of each others efforts. The Upper Columbia Regional Technical Team (RTT) is aware of this problem and desires a monitoring strategy or plan that reduces redundancy, increases efficiency, and meets the goals and objectives of the various entities.

At least three different groups within the region have drafted integrated monitoring strategies that address many of the concerns of the RTT. For example, the Independent Scientific Advisory Board (ISAB) of the Northwest Power Planning Council outlined a monitoring and evaluation plan for assessing recovery of tributary habitat (ISAB 2003). They describe a three-tiered monitoring program that includes trend or routine monitoring (Tier 1), statistical (status) monitoring (Tier 2), and experimental research (effectiveness) monitoring (Tier 3). Trend monitoring obtains repeated measurements, usually representing a single spatial unit over a period of time, with a view to quantifying changes over time. Changes must be distinguished from background noise. This type of monitoring does not establish cause-and-effect relationships and does not provide inductive inferences to larger areas or time periods. Statistical monitoring, on the other hand, provides statistical inferences that extend to larger areas and longer time periods than the sample. This type of monitoring requires probabilistic selection of study sites and repeated visits over time. Experimental research monitoring is often required to establish cause-and-effect relationships between management actions and population/habitat response. This requires the use of experimental designs incorporating "treatments" and "controls" randomly assigned to study sites.

According to the ISAB (2003), the value of monitoring is greatly enhanced if the different types of monitoring are integrated. For example, trend and statistical monitoring will help define the issues that should be addressed with more intensive, experimental research monitoring. The latter will identify which habitat attributes are most informative and will provide conclusive information about the efficacy of various restoration approaches. Implementing experimental research in the absence of trend and statistical monitoring would increase uncertainty about the generalization of results beyond

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[1] As described in Section 2, the Upper Columbia Basin includes all tributaries and the Columbia River between the Yakima River and Chief Joseph Dam.

the sampling locations. The ISAB (2003) identified the following essential elements of a valid monitoring program.

- Develop a trend monitoring program based on remotely-sensed data obtained from sources such as aerial photography or satellite imagery or both.

- Develop and implement a long-term statistical monitoring program to evaluate the status of fish populations and habitat. This requires probabilistic (statistical) site selection procedures and establishment of common (standard) protocols and data collection methods.

- Implement experimental research monitoring at selected locations to establish the underlying causes for the changes in habitat and population indicators.

Another strategy developed by the Bonneville Power Administration, the U.S. Army Corps of Engineers, the Bureau of Reclamation (collectively referred to as the Action Agencies), and NOAA Fisheries responds to the Federal Columbia River Power System (FCRPS) Biological Opinion issued by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. Although the Action Agencies/NOAA Fisheries Draft Research, Monitoring, and Evaluation (RME) Program was developed before the release of the ISAB (2003) report, it is in many respects consistent with ISAB recommendations. For example, the draft RME Program calls for the classification of all watersheds that have listed fish populations and receive restoration actions. Classification is hierarchical and captures physical/environmental differences spanning from the largest scale (regional setting) down to the channel segment. This component of the draft RME Program comports with Tier 1 Trend Monitoring in the ISAB (2003) plan. Status Monitoring (similar to Tier 2 Statistical Monitoring) and Action Effectiveness Research (similar to Tier 3 Experimental Research) are also included in the RME Program. The ISAB is currently reviewing the RME Program.

About the time the Action Agencies/NOAA Fisheries released their draft program, the Washington Salmon Recovery Funding Board (SRFB) released a draft monitoring and evaluation strategy for habitat restoration and acquisition projects. The document identified implementation, effectiveness, and validation monitoring as key components of their program. The monitoring program is scaled to capture factors operating at different hierarchical levels. At the lowest level (Level 0), the program determines if the action was implemented (implementation monitoring). Level 1 monitoring determines if projects meet the specified engineering and design criteria. Level 2 and 3 monitoring assess the effectiveness of projects on habitat and fish abundance, respectively. Levels 1-3 constitute effectiveness monitoring. Finally, level 4 (validation) monitoring addresses how management and habitat restoration actions, and their cumulative effects, affect fish production within a watershed. This type of monitoring is the most complex and technically rigorous.

Although the three programs (ISAB, Action Agencies/NOAA Fisheries, and SRFB) describe monitoring in slightly different terms, they all address the same goal. That is, all three intend to assess the effectiveness of restoration projects and management actions on tributary habitat and fish populations. Consequently, the overall approaches among the three programs are similar, with the Action Agencies/NOAA Fisheries RME Program being the most intensive and extensive, in part because of the requirements of the FCRPS Biological Opinion. Indeed, the Action Agencies/NOAA Fisheries Program calls for monitoring all tributary actions with intensive, standardized protocols and data collection methods. For each tributary action, a list of specific indicators, ranging from water quality to watershed condition, are to be measured.

As noted earlier, various entities, including the Washington Salmon Recovery Fund Board, will be funding and implementing various restoration projects and actions within the Upper Columbia Basin. These projects will be monitored to assess their effectiveness. Other groups, such as the U.S. Forest Service, U.S. Fish and Wildlife Service, Washington Department of Ecology, Washington Department of Fish and Wildlife, Chelan County, and Chelan and Douglas County Public Utility Districts, will continue their ongoing monitoring of fish and habitat in the basin. In addition, NOAA Fisheries, with funding from the Bonneville Power Administration, will implement the status/trend monitoring component of the Action Agencies/NOAA Fisheries RME Plan in the Wenatchee Basin. Because of all the activities occurring within the Upper Columbia Basin, it is important that the monitoring plan capture the needs of all entities, avoids duplication of sampling efforts, increases monitoring efficiency, and reduces overall monitoring costs.

The monitoring plan described in this document is not another regional monitoring strategy. Rather, this plan draws from the existing strategies (ISAB, Action Agencies/NOAA Fisheries, and SRFB) and outlines an approach specific to the Upper Columbia Basin. The plan described here addresses the following basic questions:

1. What are the current habitat conditions and abundance, distribution, life-stage survival, and age-composition of fish[2] in the Upper Columbia Basin (status monitoring)?
2. How do these factors change over time (trend monitoring)?
3. What effects do tributary habitat actions have on fish populations and habitat conditions (effectiveness monitoring)?

The plan is designed to address these questions and at the same time eliminate duplication of work, reduce costs, and increase monitoring efficiency. The implementation of valid statistical designs, probabilistic sampling designs, standardized data collection protocols, consistent data reporting methods, and selection of sensitive indicators will increase monitoring efficiency (Currens et al. 2000; Bayley 2002).[3] For this plan to be successful, all organizations involved must be willing to cooperate and freely share information. Cooperation includes sharing monitoring responsibilities, adjusting or changing sampling methods to comport with standardized protocols, and adhering to statistical design criteria. In those cases where the standardized method for measuring an indicator is different from what was used in the past, it may be necessary to measure the indicator with both methods for a few years so that a relationship can be developed between the two methods. Scores generated with a former method could then be adjusted to correct for any bias.

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[2] Although this plan targets ESA-listed fish species (i.e., spring chinook, summer steelhead, and bull trout), it is also applicable to other non-listed species.

[3] An efficient monitoring plan reduces "error" to the maximum extent possible. One can think of error as unexplained variability (see Section 4.3), which can reduce monitoring efficiency through the use of invalid statistical designs, biased sampling designs, poorly selected indicators, biased measurement protocols, and non-standardized reporting methods.

For convenience, this report is divided into eight major parts. The first part (Section 2) describes the area in which this plan will be implemented. Section 3 identifies valid statistical designs for status/trend and effectiveness monitoring. Section 4 discusses issues associated with sampling design, emphasizing how one selects a sample and how to minimize measurement error. Section 5 examines how sampling should occur at different spatial scales. Section 6 describes the importance of classification and identifies a suite of classification variables. Section 7 identifies and describes biological and physical/environmental indicators, while Section 8 identifies methods for measuring each indicator variable. These sections provide the foundation for implementing an efficient monitoring plan in the Upper Columbia Basin. The last section deals with how the program will be implemented. It provides a checklist of questions that need to be addressed in order to implement a valid plan. The appendices attached to this document describe how the plan will be implemented within each of the major subbasins or monitoring zones (see Section 2) within the Upper Columbia Basin.

As much as possible discussions have been kept fairly general. Because this report discusses some issues that are quite involved, footnotes are used to define technical terms, offer further explanation, offer alternative explanations, or to describe a given topic or thought in more detail. It is hoped the reader will not be too distracted by the extensive use of footnotes. In some instances, it was necessary to provide considerable detail within the text (e.g., discussion on choosing sample sizes).

As a final note, this document does not include a detailed Quality Assurance/Quality Control (QA/QC) Plan. Although the monitoring strategy includes a description of recommended sampling and experimental designs, indicators, and a general description of sampling protocols, it does not address in detail an evaluation of data, quality control,[4] or qualifications and training of personnel. These are important components of a valid monitoring program that will be developed after the monitoring strategy is finalized.

[4] Quality control refers to specific actions required to provide information for the quality assurance program. Included are standardizations, calibration, replicates, and control and check samples suitable for statistical estimates of confidence of the data.

SECTION 2: PROJECT AREA

This monitoring plan will be implemented within the Upper Columbia River Basin, which includes all tributaries and the Columbia River between the Yakima River and Chief Joseph Dam (Figure 1). This area forms part of the larger Columbia Basin Ecoregion (Omernik 1987). The Wenatchee and Entiat rivers are in the Northern Cascades Physiographic Province, and the Okanogan and Methow rivers are in the Okanogan Highlands Physiographic Province. The geology of these provinces is somewhat similar and very complex, developed from marine invasions, volcanic deposits, and glaciation. The river valleys in this region are deeply dissected and maintain low gradients except in extreme headwaters. The climate includes extremes in temperatures and precipitation, with most precipitation falling in the mountains as snow. Melting snowpack, groundwater, and runoff maintain stream flows in the area. Mullan et al. (1992) described this area as a harsh environment for fish and stated that "it should not be confused with more studied, benign, coastal streams of the Pacific Northwest."

The Upper Columbia River Basin consists of five major "subbasins" (Wenatchee, Entiat, Chelan, Methow, and Okanogan basins) and several smaller watersheds (Figure 1). This area captures the distribution of the Upper Columbia River Basin Summer Steelhead Evolutionarily Significant Unit (ESU) (listed as endangered, 1996). It also captures the Upper Columbia River Spring Chinook Salmon ESU (listed as endangered, 1999) and the Upper Columbia Recovery Unit for the Columbia River Bull Trout Distinct Population (listed as threatened, 1998). Recently, the Interior Columbia Basin Technical Recovery Team identified independent populations of summer steelhead and spring chinook within the Upper Columbia ESUs (ICBTRT 2003). They identified three independent populations of spring chinook within the Upper Columbia ESU; Wenatchee, Entiat, and Methow populations. For summer steelhead, they identified four independent populations within the ESU; Wenatchee, Entiat, Methow, and Okanogan populations. Although they identified only four geographic areas for the independent populations of steelhead within the ESU, steelhead may also exist within smaller tributaries to the Columbia River, such as Squilchuck, Stemilt, Colockum, Tarpiscan, Tekison, Quilomene/Brushy, Palisade, Douglas, Foster, Swakane, and Crab creeks, and the Chelan River and tailrace[5]. These tributaries to the Upper Columbia River will be included in the monitoring plan.

For the purpose of monitoring status and trend of habitat conditions and fish populations, this plan divides the Upper Columbia Basin into five, "status/trend monitoring zones." Four of these zones include the Wenatchee, Entiat, Methow, and Okanogan subbasins. These zones comport with the geographic locations of independent populations of summer steelhead and spring chinook. Except for the Okanogan, they also correspond with bull trout core areas (USFWS 2002). The fifth zone captures the Chelan River/tailrace and all the smaller watersheds that drain into the Columbia River.

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[5] A few steelhead spawn in the Chelan tailrace. At the present time, steelhead do not spawn in the Chelan River (bypass) because there is no year-round flow there. However, Chelan County Public Utility District proposes to provide year-round flows to the Chelan River so that steelhead and chinook can spawn in the river downstream from the natural barriers. In addition, they intend to provide suitable spawning and early rearing habitat for steelhead and summer/fall chinook in the river downstream from the natural barriers in the river.

Each zone will be monitored independently. That is, a fixed number of sites will be selected probabilistically within each of the five monitoring zones. Sites selected in one zone will not affect the number or locations of sites selected in another zone. This approach will provide information necessary to assess recovery of independent ESA-listed populations within the Upper Columbia Basin.

One can think of the mainstem Columbia River as a sixth status/trend monitoring zone. Although this plan does not describe in detail monitoring within the mainstem Columbia River, work conducted by the mid-Columbia Public Utility Districts assesses annually numbers of upstream-migrating adults and index numbers and conditions of juvenile migrants. Juvenile survival will be assessed for at least three years in the mainstem Columbia River. These studies result from Relicensing Agreements and Hydro Power Habitat Conservation Plans.

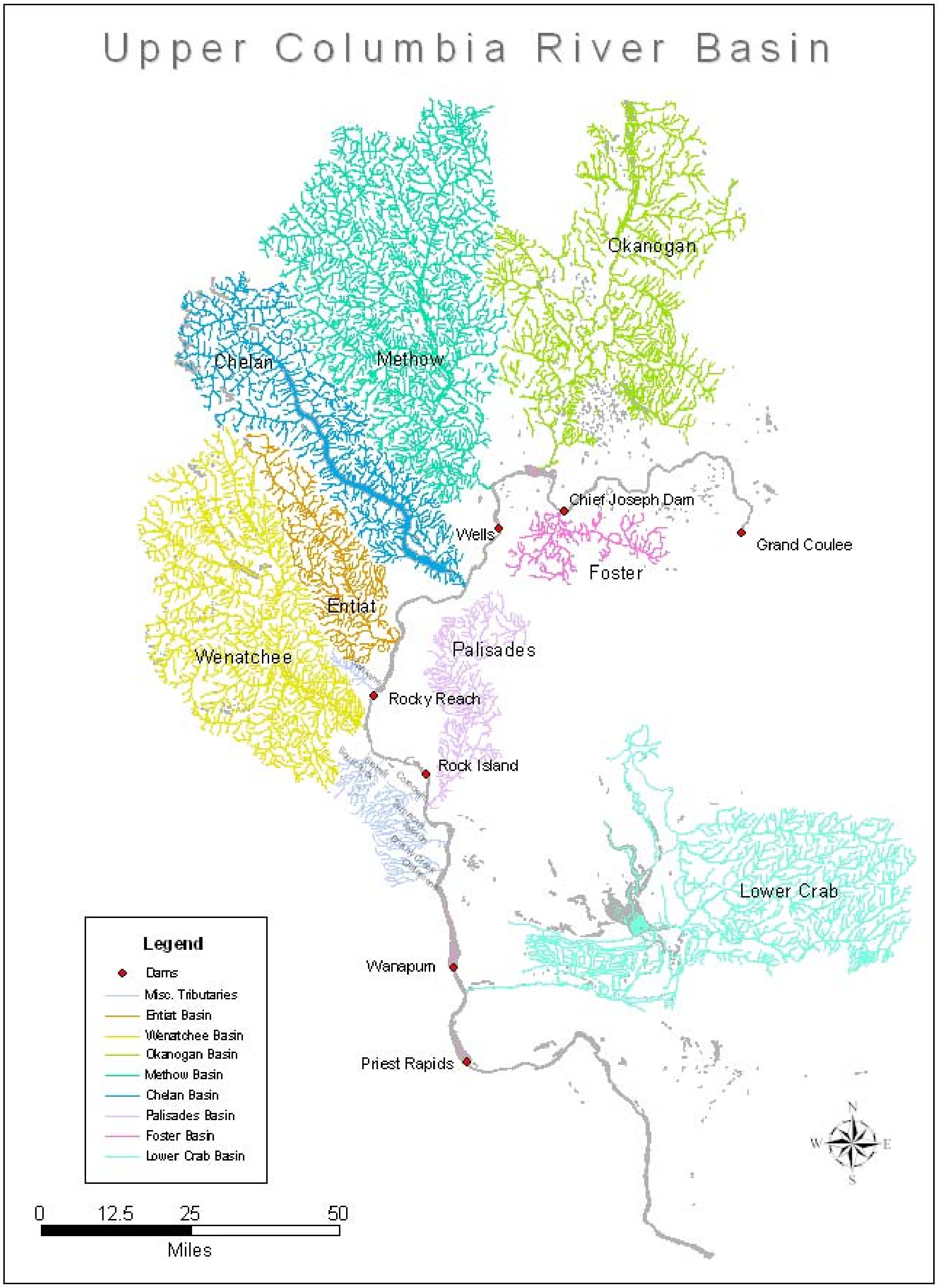

Figure 1. Major tributaries within the Upper Columbia River Basin.

SECTION 3: STATISTICAL DESIGN

This document defines "statistical design" as the logical structure of a monitoring study. It does not necessarily mean that all studies require rigorous statistical analysis. Rather, it implies that all studies, regardless of the objectives, must be designed with a logical structure that reduces bias and the likelihood that rival hypotheses are correct.[6] The purpose of this section is two-fold. First, it identifies the minimum requirements of valid statistical designs and second it identifies the appropriate designs for status/trend and effectiveness monitoring. The following discussions draw heavily on the work of Hairston (1989), Hicks et al. (1999), Krebs (1999), Manly (1992, 2001), and Hillman and Giorgi (2002).

The "validity" of monitoring designs is mentioned throughout this report. The validity of a monitoring design is influenced by the degree to which the investigator can exercise experimental control; that is, the extent to which rival variables or hypotheses can be controlled or dismissed. Experimental control is associated with randomization, manipulation of independent variables, sensitivity of dependent (indicator) variables to management activities (treatments), and sensitivity of instruments or observations to measure changes in indicator variables. There are two criteria for evaluating the validity of any effectiveness monitoring design: (1) does the study infer a cause-and-effect relationship (*internal validity*) and (2) to what extent can the results of the study be generalized to other populations or settings (*external validity*)? Ideally, when assessing cause-and-effect, the investigator should select a design strong in both internal and external validity. With some thought, one can see that it becomes difficult to design a study with both high internal and external validity.[7] Because the intent of effectiveness monitoring is to demonstrate a treatment effect, the study should err on the side of internal validity. Without internal validity the data are difficult to interpret because of the confounding effects of uncontrolled variables. Listed below are some common threats to validity.

- Sampling units that change naturally over time, but independently of the treatment, can reduce validity. For example, fine sediments within spawning gravels may decrease naturally over time independent of the treatment. Alternatively, changes in land-use activities upstream from the study area and unknown to the investigator may cause levels of fine sediments to change independent of the treatment.
- The use of unreliable or inconsistent sampling methods or measuring instruments can reduce validity. That is, an apparent change in an indicator variable may actually be nothing more than using an instrument that was not properly calibrated. Changes in indicator variables may also occur if the measuring instrument changes or disturbs the sampling site (e.g., core sampling).

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6 Rival hypotheses are alternative explanations for the outcome of an experimental study. In effect, rival hypotheses state that observed changes are due to something other than the management action under investigation.

7 Studies with high internal validity (laboratory studies) tend to have low external validity. In the same way, studies with high external validity (field studies) tend to have lower internal validity.

- Measuring instruments that change the sampling unit before the treatment is applied can reduce validity. That is, if the collection of baseline data alters the site in such a way that the measured treatment effect is not what it would be in the population, the results of the study cannot be generalized to the population.
- Differential selection of sampling units can reduce validity, especially if treatment and control sites are substantially different before the study begins. This initial difference may at least partially explain differences after treatment.
- Biased selection of treatment sites can reduce validity. The error here is that the investigator selects sites to be treated in such a way that the treatment effects are likely to be higher or lower than for other units in the population. This issue is complicated by the fact that treatment areas are often selected precisely because they are thought to be problematic.
- Loss of sampling units during the study can reduce validity. This is most likely to occur when the investigator drops sites that shared characteristics such that their absence has a significant effect on the results.
- Multiple treatment effects can reduce validity. This occurs when sampling units get more than one treatment, or the effects of an earlier treatment are present when a later treatment is applied. Multiple treatment effects make it very difficult to identify the treatment primarily responsible for causing a response in the indicator variables.
- The threats above could interact or work in concert to reduce validity.

In most cases, there are simple design elements or requirements that reduce threats to internal and external validity. What follows is a brief description of those elements.

3.1 Minimum Requirements

What are the required elements of a "valid" monitoring study? In general, the more complex the study, the more complex the requirements, but the minimum requirements include *randomization*, *replication*, *independence*, and *controls*.

Randomization—Randomization should be used whenever there is an arbitrary choice to be made of which units will be measured in the sampling frame, or of the units to which treatments will be assigned. The intent is that randomization will remove or reduce systematic errors (bias) of which the investigator has no knowledge. If randomization is not used, then there is the possibility of some unseen bias in selection or allocation. In some situations, complete randomization (both random selection of sampling units and random assignment of treatments) is not possible. Indeed, there will be instances where the investigator cannot randomly assign management activities to survey areas (e.g., removal of mine contaminants from a stream). In this case replication in time and space is needed to generalize inferences of cause-effect relationships.[8] Here, confidence in the inference comes

[8] This does not mean that one cannot infer a cause-effect relationship in the study area. The point here is that without random assignment of management activities, it is questionable if results can be generalized to other sites outside the study area.

from replication outside the given study area. The rule of thumb is simple: randomize whenever possible.

Replication—Replication is needed to estimate "experimental error," which is the basic unit of measurement for assessing statistical significance or for determining confidence limits. Replication is the means by which natural variability is accounted for in interpreting results. The only way to assess variability is to have more than one replicate for each treatment, including the controls (see Section 4). In the absence of replication, there is no way, without appealing to non-statistical arguments, to assess the importance of observed differences among experimental units. Depending on the objectives of the study, spatial and/or temporal replication may be necessary.

Independence—It is important that the investigator select replicates that are spatially and temporally independent. A lack of independence can confound the study and lead to "pseudoreplication" (Hurlbert 1984). The basic statistical problem of pseudoreplication is that replicates are not independent, and the first assumption of statistical inference is violated. The simplest and most common type of pseudoreplication occurs when the investigator only selects one replicate per treatment. It can be argued that case studies, where a single stream or watershed has been monitored for several years, suffer from pseudoreplication. Therefore, one might conclude that no inference is possible. However, the motive behind a single-replicate case study is different from that behind statistical inference. The primary purpose of a case study is to reveal information about biological or physical processes in the system. This information can then be used to formulate and test hypotheses using real statistical replicates. Indeed, case studies provide the background information necessary to identify appropriate management actions and to monitor their effectiveness.

Investigators need to be aware of spatial pseudoreplication and how to prevent it or deal with it. Spatial pseudoreplication can occur when sampling units are spaced close together. Sampling units close together are likely to be more similar than those spaced farther apart.[9] Spatially dependent sites are "subsamples" rather than replicates and should not be treated as independent replicates. Confounding also occurs when control sites are not independent of treatment sites. This is most likely to occur when control sites are placed downstream from treatments sites (although the reverse can also occur; see Underwood 1994). Understandably, there can be no detection of a management action if the treatment affects both the test and control sites similarly.

Similar, although less often recognized problems occur with temporal replication. In many monitoring studies it is common for sampling to be done once at each of several years or seasons. Any differences among samples may then be attributed to differences among years or seasons. This could be an incorrect inference because a single sample collected each year or season does not account for within year or season variability. Take for example the

[9] A common concern of selecting sampling units randomly is that there is a chance that some sampling units will be placed next to each other and therefore will lack independence. Although this is true, if the investigator has designed the study so that it accounts for the obvious sources of variation, then randomization is always worthwhile as a safeguard against the effects of unknown factors.

monitoring of fine sediments in spawning gravels in, say, the Chiwawa River. An investigator measures fine sediments at five random locations (spatial replication) during six consecutive years during the second week of July. A simple statistical analysis of the data could indicate that mean percentages of fine sediments decreased significantly during the latter three years. The investigator may then conclude that fines differed among years.

The conclusion may be incorrect because the study lacked adequate temporal replication. Had the investigator taken samples several times during each year (thereby accounting for within year variability), the investigator may have found no difference among years. A possible reason for the low values during the last three years is because the investigator collected samples before the stream had reached baseflow (i.e., there was a delay in the time that the stream reached baseflow during the last three years compared to the first three years). The higher flows during the second week of July in the last three years prevented the deposition of fines in spawning gravels. An alternative to collecting several samples within years or seasons is to collect the annual sample during a period when possible confounding factors are the same among years. In this case, the investigator could have collected the sample each year during baseflow. The results, however, would apply only to baseflow conditions.

The use of some instruments to monitor physical/environmental indicators may actually lead to pseudoreplication in monitoring designs. This can occur when a "destructive" sampling method is used to sample the same site repeatedly. To demonstrate this point one can look at fine-sediment samples collected repeatedly within the same year. In this example, the investigator designs a study to sample five, randomly-selected locations once every month from June through November (high flows or icing preclude sampling during other months). The investigator randomly selects the week in June to begin sampling, and then samples every fourth week thereafter (systematic sampling). To avoid systematic bias, the same well-trained worker using the same equipment (McNeil core sampler) collects all samples. After compiling and analyzing the data, the investigator may find that there is no significant difference in percent fines among replicates within the year. This conclusion is tenuous because the sampling method (core sampler) disturbed the five sampling locations, possibly reducing fines that would have been measured in following surveys. A more appropriate method would have been to randomly select five new sites (without replacement) during each survey period.

Although replication is an important component of monitoring and should be included whenever possible, it is also important to understand that using a single observation per treatment, or replicates that are not independent, is not necessarily wrong. Indeed, it may be unavoidable in some field studies. What is wrong is to ignore this in the analysis of the data. There are several analyses that can be used to analyze data that are spatially or temporally dependent (see Manly 2001). Because it is often difficult to distinguish between true statistical replicates and subsamples, even with clearly defined objectives, investigators should consult with a professional statistician during the development of monitoring studies.

Controls—Controls are a necessary component of effectiveness research because they provide observations under normal conditions without the effects of the management action or treatment. Thus, controls provide the standard by which the results are compared.[10] The exact nature of the controls will depend on the hypothesis being tested. For example, if an investigator wishes to implement a rest-rotation grazing strategy along a stream with heavy grazing impacts, the investigator would monitor the appropriate physical/environmental indicators in both treatment (modified grazing strategy) and control (unmodified intensive grazing) sites. Because stream systems are quite variable, the study should use "contemporaneous controls." That is, both control and treatment sites should be measured at the same time.

Temporal controls can be used to increase the "power" of the statistical design. In this case the treatment sites would be measured before and after the treatment is applied. Thus, the treatment sites serve as their own controls. However, unless there are also contemporaneous controls, all before-after comparisons must assume homogeneity over time, a dubious assumption that is invalid in most ecological studies (Green 1979). Examples where this assumption *is* valid include activities that improve fish passage at irrigation diversions or screen intake structures. These activities do not require contemporaneous controls. However, a temporal control is needed to describe the initial conditions. Therefore, a before-after comparison is appropriate. The important point is that if a control is not present, it is impossible to conclude anything definite about the effectiveness of the treatment.

It should be clear that the minimum requirements of valid monitoring include randomization, replication, independence, and controls. In some instances monitoring studies may lack one or more of these ingredients. Such studies are sometimes called "quasi-experiments." Although these studies are often used in environmental science, they have inherent problems that need to be considered during data analysis. There is no space here to discuss these problems; however, many of them are fairly obvious. The reader should consult Cook and Campbell (1979) for a detailed discussion of quasi-experimental studies.

3.2 __Recommended Statistical Designs__

A perfect study design would take into account all sources of variability associated with fluctuations in indicator variables. In the absence of perfection, the best approach is to use a design that accounts for all known sources of variation not directly associated with treatment (management action) differences. A reasonable rule is to use the simplest design that provides adequate control of variability. The design should also provide the desired level of precision with the smallest expenditure

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[10] Lee (1993, pg 205) offers a quote from Tufte that adequately describes the importance of controls in study designs. Lee writes, "One day when I was a junior medical student, a very important Boston surgeon visited the school and delivered a great treatise on a large number of patients who had undergone successful operations for vascular reconstruction. At the end of the lecture, a young student at the back of the room timidly asked, 'Do you have any controls?' Well, the great surgeon drew himself up to his full height, hit the desk, and said, 'Do you mean did I not operate on half of the patients?' The hall grew very quiet then. The voice at the back of the room very hesitantly replied, 'Yes, that's what I had in mind.' Then the visitor's fist really came down as he thundered, 'Of course not. That would have doomed half of them to their death.' God, it was quiet then, and one could scarcely hear the small voice ask, 'Which half?' (Tufte 1974, p.4--attributed to Dr. E. Peacock, Jr., chairman of surgery, University of Arizona College of Medicine, in Medical World News, Sept. 1, 1974, p. 45.)"

of time and effort. A more complex design has little merit if it does not improve the performance of statistical tests or provide more precise parameter estimates. Furthermore, an efficient design usually leads to simpler data analysis and cleaner inferences. Described below are valid designs for both effectiveness and status/trend monitoring.

Effectiveness Monitoring—Because effectiveness monitoring attempts to explain cause-and-effect relationships (e.g., effect of a tributary project on fish abundance), it is important to include as many elements of valid statistical design as possible. An appropriate design recommended by the Action Agencies/NOAA Fisheries (2003), ISAB (2003), and WSRFB (2003) is the Before-After-Control-Impact or BACI design (Stewart-Oaten et al. 1986, 1992; Smith et al. 1993). This type of design is also known as a Control-Treatment Paired or CTP design (Skalski and Robson 1992), or Comparative Interrupted Time Series design (Manly 1992). Although names differ, the designs are essentially the same. That is, they require data collected simultaneously at both treatment and control sites before and after treatment. These data are paired in the sense that the treatment and control sites are as similar as possible and sampled simultaneously. Replication comes from collecting such paired samples at a number of times (dates) both before and after treatment. Spatial replication is possible if the investigator selects more than one treatment and control site.[11] The pretreatment sampling serves to evaluate success of the pairings and establishes the relationship between treatment and control sites before treatment. This relationship is later compared to that observed after treatment.

The success of the design depends on indicator variables at treatment and control sites "tracking" each other; that is, maintaining a constant proportionality. The design does not require exact pairing; indicators simply need to "track" each other. Such synchrony is likely to occur if similar climatic and environmental conditions equally influence sampling units (NRC 1992). Precision of the design can be improved further if treatment and control stream reaches are paired according to a hierarchical classification approach (see Section 6). Thus, indicator variables in stream reaches with similar climate, geology, geomorphology, and channel types should track each other more closely than those in reaches with only similar climates.

It is important that control and treatment sites be independent; treatment at one site cannot affect indicators in another site. The NRC (1992) recommends that control data come from another stream or from an independent reach in the same stream. After the pretreatment period, sites to be treated should be selected randomly.[12] Randomization eliminates site location as a confounding factor and removes the need to make model-dependent inferences (Skalski and Robson 1992). Hence, conclusions carry the authority of a "true" experiment

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[11] The use of several test and control sites is recommended because it reduces spatial confounding. In some instances it may not be possible to replicate treatments, but the investigator should attempt to replicate control sites. These "Beyond BACI" designs and their analyses are described in more detail in Underwood (1996).

[12] In most cases treatments will not be randomly assigned to sites. Thus, the studies will be "causal-comparative," rather than "true" experimental studies.

and will generally be more reliable and less controversial. Post-treatment observations should be made simultaneously in both treatment and control sites.

Several different statistical procedures can be used to analyze BACI designs. Manly (1992) identified three methods: (1) a graphical analysis that attempts to allow subjectively for any dependence among successive observations, (2) regression analysis, which assumes that the dependence among successive observations in the regression residuals is small enough to ignore, and (3) an analysis based on a time series model that accounts for dependence among observations. Cook and Campbell (1979) recommend using autoregressive integrated moving average models and the associated techniques developed by Box and Jenkins (1976). Skalski and Robson (1992) introduced the odd's-ratio test, which looks for a significant change in dependent variable proportions in control-treatment sites between pretreatment and post-treatment phases. A common approach, recommended by WSRFB (2003), includes analysis of difference scores. Differences are calculated between paired control and treatment sites. These differences are then analyzed for a before-after treatment effect with a two-sample t-test, Welch modification of the t-test, or with nonparametric tests like the randomization test, Wilcoxon rank sum test, or the Mann-Whitney test (Stewart-Oaten et al. 1992; Smith et al. 1993). Choice of test depends on the type of data collected and whether those data meet the assumptions of the tests.

In some cases, the investigator will not be able to randomly assign treatments to sampling locations. Despite a lack of randomization of treatment conditions, if the treatment conditions are replicated spatially or temporally, a sound inference to effects may be possible. Although valid statistical inferences can be drawn to the sites or units, the authority of a randomized design is not there to "prove" cause-effect relationships. Skalski and Robson (1992) describe in detail how to handle BACI designs that lack randomization.

Status/Trend Monitoring—Because the intent of status/trend monitoring is simply to describe existing conditions and document changes in conditions over time, it does not require all the elements of valid statistical design found in effectiveness monitoring studies. For example, controls are not required in status/trend monitoring. Controls would be important if one desires to assess cause-and-effect relationships (goal of effectiveness monitoring), which is not the purpose of status/trend monitoring. However, status/trend monitoring does require temporal and spatial replication and probabilistic sampling.

Monitoring the status and trends of recovery units, Evolutionarily Significant Units (ESUs), populations, subpopulations, and habitat characteristics is an important component of the Action Agencies/NOAA Fisheries RME Plan, which will be implemented within the Upper Columbia Basin. The RME Plan calls for the implementation of the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) design, which is a spatially-balanced, site-selection process developed for aquatic systems. The state of Oregon has successfully implemented an EMAP-based program for coastal coho salmon (Moore 2002). The monitoring program has also been implemented successfully in subbasins in the upper Columbia (e.g., Okanogan Basin). The monitoring program is spatially explicit, unbiased, and has reasonably high power for detecting trends. The design is sufficiently flexible to use on the scale of multiple large river basins and can be used to estimate the numbers of adult salmon returning each year, the distribution and rearing density of juvenile salmon, productivity and relative condition of stream biota, and freshwater habitat conditions. In addition, the EMAP site-selection approach supports sampling at varying spatial extents.

Specifically, EMAP is a survey design that was developed to describe current status and to detect trends in a suite of indicators. These two objectives have conflicting design criteria; status is ordinarily best assessed by including as many sample units as possible, while trend is best detected by repeatedly observing the same units over time (Overton et al. 1990; Roper et al. 2003). EMAP addresses this conflict by using rotating panels (Stevens 2002). Each panel consists of a collection of sites that will have the same revisit schedule over time. For example, sites in one panel could be visited every year, sites in another revisited every five years, and sites in still another revisited every ten years. This plan recommends that each of the five status/trend monitoring zones (see Section 2) include six panels, with one panel defining sites visited every year and five panels defining sites visited on a five-year cycle (Table 1). If each panel consists of 25 independent sites, one would need a total of 150 sites within each monitoring zone. The process by which sites are selected for each panel and the statistical methods used to analyze data are described in Section 4.

Table 1. Rotating panel design for status/trend monitoring within a given status/trend monitoring zone (e.g., Wenatchee Basin). Shading indicates the years in which sites within each panel are sampled. For example, sites in panel 1 are visited every year, while sites in panel 2 are visited only in years 1, 6, 11, and 16, assuming a 20-year sampling frame.

	Year																			
Panel	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2	■					■					■					■				
3		■					■					■					■			
4			■					■					■					■		
5				■					■					■					■	
6					■					■					■					■

SECTION 4: SAMPLING DESIGN

Once the investigator has selected a valid statistical design, the next step is to select "sampling" sites. *Sampling* is a process of selecting a number of units for a study in such a way that the units represent the larger group from which they were selected. The units selected comprise a *sample* and the larger group is referred to as a *population*.[13] All the possible sampling units available within the area (population) constitute the *sampling frame*.[14] The purpose of sampling is to gain information about a population. If the sample is well selected, results based on the sample can be generalized to the population. Statistical theory assists in the process of drawing conclusions about the population using information from a sample of units.

Defining the population and the sample units may not always be straightforward, because the extent of the population may be unknown, and natural sample units may not exist. For example, a researcher may exclude livestock grazing from sensitive riparian areas in a watershed where grazing impacts are widespread. In this case the management action may affect aquatic habitat conditions well downstream from the area of grazing. Thus, the extent of the area (population) that might be affected by the management action may be unclear, and it may not be obvious which sections of streams to use as sampling units.

When the population and/or sample units cannot be defined unambiguously, the investigator must subjectively choose the potentially affected area and impose some type of sampling structure. For example, sampling units could be stream habitat types (e.g., pools, riffles, or glides), fixed lengths of stream (e.g., 150-m long stream reaches), or reach lengths that vary according to stream widths (e.g., see Simonson et al. 1994). Before selecting a sampling method, the investigator must define the population, size and number of sample units, and the sampling frame.

4.1 <u>Methods of Selecting a Sample</u>

Selection of a sample is a crucial step in monitoring fish populations and physical/environmental conditions in streams. The "goodness" of the sample determines the general applicability of the results. Because monitoring studies usually require a large amount of time and money, non-representative results are wasteful. Therefore, it is important to select a method or combination of methods that increases the degree to which the selected sample represents the population. Described below are the five most commonly used sampling designs for monitoring fish populations and physical/environmental conditions: random sampling, stratified sampling, systematic sampling, cluster

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[13] This definition makes it clear that a "*population*" is not limited to a group of organisms. In statistics, it is the total set of elements or units that are the target of our curiosity. For example, habitat parameters will be monitored at sites selected from the *population* of all possible stream sites in the watershed.

[14] The *sampling frame* is a "list" of all the available units or elements from which the sample can be selected. The sampling frame should have the property that every unit or element in the list has some chance of being selected in the sample. A sampling frame does not have to list all units or elements in the population.

sampling, and multi-stage sampling. See Scheaffer et al. (1990) for a more detailed discussion of sampling methods.

> **<u>Random sampling</u>**—A simple random sample is one that is obtained in such a way that all units in the defined sampling frame have an equal and independent chance of being selected. Stated differently, every unit has the same probability of being selected and the selection of one unit in no way affects the selection of another unit. Random sampling is the best single way to obtain a representative sample.[15] Random sampling should lead to small and unsystematic differences between the sample and the population because differences are a function of chance and not the result of any conscious or unconscious bias on the part of the investigator. Random sampling is also required by inferential statistics. This is important because statistics permit the researcher to make inferences about populations based on the behavior of samples. If samples are not randomly selected, then one of the major assumptions of inferential statistics is violated, and inferences are correspondingly tenuous.
>
> The process of selecting a random sample involves defining the sampling frame, identifying each unit within the frame, and selecting units for the sample on a completely chance basis. If the sampling frame contains units numbered from 1 to **N**, then a simple random sample of size **n** is obtained without replacement by drawing **n** numbers one by one in such a way that each choice is equally likely.
>
> **<u>Stratified sampling</u>**—Stratified sampling is the process of selecting a sample in such a way that identified strata in the sampling frame are represented in the sample.[16] This sampling method addresses the criticism that simple random sampling leaves too much to chance, so that the number of sampling units in different parts of the population may not match the distribution in the population.
>
> Stratified sampling involves dividing the units in the sampling frame into non-overlapping strata, and selecting an independent random sample from each of the strata. An example would be to stratify a stream based on habitat types (i.e., pools, riffles, glides, etc.) and then randomly selecting **n** units within each habitat type. This would ensure that each habitat type is represented in the sample. There are a couple of advantages of stratified sampling: (1) if the sampling units within the strata are more similar than units in general, the estimate of the overall population mean will have a smaller standard error than a mean calculated with simple random sampling; and (2) there may be value in having separate estimates of population parameters for the different strata. Stratification requires the investigator to consider spatial location, areas within which the population is expected to be uniform, and the size of sampling units. Generally, the choice of how to stratify is just a question of common sense.

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[15] No sampling technique guarantees a representative sample, but the probability is higher for random sampling than for other methods.

[16] The number of units selected from each strata could be equal (i.e., n is the same for all strata), or the number could be proportional to the size of the strata. Equal-sized samples would be desired if one wanted to compare the performance of different strata.

In some situations there may be value in analyzing a simple random sample as if it were obtained by stratified random sampling. That is, one takes a simple random sample and then places the units into strata, possibly based on information gathered at the time of sampling. The investigator then analyzes the sample as if it were a stratified random sample. This procedure is known as *post-stratification*. Because a simple random sample should place sample units in different strata according to the size of those strata, post-stratification should be similar to stratified sampling with proportional allocation, provided the total sample size is reasonably large. This may be valuable particularly when the data may be used for a variety of purposes, some of which are unknown at the time of sampling.

Systematic sampling—Systematic sampling is sampling in which units are selected from a list by taking every k^{th} unit. If k = 4, one would sample every 4^{th} unit; if k = 10, one would sample every 10^{th} unit. The value of **k** depends on the size of the sampling frame (i.e., the total number of units) and the desired sample size. The major difference between systematic sampling and the methods discussed above is that all units of the population do not have an independent chance of being selected. Once the first unit is selected, all remaining units to be included in the sample are automatically determined. Nevertheless, systematic sampling is often used as an alternative to simple random sampling or stratified sampling for two reasons. First, the process of selecting sample units is simpler for systematic sampling. Second, under certain circumstances, estimates for systematic sampling may be more precise because the population is covered more evenly. Systematic sampling is not recommended if the population being sampled has some cyclic variation (e.g., regular occurrence of pools and riffles along the course of a stream). Simple random sampling and stratified sampling are not affected by patterns in the population.

Cluster sampling—Cluster sampling is sampling in which groups, not individual units, are randomly selected. Thus, cluster sampling involves sampling clusters of units rather than single units. All units of selected groups have similar characteristics. For example, instead of randomly selecting pools throughout a watershed, one could randomly select channel bed-form types (e.g., plane-bed, step-pool, etc.) within the watershed and use all the pools within those randomly-selected channel types. Cluster sampling is more convenient when the population is very large or spread out over a wide geographic area. This advantage is offset to some extent by the tendency of sample units that are close together to have similar measurements. Therefore, in general, a cluster sample of **n** units will give estimates that are less precise than a simple random sample of **n** units. Cluster sampling can be combined with stratified sampling (see Scheaffer et al. 1990 for more details).

Multi-Stage Sampling—Multi-stage sampling is sampling in which clusters or stages (and clusters within clusters) are randomly selected and then sample units are randomly selected from each sampled cluster. With this type of sampling, one regards sample units as falling within a hierarchical structure. The investigator randomly samples at each of the various levels within the structure. For example, suppose that an investigator is interested in describing changes in fine sediments in stream riffles after livestock grazing is removed from sensitive riparian areas in a large watershed. The investigator may be able to divide the watershed into different geological/geomorphic units (primary sampling units) and then divide each geological/geomorphic unit into channel types (secondary sampling unit). Finally, the investigator may divide each channel type into habitat types (e.g., pools, riffles, glides, etc.). The investigator would obtain a "three-stage" sample of riffle habitats by first randomly selecting several primary sampling units (geological/geomorphic units), next randomly selecting one or more channel types (second-stage units) within each sampled primary unit, and finally randomly selecting one or more riffles (third-stage units) from each sampled channel type. This type of sampling is useful when a hierarchic structure exists, or when it is simply convenient to sample at two or more levels.

It is important to note that some monitoring programs include a combination of sampling designs. As you will see later in this section, the EMAP approach is a combination of random and systematic sampling. Juvenile fish monitoring in the Chiwawa Basin included a combination of stratified random sampling and two-stage sampling (Hillman and Miller 2002). These complex sampling designs require an understanding of the more basic designs.

4.2 Choosing Sample Size

It is now necessary to address the question, "to have a high probability of detecting a management or treatment effect (effectiveness monitoring) or a change in current conditions (status/trend monitoring), what sample size should the investigator use?" This is one of the most important questions of a monitoring plan.[17] If the sample is too small, the results of the study may not be generalized to the population. In addition, the wrong decision may be made concerning the validity of the hypothesis. Therefore, it is important that the investigator select a sample size that will increase the validity of the hypothesis. Fortunately, there are a number of equations and tables that can assist in selecting sample sizes. Before these are considered, it is appropriate to discuss the factors that one needs to consider when selecting a total sample size.

In general, the total sample size for status/trend monitoring depends upon the population size (total number of units in the sampling frame), population variance or standard deviation, and the level of error that the investigator considers acceptable. Quite often the population standard deviation is unknown. In this situation, the investigator can replace the population standard deviation with the sample standard deviation, which may be available from previous studies (an informal "meta-analysis"). Scheaffer et al. (1990) and Browne (2001) describe methods for guessing the population standard deviation when little prior information is available.[18] The level of error is selected by the investigator and should be based on the objectives of the study. Many studies set the error at 0.05. Scheaffer et al. (1990) provide equations for estimating sample sizes for simple random, stratified, systematic, and cluster sampling. There are also a number of computer packages that can be used to

17 Although the paradigm, "for a difference X, I need sample size Y" is important, perhaps an equally important paradigm is, "for a sample size Y, I get information Z." In some cases, an investigator is only able to study a small sample. In this sense, sample size is viewed not as a unique "right" number, but rather as a factor needed to assess the utility of a study (e.g., see Parker and Berman 2003).

18 For simple random sampling, the guess is one-fourth the range of possible values. The idea being that for many distributions the effective range is the mean plus and minus about two standard deviations. This type of approximation is often sufficient because it is only necessary to get the sample size roughly right.

estimate sample sizes, such as PASS 2000 (Power Analysis and Sample Size), which is produced by NCSS Statistical Software (2000), and Methodologist's Toolchest, which is produced by Idea Works (1997).[19]

Effectiveness monitoring, on the other hand, almost always requires the testing of statistical hypotheses, which means that additional factors must be considered when selecting a total sample size. Indeed, statistical significance is usually the desired outcome of effectiveness monitoring (i.e., statistical significance indicates that the management action did what it was suppose to do).[20] Therefore, when selecting a total sample size for effectiveness monitoring, the investigator must carefully evaluate all the factors that influence the validity of statistical hypotheses. These factors include significance level, effect size, variability, and statistical power.[21] What follows is a brief description of each of these factors. First, however, I briefly describe the errors of inference.

There are four possible outcomes of a statistical hypothesis test. If the hypothesis of no difference (null hypothesis) is really true, then two outcomes are possible: not rejecting the null hypothesis is a correct inference, while rejecting it constitutes a Type I error. That is, a Type I error occurs when the investigator concludes that a difference between or among treatments is real when in fact it is not. Similarly, if the null hypothesis is really false, the correct inference is to reject it, and failing to do so constitutes a Type II error. To recap quickly, a Type I error occurs when the investigator concludes that a difference is real when in fact it is not. A Type II error occurs when the investigator concludes that there is no difference when in fact a difference exists. In statistical terms, the probability of committing a Type I error is α, while the probability of a Type II error is β. The power of the test (**1-** β) is the probability of correctly rejecting the null hypothesis when it is really false.

Both types of errors can be costly in monitoring studies where management actions involve the effects of commercial activities, such as timber harvesting or road building, on stream ecosystems. For example, a Type I error may lead to unnecessary limitations on commercial activities, while a Type II error may result in the continuation of activities damaging to the stream ecosystem. While it is impossible to calculate the probability that a hypothesis is true using classical statistical tests, the probability of incurring either a Type I or a Type II error can be controlled to acceptable levels. For example, Type I error is typically limited by the conventional significance level of statistical tests to a frequency of less than five errors per 100 tests performed ("**critical** α"<0.05). In other words, a critical α of 0.05 means that if the null hypothesis was really true and the experiment was repeated many times, the null hypothesis would be rejected incorrectly in at most 5% of the replicate experiments. In contrast, "statistical power analysis" is used to estimate and limit Type II error. With this understanding, I now present a brief description of the factors that affect sample size.

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19 The use of trade or firm names in this paper is for reader information only and does not imply endorsement by an agency of any product or service.

20 As pointed out earlier, not all effectiveness research requires the testing of statistical hypotheses. For example, improving fish passage at a culvert or irrigation diversion does not require one to test a statistical hypothesis. It does require that the results of the action comply with the desired outcome.

21 Total sample size is also affected by the choice of experimental design and statistical analysis. Because these two factors are used to explain or partition variability, they are included in the discussion on variability.

Significance Level—The significance level is a critical value of α, which is the maximum probability of a Type I error that the researcher is willing to accept. When a P-value is less than 0.05 (the usual critical value of α), the researcher rejects the null hypothesis with the guarantee that the chance is less than 1 in 20 that a true null hypothesis has been rejected. Of course, this guarantee about the probability of making a Type I error is valid only if the assumptions of the test are met. The probability of a Type I error (significance level) is completely under the control of the investigator and is inversely related to total sample size. However, increasing critical α-level is not the most effective way to reduce total sample size or to gain statistical power (Lipsey 1990). Generally one increases the significance level when the cost of Type II errors is much larger than the cost of Type I errors.

Effect size—The effect size is the size of change in the parameter of interest that can be detected by an experiment. In statistical jargon, effect size is the difference between the equality components of the null and alternative hypotheses, usually chosen to represent a biologically or practically significant difference.[22] For example, a practical significant effect size of interest might be the difference between the maximum acceptable percentage of fine sediments in spawning gravels and the current percentage of fines in spawning gravels. The investigator must select an effect size to calculate total sample size.

Selection of significant effect size can be straightforward for some designs. In the example above, the practical significant effect size was the difference between a population mean and a known constant (e.g., maximum acceptable percentage of fines in spawning gravels). Similarly, when comparing two population means or two correlation coefficients, the estimate of effect size is simply the difference between the two values. However, formulas for effect size become more complex in designs that involve many relationships among statistical parameters, such as analysis of variance or multiple regression.

In other cases the selection of an appropriate effect size is difficult because it is very subjective. Ideally the effect size to be detected should be practically significant, but quite often this value cannot be expressed quantitatively because of a lack of information. In the absence of information, Cohen (1988) proposes small, medium, and large standardized effect sizes. Standardized effect sizes include measures of variance as well as summaries of the magnitude of treatment effects. For example, the standardized effect size for the difference between two means is expressed as the effect size (μ_1-μ_2), divided by the common standard deviation (σ). According to Cohen (1988), small effects sizes [$(\mu_1-\mu_2)/\sigma = 0.2$] are subtle, medium effect sizes (0.5) are large enough to be perceived in the course of normal experience, and large effect sizes (0.8) are easily perceived at a glance. One should use caution when selecting standardized effect sizes based on Cohen. His standardized effect sizes are derived from behavioral studies, which may not represent ecological studies. In general, sample size

22 Often, statistical significance and biological significance differ. For example, a temperature difference of 0.2ºC may be significant statistically, but not biologically. On the other hand, a 1.0ºC may be biologically significant, but because of a small sample size, the difference is not significant statistically. It is important that the investigator design the study to assess biological or practical significance.

is inversely related to effect size. In other words, a larger sample size is needed to detect a small significant effect size.

Variability—Variability is a measure of how much scores (e.g., water temperatures) differ (vary) from one another. A measure of variability simply indicates the degree of dispersion among the set of scores. If the scores are similar, there is little dispersion and little variability. If the scores are dissimilar, there is a high degree of dispersion (variability). In short, a measure of variability does nothing more than indicate the spread of scores. The variance and the standard deviation are often used to describe the variability among a group of scores. An estimate of the population variability is generally needed to calculate sample size. As indicated earlier, if the population standard deviation is not available, one can use the sample standard deviation (from other studies or pilot studies) as an estimate of the population standard deviation, or one can guess the variability using methods described in Scheaffer et al. (1990).[23] In general, the greater the variability the larger the sample size needed to detect a significant difference.

Statistical Power—Statistical power is the probability that a statistical test will result in statistical significance (Cohen 1988). More technically, statistical power (**1-β**) is the probability of detecting a specified treatment effect (management action) when it is present. Its complement, β, is the probability of a Type II error. Statistical power is directly proportional to sample size. That is, greater statistical power requires a larger sample size. Cohen (1988) suggested that experiments should be designed to have a power of 0.80 (β = 0.20). This comports with Peterman (1990) and Green (1994), who suggest that fisheries researchers should prefer β at least <0.2, or power ≥ 0.8. If the investigator desires to be as conservative about making Type II as Type I errors, β should equal α, or desired power = 0.95 if $\alpha = 0.05$ (Lipsey 1990).

In summary, significance level, effect size, variability, and statistical power affect the total sample size needed for most effectiveness monitoring studies. Because of the time and cost of sampling fish and physical/environmental conditions in tributary habitats, it should be the desire of the investigator to sample the minimum possible number of units. There are several ways that one can reduce sample size. One can reduce statistical power, increase effect size, decrease the variance of the observed variables, or increase the probability of making a Type I error. Although any one of these can be used to reduce the total sample size, it is not necessarily wise (or even possible) to manipulate all of them.

Alpha is completely under the control of the researcher and there may be good reasons to choose critical α-levels other than 0.05. However, changing the critical α-level is not the most effective way

[23] If there are no estimates of variability, one can use the "signal-to-noise ratio" to estimate sample size (see Green 1994). The signal-to-noise ration is the ratio of the effect size to standard deviation. This approach may be appealing because an estimate of population variability seems to disappear, as does the need to estimate it. However, this plan does not recommend using this ratio to calculate sample size because it really does matter what the standard deviation is. The standard deviation is partly natural variation, but it also contains sampling and analysis error. The latter sources of error will affect the estimate of total sample size. Furthermore, to some degree the investigator can control the size of the standard deviation (by using valid designs and selecting sensitive indicators and reliable measurements). Therefore it is best to have some estimate of population standard deviation.

to reduce sample size (Lipsey 1990). In addition, it is unwise to reduce statistical power ($1-\beta$), unless there is good reason to do so. The objective of the study should guide the value of α and β. Data snooping or exploratory research, for example, will often be more cost-effective if α is set relatively high and β relatively low, because the objective is to detect previously unknown relationships. In addition, one should consider the prior probability that each hypothesis is true. A hypothesis that seems likely to be true, based on previous work, should be treated more cautiously with respect to erroneous rejection than a hypothesis that seems less credible (Lipsey 1990). Mapstone (1995) offers a method of selecting α and β based on the relative weighting of the perceived consequences of Type I and Type II errors. It is recommended that investigators review the methods proposed in Mapstone (1995).

Increasing effect size and/or decreasing variability may be the most effective ways to reduce sample size. However, the investigator has little flexibility in selecting significant effect sizes. Effect size is based on "practical significance" or the difference between some desirable condition and current conditions. It is inappropriate to "stretch" the effect size beyond what is considered practically significant. Consequently, the investigator is left primarily with reducing variability as a means of reducing sample size. Because physical/environmental variables often exhibit large variances, strategies for reducing variability are especially important for reducing sample size (and achieving high statistical power). Variability is generally reduced by improving measurement precision, selecting dependent (indicator) variables that are sensitive to the management action, and by various techniques of experimental design (e.g., blocking,[24] stratification, or covariate analysis). Later sections of this report identify sensitive indicator variables (Section 7) and reliable methods for measuring those variables (Section 8).

There are a number of aids that the investigator can use to estimate total sample size. Cohen (1988) provides tables and equations for calculating sample sizes. Various computer packages also estimate sample sizes, such as PASS 2000, SYSTAT, and Methodologist's Toolchest. It is recommended that the investigator use the method that meets their particular needs.

4.3 Measurement Error

Measurements and estimates are never perfect. Indeed, most fish population and habitat variables are difficult to measure, and the errors in these measurements are often large. It is tempting to ignore these errors and proceed as though the estimates reflect the true state of the resource. One should resist this temptation because it could lead to missing a treatment effect, resulting in a waste of money and effort. Investigators need to be aware of the types of errors and how they can be identified and minimized. This is important because total sample size and statistical power are related to variability. By reducing measurement error and bias, one effectively reduces variability, resulting in greater statistical power. This section identifies and describes the various types of errors and describes ways to minimize these errors.

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[24] Although unreplicated random block designs are useful methods of reducing variability, they are not recommended for monitoring tributary conditions because they fail to deal with interactions between treatments (management actions) and blocks. The assumption of no interaction is unrealistic in environmental studies (Underwood 1994).

In general, "error" indicates the difference between an estimated value (from a sample) and its "true" or "expected" value. The two common types of error are *random error* and *systematic error*. Random error (a.k.a. chance error) refers to variation in a score or result that displays no systematic *bias*[25] when taking repeated samples. In other words, random error is the difference between the estimate of a population parameter that is determined from a random sample and the true population value, absent any systematic bias. One can easily detect the presence of random errors by simply repeating the measurement process several times under similar conditions. Different results, with no apparent pattern to the variation (no bias) indicate random error. Although random errors are not predictable, their properties are understood by statistical theory (i.e., they are subject to the laws of probability and can be estimated statistically). The standard deviation of repeated measurements of the same phenomenon gauges the average size of random errors.[26]

Random errors can occur during the collection and compilation of sample data. These errors may occur because of carelessness in recording field data or because of missing data. Recording errors can occur during the process of transferring information from the equipment to field data sheets. This often results from misplacing decimal points, transposing numbers, mixing up variables, or misinterpreting hand-written records. Although not always the fault of the investigator, missing data are an important source of error.

Systematic errors or bias, on the other hand, are not subject to the laws of probability and cannot be estimated or handled statistically without an independent estimate of the bias. Systematic errors are present when estimates consistently over or underestimate the true population value. An example would be a poorly calibrated thermometer that consistently underestimates the true water temperature. These errors are often introduced as a result of poorly calibrated data-recording instruments, miscoding, misfiling of forms, or some other error-generating process. They may also be introduced via interactions among different variables (e.g., turbidity is usually highest at high flows). Systematic error can be reduced or eliminated through quality control procedures implemented at the time data are collected or through careful checking of data before analysis. For convenience, systematic errors are divided into two general classes: those that occur because of inadequate procedures and those that occur during data processing. Each is considered in turn.

> **Biased Procedures**—A biased procedure involves problems with the selection of the sample, the estimation of population parameters, the variables being measured, or the general operation of the survey. For example, selecting sample units based on access can increase systematic error because the habitat conditions near access points may not represent the overall conditions of the population. Changing sampling times and sites during the course of a study can introduce systematic error. Systematic errors can grow imperceptibly as equipment ages or observers change their perspectives (especially true of "visual" measurements). Failure to calibrate equipment introduces error, as does demanding more

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25 *Bias* is a measure of the divergence of an estimate (statistic) from the population parameter in a particular direction. The greater the divergence the greater the bias. Nonrandom sampling often produces such bias.

26 It is important not to confuse standard deviation with standard error. The *standard error of a sample average* gauges the average size of the fluctuation of means from sample to sample. The *sample standard deviation* gauges the average size of the fluctuations of the values within a sample. These two quantities provide different information.

accuracy than can be expected of the instrument or taking measurements outside the range of values for which the instrument was designed.

Processing Errors—Systematic errors can occur during compiling and processing data. Errors can occur during the transfer of field records to computer spreadsheets. Investigators can also introduce large systematic errors by using faulty formulas (e.g., formulas for converting variables). Processing errors are the easiest to control.

The investigator must consider all these sources of error and develop a plan (quality control plan) that minimizes measurement bias. Certainly some errors are inevitable, but a substantial reduction in systematic errors will benefit a monitoring study considerably. The following guidelines will help to reduce systematic errors.

(1) Measures based on counts (e.g., Redds, LWD, Pools)

- Make sure that new personnel are trained adequately by experienced workers.
- Reduce errors by taking counts during favorable conditions and by implementing a rigorous protocol.
- If an over or underestimate is assumed, attempt to assess its extent by taking counts of populations of known size.

(2) Measures based on visual estimates (e.g., snorkel surveys, bank stability)

- Make sure that all visual estimates are conducted according to rigorous protocols by experienced observers.
- Attempt to assess observer bias by using trained personnel to check observations of new workers.

(3) Measures based on instruments (e.g., dissolved oxygen, temperature)

- Calibrate instruments before first use and periodically thereafter.
- Personnel must be trained in the use of all measuring devices.
- Experienced workers should periodically check measurements taken by new personnel.
- Use the most reliable instruments.

(4) Re-measurement of indicators

- Use modern GPS technology, photographs, permanent station markers (e.g., orange plastic survey stakes), and carefully marked maps and diagrams to relocate previous sampling units.
- Guard against the transfer of errors from previous measurements.
- Make sure that bias is not propagated through the use of previous measurements as guides to subsequent ones.

(5) Handling of data

- Record data directly into electronic form where possible.
- Back-up all data frequently
- Design manual data-recording forms and electronic data-entry interfaces to minimize data-entry errors.
- Use electronic data-screening programs to search for aberrant measurements.
- Frequently double-check the transfer of data from field data forms to computer spreadsheets.

Before leaving this discussion, it is important to describe briefly how one should handle outliers. Outliers are measurements that look aberrant (i.e., they appear to lie outside the range of the rest of the values). Because they stand apart from the others, it appears as if the investigator made some gross measurement error. It is tempting to discard them not only because they appear unreasonable, but because they also draw attention to possible deficiencies in the measurement process. Before discarding an apparent outlier, the investigator should look thoroughly at how they were generated. Quite often apparent outliers result from simple errors in data recording, such as a misplaced decimal point. On the other hand, they may be part of the natural variability of the system and therefore should not be ignored or discarded.[27] If one routinely throws out aberrant values, the resulting data set will give false impressions of the structure of the system. Therefore, as a general rule, investigators should not discard outliers unless it is known for certain that measurement errors attend the estimates.

4.4 Recommended Sampling Designs

Using the basic tools described above, valid sampling designs can be identified for status/trend and effectiveness monitoring in the Upper Columbia Basin. The recommended sampling designs, if implemented correctly, should reduce bias and error.

> **Effectiveness Monitoring**—This plan recommends that sampling units for effectiveness monitoring be selected according to a stratified random sampling design. The plan requires that streams or stream segments to be treated with some action(s) will be classified according to a hierarchical classification system (see Section 6). Once classification identifies non-overlapping strata, sampling sites are then selected randomly within each stratum. The same process occurs within control or reference areas, which are similar to treatment areas based on classification. The number of sites selected will depend on effect size, variability, power, and significance levels. The number of sites within each stratum should be proportional to the size of the stratum. That is, a larger stratum would receive more sites than a smaller stratum. The investigator will record the location of the upstream and downstream end of each sampling site with GPS, photographs, permanent station markers, and site diagrams.

[27] Another reason that outliers should be treated carefully is because they can invalidate standard statistical inference procedures. Outliers tend to affect assumptions of variability and normality.

<u>Status/Trend Monitoring</u>—Because the plan follows EMAP, which requires spatially balanced samples, sites will be selected according to the generalized random tessellation stratified design (GRTS) (Stevens 1997; Stevens and Olsen 1999; Stevens and Urquhart 2000; Stevens 2002). Briefly, the GRTS design achieves a random, nearly regular sample point pattern via a random function that maps two-dimensional space onto a one-dimensional line (linear space). A systematic sample is selected in the linear space, and the sample points are mapped back into two-dimensional space. The GRTS design is used to select samples for all panels.

As a starting point, this plan recommends a sample size of 25 sites per panel. This means that GRTS will select a total of 150 sites (6 panels x 25 sites per panel = 150 sites) for each of the five status/trend monitoring zones, regardless of the size of the zones. Two panels of sites will be monitored each year (see Section 3.2), resulting in a total of 50 sites sampled annually within each zone. Some of the sites may fall in areas that are physically inaccessible or cannot be accessed because of landowner denial. Therefore, GRTS will select an additional 150 sites (100% oversample) for each zone, any one of which can replace an inaccessible site.

Within each monitoring zone, the sampling frame for the 150 sites (and the 150 oversample sites) will consist of all portions of first through fifth-order[28] streams (based on 1:100,000 scale USGS topographic maps) with reach gradients less than 12%[29]. These stream segments were selected because most spawning and rearing of ESA-listed fish species occur in these areas. However, spawning and rearing are not evenly distributed among stream orders or among different gradient classes within stream orders. Therefore, this plan recommends that each stream within the sampling frame be divided into gradient classes. This plan recommends the following gradient classes: 0-2%, 2-4%, 4-8%, and 8-12%, which correspond roughly to dune-ripple/pool-riffle, plane-bed, step-pool, and cascade channel types, respectively (Montgomery and Buffington 1997; Roni et al. 1999). The first two classes represent response reaches, while the latter two represent transport reaches.

Although salmon and steelhead are more likely to spawn in stream segments with gradients less than 4% (Roni et al. 1999), it is unclear at this time how sites should be distributed among the four gradient classes. Therefore, this plan recommends that a variety of scenarios be modeled (Table 2). The first places 75% of the sites within gradient classes less than 4%, while the second scenario places 70% of the sites within these gradient classes. The third places 60% of the sites in classes with gradients less than 4%. The last examines the first three scenarios under the criteria that only 10% of the sites can fall within fifth-order streams. The purpose here is to limit the number of sites that fall within large streams. The results of these scenarios should be evaluated to see which one most closely fits the objectives of status/trend monitoring in the zones. Importantly, estimates of subbasin-wide variables will not be biased by the choice of site-selection scenario (P. Larsen, personal communication,

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[28] Stream order is based on Strahler (1952). This method of ordering streams is described in Gordon et al. (1992).

[29] Here, a reach is defined as a 300-m long stretch of stream. Therefore, all 300-m long reaches with a sustained gradient of >12% will be excluded from the sampling frame.

USEPA). Therefore, a different site-selection scenario can be used in different monitoring zones.

In order to estimate precision, 10% of the sites within each of the five zones will be sampled by two independent crews each year for five years. This means that each year, five randomly selected sites within each zone will be surveyed by two different crews. Sampling by the two independent crews will be no more than two-days apart. This will minimize the effects of site changes on estimates of precision. These sites will also be used to compare protocols (e.g, comparison of the protocols in this plan with the Hankin-Reeves methods currently used by the Forest Service).

Data collected within the EMAP design will be analyzed according to the statistical protocols outlined in Stevens (2002). The Horvitz-Thompson or π-estimator is recommended for estimation of population status. Multi-phase regression analyses are recommended for estimating the distribution of trend statistics. These approaches are fully explained in Diaz-Ramos et al. (1996) and Stevens (2002).

Table 2. Proportion of sample sites distributed among stream gradient classes within a status/trend monitoring zone.

Scenario	Gradient classes			
	0-2%	2-4%	4-8%	8-12%
1	0.45	0.30	0.15	0.10
2	0.45	0.25	0.20	0.10
3	0.30	0.30	0.20	0.20
4	Above scenarios but only 10% of the sites can fall within 5th order streams			

SECTION 5: SAMPLING AT DIFFERENT SPATIAL SCALES

Because monitoring will occur at a range of spatial scales, there may be some confusion between the roles of status/trend monitoring and effectiveness monitoring. Generally, one thinks of status/trend monitoring as monitoring that occurs at coarser scales and effectiveness monitoring at finer scales. In reality, both occur across different spatial scales, and the integration of both is needed to develop a valid monitoring program (ISAB 2003; AA/NOAA Fisheries 2003; WSRFB 2003).

The scale at which status/trend and effectiveness monitoring occurs depends on the objectives of the study, the size or distribution of the target population, and the indicators that will be measured. In status/trend monitoring, for example, the objective may be to measure egg-parr survival of spring chinook salmon in the Wenatchee Basin. Because the Wenatchee Basin consists of one population of spring chinook (ICBTRT 2003), the entire basin is the spatial scale at which egg-parr survival is monitored. In contrast, if the objective is to assess egg-parr survival of spring chinook in the Chiwawa Basin (a sub-population of the Wenatchee population), the spatial scale at which monitoring occurs includes only the Chiwawa Basin, a much smaller area than the entire Wenatchee Basin. Thus, status/trend monitoring can occur at various scales depending on the distribution of the population of interest.

In the same way, effectiveness monitoring can occur at different spatial scales. That is, one can assess the effect of a tributary action on a specific Recovery Unit or ESU (which may encompass several populations), a specific population (may include several sub-populations), at the sub-population level (may encompass a watershed within a basin), or at the reach scale. Clearly, the objectives and hence the indicators measured dictate the spatial scale at which effectiveness monitoring is conducted. For example, if the objective is to assess the effects of nutrient enhancement on 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 study must include the entire area inhabited by the eggs, fry, parr, and smolts. If, on the other hand, the objective is to assess the effects of a sediment reduction project on egg-fry survival of a local group of spring chinook (i.e., chinook within a specific reach of stream), then the study area would only encompass the reach of stream used by spawners of that local group.

In theory there might be no limit to the scale at which effectiveness monitoring can be applied, but in practice there is a limit. This is because as the spatial scale increases, the tendency for multiple treatments (several habitat actions) affecting the same population increases (Table 3). That is, at the spatial scale representing a Recovery Unit, ESU, or population, there may be many habitat actions within that area. Multiple treatment effects make it very difficult to assess the effects of specific actions on an ESU (see Section 3). Even though it may be impossible to assess specific treatment effects at larger spatial scales, it does not preclude one from conducting effectiveness monitoring at this scale. Indeed, one can assess the combined or cumulative effects of tributary actions on the Recovery Unit, ESU, or population. However, additional effectiveness monitoring may be needed at finer scales to assess the effects of individual actions on the ESU or population.

Table 3. Relationship between biological indicators, spatial scales, and our ability to assess effects of specific management actions. Examples of each scale are shown in parentheses. Table is modified from Action Agencies/NOAA Fisheries RME Plan (2003).

Biological Indicators	Example of spatial scales	Ability to assess effects of specific tributary actions
ESU (Upper Columbia Spring Chinook) ↓	**Basins** (Upper Columbia) ↓	**Low**
Population (Wenatchee Spring Chinook) ↓	**Basin** (Wenatchee) ↓	↓
Sub-Population (Chiwawa River Spring Chinook) ↓	**Watershed** (Chiwawa River) ↓	
Local Group	**Reach** (5 km of the Chiwawa River)	**High**

Given the potential problems of multiple treatment effects, there are two general strategies for conducting effectiveness monitoring at different spatial scales. One strategy is a "project-based" approach, which addresses the effects of individual tributary projects at smaller spatial scales (e.g., stream or stream reach). This approach is identified in the Action Agencies/NOAA Fisheries Plan as the "Bottom-Up" approach. It is designed to assess the effects of specific projects in isolation of other tributary actions. That is, results from this type of effectiveness monitoring would not be confounded by actions occurring elsewhere in the basin. This approach requires that the investigator maintain control of all actions that occur within the assessment area (stream, watershed, or basin).

The second strategy is an "intensive" approach that addresses the cumulative effects of tributary actions at larger spatial scales (e.g., watershed or basin). This approach is identified in the Action Agencies/NOAA Fisheries Plan as the "Top-Down" Approach. The WSRFB (2003) refers to it as "Intensive (Validation) Monitoring." This approach requires intensive and extensive sampling of several indicator variables 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.

Both approaches (project-based and intensive) require valid statistical and sampling designs. That is, both approaches require controls (reference conditions), replication, and probabilistic sampling. This plan recommends the use of BACI designs (see Section 3) with stratified random sampling (see Section 4) for both approaches. Both approaches will likely be implemented within subbasins in the Upper Columbia Basin.

SECTION 6: CLASSIFICATION

Both status/trend and effectiveness monitoring require landscape classification. The purpose of classification is to describe the "setting" in which monitoring occurs. This is necessary because biological and physical/environmental indicators may respond differently to tributary actions depending on landscape characteristics. An hierarchical classification system that captures a range of landscape characteristics should adequately describe the setting in which monitoring occurs. The idea advanced by hierarchical theory is that ecosystem processes and functions operating at different scales form a nested, interdependent system where one level influences other levels. Thus, an understanding of one level in a system is greatly informed by those levels above and below it.

A defensible classification system should include both ultimate and proximate control factors (Naiman et al. 1992). Ultimate controls include factors such as climate, geology, and vegetation that 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. Proximate controls are a function of ultimate factors and refer to local conditions of geology, landform, and biotic processes that operate over smaller areas and over shorter time periods. These factors include processes such as discharge, temperature, sediment input, and channel migration. Ultimate and proximate control characteristics help define flow (water and sediment) characteristics, which in turn help shape channel characteristics within broadly predictable ranges (Rosgen 1996).

This plan proposes a classification system that incorporates the entire spectrum of processes influencing stream features and recognizes the tiered/nested nature of landscape and aquatic features. This system captures physical/environmental differences spanning from the largest scale (regional setting) down to the channel segment (Table 4). The Action Agencies/NOAA Fisheries RME plan proposes a similar classification system. By recording these descriptive characteristics, the investigator will be able to assess differential responses of indicator variables to proposed actions within different classes of streams and watersheds. Importantly, the classification work described here fits well with Level 1 monitoring under the ISAB (2003) monitoring and evaluation plan. Classification variables and recommend methods for measuring each variable are defined below.

Table 4. List of classification (stratification) variables, their corresponding measurement protocols, and temporal sampling frequency. The variables are nested according to spatial scale and their general characteristics. Table is modified from Action Agencies/NOAA Fisheries RME Plan (2003).

Spatial scale	General characteristics	Classification variable	Recommended protocols	Sampling frequency (years)
Regional setting	Ecoregion	Bailey classification	Bain and Stevenson (1999)	20
		Omernik classification	Bain and Stevenson (1999)	20
	Physiography	Province	Bain and Stevenson (1999)	20
	Geology	Geologic districts	Overton et al. (1997)	20
Drainage basin	Geomorphic features	Basin area	Bain and Stevenson (1999)	20
		Basin relief	Bain and Stevenson (1999)	20
		Drainage density	Bain and Stevenson (1999)	20
		Stream order	Gordon et al. (1992)	20
Valley segment	Valley characteristics	Valley bottom type	Cupp (1989); Naiman et al. (1992)	20
		Valley bottom width	Naiman et al. (1992)	20
		Valley bottom gradient	Naiman et al. (1992)	20
		Valley containment	Bisson and Montgomery (1996)	20
Channel segment	Channel characteristics	Elevation	Overton et al. (1997)	10
		Channel type (Rosgen)	Rosgen (1996)	10
		Bed-form type	Bisson and Montgomery (1996)	10
		Channel gradient	Overton et al. (1997)	10
	Riparian veg.	Primary vegetation type	Platts et al. (1983)	5

As noted above, all watersheds that will be monitored will be classified according to their landscape characteristics. Table 4 lists the "core" set of classification variables. Investigators may elect to describe additional classification variables depending on the objectives of the study. Only a general description of each classification variable is provided here. Because time and space do not allow for a detailed description of methods, this plan only identifies recommended methods and instruments. The reader should refer to the cited documents for detailed descriptions of methods and measuring instruments.

The classification work described here relies heavily on remote-sensed data and GIS. The majority of this work can be conducted in an office with GIS. It is important, however, to spend some time in the field verifying spatial data. This plan recommends that at least 10% of the channel segments identified in a subbasin be verified in the field. These segments can be selected randomly. Additional verification may be needed for those segments that cannot be accurately delineated from remote-sensed data. Variables such as primary riparian vegetation type, channel type, and bed-form type will be verified during field surveys (described in Section 8).

Regional Setting

Ecoregions:

Ecoregions are relatively uniform areas defined by generally coinciding boundaries of several key geographic variables. Ecoregions have been defined holistically using a set of physical and biotic factors (e.g., geology, climate, landform, soil, vegetation, and water). Of the systems available, this plan includes the two most commonly used ecoregion systems, Bailey (1978) and Omernik (1987). Bailey's approach uses macroclimate and prevailing plant formations to classify the continent into various levels of detail. Bailey's coarsest hierarchical classifications include domains, divisions, provinces, and sections. These regional classes are based on broad ecological climate zones and thermal and moisture limits for plant growth (Bailey 1998). Specifically, domains are groups of related climates, divisions are types of climate based on seasonality of precipitation or degree of dryness or cold, and provinces are based on macro features of vegetation. Provinces include characterizations of land-surface form, climate, vegetation, soils, and fauna. Sections are based on geomorphology, stratigraphy and lithology, soil taxa, potential natural vegetation, elevation, precipitation, temperature, growing season, surface water characteristics, and disturbance. Information from domains, divisions, and provinces can be used for modeling, sampling, strategic planning, and assessment. Information from sections can be used for strategic, multi-forest, statewide, and multi-agency analysis and assessment.

The system developed by Omernik (1987) is used to distinguish regional patterns of water quality in ecosystems as a result of land use. Omernik's system is suited for classifying aquatic ecoregions and monitoring water quality because of its ecological foundation, its level of resolution, and its use of physical, chemical, and biological information. Like Bailey's system, this system is hierarchical, dividing an area into finer regions in a series of levels. These levels are based on characterizations of land-surface form, potential natural vegetation, land use, and soils. Omernik's system has been extensively tested and found to correspond well to spatial patterns of water chemistry and fish distribution (Whittier et al. 1988).

Until there is a better understanding of the relationships between fish abundance/distribution and the two classes of ecoregions, investigators should use both classifications. Chapter 3 in Bain and Stevenson (1999) outlines protocols for describing ecoregions. Published maps of ecoregions are available to assist with classification work.[30] This work will be updated once every 20 years.

Physiographic Province:

Physiographic province is the simplest division of a land area into hierarchical natural regions. In general, delineation of physiographic provinces is based on topography (mountains, plains,

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[30] Bailey's digital-compressed ARC/INFO ecoregion maps are available at http://www.fs.fed.us/institute/ecolink.html. Omernik's digital level III ecoregion maps of the conterminous U.S. are available at http://www.epa.gov/OST/BASINS/gisdata.html (download BASINS core data) with documentation at http://www.epa.gov/envirofw/html/nsdi/nsditxt/useco.txt.

plateaus, and uplands) and, to a lesser extent, climate, which governs the processes that shape the landscape (weathering, erosion, and sedimentation). Specifically, provinces include descriptions of climate, vegetation, surficial deposits and soils, water supply or resources, mineral resources, and additional information on features particular to a given area (Hunt 1967). Physiographic provinces and drainage basins have traditionally been used in aquatic research to identify fish distributions (Hughes et al. 1987; Whittier et al. 1988).

Chapter 3 in Bain and Stevenson (1999) outlines methods for describing physiographic provinces. Physiographic maps are available to aid classification work.[31] Investigators will update physiographic provinces once every 20 years.

Geology:

Geologic districts are areas of similar rock types or parent materials that are associated with distinctive structural features, plant assemblages, and similar hydrographic character. Geologic districts serve as ultimate controls that shape the overall character and attainable conditions within a watershed or basin. They are corollary to subsections identified in the U.S. Forest Service Land Systems Inventory (Wertz and Arnold 1972). Watershed and stream morphology are strongly influenced by geologic structure and composition (Frissell et al. 1986; Nawa et al. 1988). Structural features are the templates on which streams etch drainage patterns. The hydrologic character of landscapes is also influenced by the degree to which parent material has been weathered, the water-handling characteristics of the parent rock, and its weathering products. Like ecoregions, geologic districts do not change to other types in response to land uses.

Geologic districts can be identified following the methods described in Overton et al. (1997). Published geology maps aid in the classification of rock types. This work will be updated once every 20 years.

Drainage Basin

Geomorphic Features:

This plan includes four important geomorphic features of drainage basins: basin area, basin relief, drainage density, and stream order. Basin area (a.k.a. drainage area or catchment area) is the total land area (km^2), measured in a horizontal plane, enclosed by a drainage divide, from which direct surface runoff from precipitation normally drains by gravity into a wetland, lake, or river. Basin relief (m) is the difference in elevation between the highest and lowest points in the basin. It controls the stream gradient and therefore affects flood patterns and the amount of sediment that can be transported. Hadley and Schumm (1961) demonstrated that sediment load increases exponentially with basin relief. Drainage density (km) is an index of the length of stream per unit area of basin and is calculated as the drainage area (km^2) divided

[31] Detailed information about physiographic provinces of the U.S. can be found at http://www.salem.mass.edu/~lhanson/. Digital maps can be found at http://water.usgs.gov/GIS/.

by the total stream length (km). This ratio represents the amount of stream necessary to drain the basin. High drainage density may indicate high water yield and sediment transport, high flood peaks, steep hills, and low suitability for certain land uses (e.g., agriculture). The last geomorphic feature, stream order, is based on the premise that the order number is related to the size of the contributing area, to channel dimensions, and to stream discharge. Stream ordering follows the Strahler ordering system. In that system, all small, exterior streams are designated as first order. A second-order stream is formed by the junction of any two first-order streams; third-order by the junction of any two second-order streams. In this system only one stream segment has the highest order number.

Chapter 4 in Bain and Stevenson (1999) outlines standard methods for estimating basin area, basin relief, and drainage density. Gordon et al. (1992) describes the Strahler stream-ordering method. Investigators will use USGS topographic maps (1:100,000 scale) and GIS to estimate these parameters. This work will be updated once every 20 years.

Valley Segment

Valley Characteristics:

The plan incorporates four important features of the valley segment: valley bottom type, valley bottom width, valley bottom gradient, and valley confinement. Valley bottom types are distinguished by average channel gradient, valley form, and the geomorphic processes that shaped the valley (Cupp 1989a,b; Naiman et al. 1992). They correspond with distinctive hydrologic characteristics, especially the relationship between stream and alluvial ground water (Table 5). Valley bottom width is the ratio of the valley bottom[32] width (m) to active channel width (m). Valley gradient is the slope or the change in vertical elevation (m) per unit of horizontal valley distance (m). Valley gradient is typically measured in lengths of about 300 m (1,000 ft) or more. Valley confinement refers to the degree that the valley walls confine the lateral migration of the stream channel. The degree of confinement can be classified as strongly confined (valley floor width < 2 channel widths), moderately confined (valley floor width = 2-4 channel widths), or unconfined (valley floor width > 4 channel widths).

The latter three variables, valley bottom width, valley gradient, and confinement, are nested within valley bottom types. Therefore, these three variables will be described for each valley bottom type identified within the drainage basin (i.e., the valley bottom type defines the scale at which these variables are described).

Investigators should follow the methods of Cupp (1989a,b) and Naiman et al. (1992) to describe valley bottom types. Naiman et al. (1992) also describe methods for measuring valley bottom width and valley bottom gradient. Bisson and Montgomery (1996) outline methods for measuring valley confinement. GIS will aid in estimating these parameters. These variables will be updated once every 20 years.

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32 Valley bottom is defined as the essentially flat area adjacent to the stream channel.

Table 5. Examples of valley bottom types and valley geomorphic characteristics in forested lands of Washington. Table is from Naiman et al. (1992).

Valley bottom type[a]	Valley bottom gradient[b]	Sideslope gradient[c]	Valley bottom width[d]	Channel patterns	Strahler stream order	Landform and geomorphic features
F1 Estuarine delta	≤0.5%	<5%	>5X	Unconstrained; highly sinuous; often braided	Any	Occur at mouth of streams on estuarine flats in and just above zone of tidal influence
F2 Alluviated lowlands	≤1%	>5%	>5X	Unconstrained; highly sinuous	Any	Wide floodplains typically formed by present or historic large rivers within flat to gently rolling lowland landforms; sloughs, oxbows, and abandoned channels commonly associated with mainstream rivers
F3 Wide mainstream valley	≤2%	<5%	>5X	Unconstrained; moderate to high sinuosity; braids common	Any	Wide valley floors bounded by mountain slopes; generally associated with mainstream rivers and the tributary streams flowing through the valley floor; sloughs and abandoned channels common.
F4 Wide mainstream valley	≤1-3%	≤10%	>3X	Variable; generally unconstrained	1-4	Generally occur where tributary streams enter low-gradient valley floors; ancient or active alluvial/colluvial fan deposition overlying floodplains of larger, low-gradient stream segments; stream may actively downcut through deep alluvial fan deposition.
F5 Gently sloping plateaux and terraces	≤2%	<10%	1-2X	Moderately constrained; low to moderate sinuosity	1-3	Drainage ways shallowly incised into flat to gently sloping landscape; narrow active floodplains; typically associated with small streams in lowlands, cryic uplands or volcanic flanks.
M1 Moderate sloping plateaux and terraces	2-5%	<10-30%	<2X	Constrained; infrequent meanders	1-4	Constrained, narrow floodplains bounded by moderate gradient sideslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks.
M2 Alluviated, moderate slope bound	≤2%	<5%, gradually increase to 30%	2-4X	Unconstrained; moderate to high sinuosity	1-4	Active floodplains and alluvial terraces bounded by moderate gradient hillslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks.
V1 V-shaped moderate-gradient bottom	2-6%	30-70%	<2X	Constrained	≥2	Deeply incised drainage ways with steep competent sideslopes; very common in uplifted mountainous topography; less commonly associated with marine or glacial outwash terraces in lowlands and foothills.
V2 V-shaped high-gradient bottom	6-11%	30-70%	<2X	Constrained	≥2	Same as above, but valley bottom longitudinal profile steep with pronounced stair-step characteristics.

Table 5. (continued)

Valley bottom type[a]	Valley bottom gradient[b]	Sideslope gradient[c]	Valley bottom width[d]	Channel patterns	Strahler stream order	Landform and geomorphic features
V3 V-shaped, bedrock canyon	3-11%	70%+	<2X	Highly constrained	≥2	Canyon-like stream corridors with frequent bedrock outcrops; frequently stair-stepped profile; generally associated with folded, faulted or volcanic landforms.
V4 Alluviated mountain valley	1-4%	Channel adjacent slopes <10%; increase to 30%+	2-4X	Unconstrained; high sinuosity with braids and side-channels common	2-5	Deeply incised drainage ways with relatively wide floodplains; distinguished as "alluvial flats" in otherwise steeply dissected mountainous terrain.
U1 U-shaped trough	<3%	<5%; gradually increases to 30%+	>4X	Unconstrained; moderate to high sinuosity; side channels and braids common	1-4	Drainage ways in mid to upper watersheds with history of glaciation, resulting in U-shaped profile; valley bottom typically composed of glacial drift deposits overlain with more recent alluvial material adjacent to channel.
U2 Incised U-shaped valley, moderate-gradient bottom	2-5%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately contrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate side-slopes composed of unconsolidated and often unsorted coarse-grained deposits.
U3 Incised U-shaped valley, high-gradient bottom	6-11%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate side-slopes composed of unconsolidated and often unsorted coarse-grained deposits.
U4 Active glacial out-wash valley	1-7%	Initially <5%, increasing to >60%	<4X	Unconstrained; highly sinuous and braided	1-3	Stream corridors directly below active alpine glaciers; channel braiding and shifting common; active channel nearly as wide as valley bottom.
H1 Moderate-gradient valley wall/head-water	3-6%	>30%	<2X	Constrained	1-2	Small drainage ways with channels slightly to moderately entrenched into mountain toe-slopes or head-water basins.
H2 High-gradient valley wall/head-water	6-11%	>30%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial terrace deposition.

Table 5. (concluded)

Valley bottom type[a]	Valley bottom gradient[b]	Sideslope gradient[c]	Valley bottom width[d]	Channel patterns	Strahler stream order	Landform and geomorphic features
H3 Very high-gradient valley wall/head-water	11%+	>60%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and out-crops common; localized alluvial/colluvial terrace deposition.

[a]Valley bottom type names include alphanumeric mapping codes in italic (from Cupp 1989a, b).
[b]Valley bottom gradient is measured in length of about 300 m (1,000 ft).
[c]Sideslope gradient characterizes the hillslopes within 1,000 horizontal and about 100 m (300 ft) vertical distance from the active channel.
[d]Valley bottom width is a ratio of the valley bottom width to active channel width.

Channel Segment

Channel Characteristics:

The plan includes four important characteristics of the channel segment: elevation, channel gradient, channel type, and bed-form type. These characteristics are nested within valley bottom types and therefore should be described for each valley bottom type identified within the drainage basin. Elevation (m) is the height of the stream channel above or below sea level. Channel gradient is the slope or the change in the vertical elevation of the channel per unit of horizontal distance. Channel gradient can be presented graphically as a stream profile.

Channel type follows the classification technique of Rosgen (1996) and is based on quantitative channel morphology indices.[33] These indices result in objective and consistent identification of stream types. The Rosgen technique consists of four different levels of classification. Level I describes the geomorphic characteristics that result from the integration of basin relief, landform, and valley morphology. Level II provides a more detailed morphological description of stream types. Level III describes the existing condition or "state" of the stream as it relates to its stability, response potential, and function. Level IV is the level at which measurements are taken to verify process relationships inferred from preceding analyses. All monitoring in subbasins in the Upper Columbia Basin will include at least Level I (geomorphic characterization) classification (Table 6).

33 Indices include entrenchment, gradient, width/depth ratio, sinuosity, and dominant channel material.

Table 6. General stream type descriptions and delineative criteria for Level I channel classification. Table is from Rosgen (1996).

Stream type	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope %	Landform/ soils/features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0-1.1	>10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0-1.2	4-10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle-dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4-2.2	>12	>1.2	2-4	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.4	<2	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<4	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply. Covergence/divergence bed features, aggradational processes, high bedload and bank erosion.

Table 6. (concluded)

Stream type	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope %	Landform/ soils/features
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth rations. Very stable streambanks.	>2.2	Highly variable	Highly variable	<0.5	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low sidth/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<2	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.4	<2	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	2-4	Gullies, step/pool morphology with moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

Bed-form type follows the classification proposed by Montgomery and Buffington (1993). This technique is comprehensive and is based on hierarchies of topographic and fluvial characteristics. This system provides a geomorphic, process-oriented method of identifying valley segments and stream reaches. It employs descriptors that are measurable and ecologically relevant. Montgomery and Buffington (1993) identified three valley segment types: colluvial, alluvial, and bedrock. They subdivided the valley types into one or more stream-reach types (bed-form types) depending on whether substrates are limited by the supply of sediment or by the fluvial transport of sediment (Table 7). For example, depending on sediment supply and transport, Montgomery and Buffington (1993) recognized six alluvial bed-form types: braided, regime, pool/riffle, plane-bed, step-pool or cascade. Both colluvial and bedrock valley types consist of only one bed-form type. Only colluvial bed-forms occur in colluvial valleys and only bedrock bed-forms occur in bedrock valleys.

Table 7. Characteristics of different bed-form types. Table is modified from Montgomery and Buffington (1993).

Valley types	Bed-form types	Predominant bed material	Dominant roughness elements	Typical slope (%)	Typical confinement	Pool spacing (channel widths)
Colluvial	Colluvial	Variable	Boulders, large woody debris	>20	Strongly confined	Variable
Bedrock	Bedrock	Bedrock	Streambed, banks	Variable	Strongly confined	Variable
Alluvial	Cascade	Boulder	Boulders, banks	8-30	Strongly confined	<1
	Step-pool	Cobble/boulder	Bedforms (steps, pools) boulders, large woody debris, banks	4-8	Moderately confined	1-4
	Plane-bed	Gravel/cobble	Boulders and cobbles, banks	1-4	Variable	None
	Pool-riffle	Gravel	Bedforms (bars, pools) boulders and cobbles, large woody debris, sinuosity, banks	0.1-2	Unconfined	5-7
	Regime	Sand	Sinuosity, bed-forms (dunes, ripples, bars), banks	<0.1	Unconfined	5-7
	Braided	Variable	Bedforms (bars, pools)	<3	Unconfined	Variable

Methods for measuring elevation and channel gradient can be found in Overton et al. (1997). Bisson and Montgomery (1996) describe in detail the method for identifying channel bed-form types, while Rosgen (1996) describes methods for classifying channel types. All classification work will include at least Level I (geomorphic characterization) channel type classification. Depending on the objectives of the monitoring program, additional levels of classification may be necessary. These variables will be updated once every 10 years.

Riparian Vegetation:

Because riparian vegetation has an important influence on stream morphology and aquatic biota, the plan incorporates primary vegetation type as a characteristic of riparian vegetation. Primary vegetation type refers to the dominant vegetative cover along the stream. At a minimum, vegetation should be described as barren, grasses or forbs, shrubs, and trees. If remote sensing allows, it would be better to further classify the types of shrubs and trees. For example, trees could be described as cottonwoods, fir, cedar, hemlock, pine, etc. Primary vegetation type should be described for a riparian width of at least 30 m along both sides of the stream. More desirably, primary vegetation type should be described for the entire floodplain.

Remote sensing will be used to describe the primary vegetation type along streams within valley bottom types. Remote sensing may include aerial photos, LANDSAT ETM+, or both.

SECTION 7: SELECTION OF INDICATORS

This section identifies the "core" set of biological and physical/environmental indicator variables that will be measured within all watersheds and streams that receive status/trend and effectiveness monitoring. The "core" list of variables represents the minimum, required variables that will be measured. Investigators can measure additional variables depending on their objectives and past activities. For example, reclamation of mining-impact areas may require the monitoring of pollutants, toxicants, or metals. Some management actions may require the measurement of thalweg profile, placement of artificial instream structures, or livestock presence. Adding these indicators will supplement the core list.

Indicator variables identified in this plan are consistent with those identified in the Action Agencies/NOAA Fisheries RME Plan and with most of the indicators identified in the WSRFB (2003) monitoring strategy. The Action Agencies/NOAA Fisheries selected indicators based on their review of the literature (e.g., Bjornn and Reiser 1991; Spence et al. 1996; Gregory and Bisson 1997; and Bauer and Ralph 1999) and several regional monitoring programs (e.g., PIBO, AREMP, EMAP, WSRFB, and the Oregon Plan). They selected variables that met various purposes including assessment of fish production and survival, identifying limiting factors, assessing effects of various land uses, and evaluating habitat actions. Their criteria for selecting variables were based on the following characteristics:

- Indicators should be sensitive to land-use activities or stresses.
- They should be consistent with other regional monitoring programs.
- They should lend themselves to reliable measurement.
- Physical/environmental indicators would relate quantitatively with fish production.

The indicators that the Action Agencies/NOAA Fisheries selected were consistent with most of the variables identified by the NMFS (1996) and USFWS (1998) as important attributes of "properly functioning condition." Indeed, NMFS and USFWS use these indicators to evaluate the effects of land-management activities for conferencing, consultations, and permits under the ESA.

The indicators selected by the Action Agencies/NOAA Fisheries were also consistent with "key" parameters used in the Ecosystem Diagnosis and Treatment model. Recent analyses by Mobrand Biometrics indicated that certain physical/environmental parameters have a relatively important influence on modeled salmon production. These parameters included channel configuration, gradient, pool/riffle frequency, migration barriers, flow characteristics, water temperature, riparian function, fine sediment, backwater areas, and large woody debris (LWD) (K. Malone, Mobrand Biometrics, personal communication).

Identified and described below are the "core" set of biological and physical/environmental indicators that will be monitored in the Upper Columbia Basin.

7.1 Biological Variables

The biological variables that will be measured in the Upper Columbia River Basin can be grouped into five general categories: adults, redds, parr, smolts, and macroinvertebrates. Each of these general categories consists of one or more indicator variables (Table 8). These biological indicators in concert will describe the characteristics of populations or sub-populations of fish in the monitoring zones (see Section 2) and will provide information necessary for assessing recovery of listed stocks.

Table 8. Biological indicator variables to be monitored in the Upper Columbia River Basin.

General characteristics	Specific indicators
Adults	Escapement/Number
	Age structure
	Size
	Sex ratio
	Origin (hatchery or wild)
	Genetics
	Fecundity
Redds	Number
	Distribution
Parr/Juveniles	Abundance
	Distribution
	Size
Smolts	Number
	Size
	Genetics
Macroinvertebrates	Transport
	Composition

Adults

Escapement:

The plan includes escapement of mature adults as an important biological indicator of population health. "Total" escapement is the total number of mature adults that enter or occur within a stream or watershed. "Spawning" escapement is the number of adults that spawn in a stream or watershed. Numbers of mature adults within a stream or watershed is a function of all the factors that affect the life history of the population.

Spawners:

The plan includes six indicators associated with the characteristics of the spawning populations: age structure, size, sex ratio, origin, genetics, and fecundity. Age structure describes the ages of adult fish within the spawning population. For anadromous species, age structure includes the number of years the fish spent in freshwater and number of years in salt water. Size describes the lengths and weights of adult fish within the spawning population. Sex ratio is the ratio of males to females within the spawning population. Origin identifies the parentage (hatchery or wild) of individuals within the spawning populations, while genetics defines not only the parentage but also within and between population variability. Fecundity is the number of eggs produced by a female.[34]

Redds

Abundance/Distribution:

Abundance describes the number of redds (nests) of fish species within a subbasin. Total numbers (based on a complete census) will be estimated for fall-spawning anadromous species, while numbers of redds of other species (e.g., steelhead and bull trout) will be estimated within index areas and sites selected randomly (following EMAP). Distribution indicates the spatial arrangement (e.g., random, even, or clumped) and geographic extent of redds within the basin.

Parr

Abundance/Distribution:

Abundance describes the number of juvenile fish within specified stream reaches. Distribution is the spatial arrangement of juvenile fish within populations. It also captures the geographic range of individuals within the watershed or basin.

Condition:

The condition (or well-being) of fish can be assessed by measuring the length (fork length for salmonids, FL mm; total length for all other species, TL mm) and weight (g) of juvenile fish. The plan includes Fulton-type condition as the metric for well-being of juvenile fish (Anderson and Neumann 1996). The Fulton-type condition factor is of the form:

$$K = (W/L^3) \times 100{,}000,$$

[34] By definition, *fecundity* refers to the number of eggs readied for spawning by a female (Royce 1996). *Relative fecundity* is the number of eggs per unit of weight, while *total fecundity* is the number of eggs laid during the lifetime of the female. This plan refers to fecundity as the number of eggs per size (length and weight) of female.

where K = Fulton-type condition, W = weight in grams, and L = length in millimeters. The constant 100,000 is a scaling constant used to convert small decimals to mixed numbers so that the numbers can be more easily comprehended.

Smolts

Abundance:

Abundance of smolts is an estimate of the total number of smolts produced within a watershed or basin. The estimate should be for an entire population or subpopulation.

Condition:

The Fulton-type condition factor describes the well-being of smolts within a population or subpopulation.

Genetics:

Genetic characterization (via DNA microsatellites) describes within- and between-population genetic variability of smolts.

Macroinvertebrates

Transport:

The plan includes export of invertebrates (aquatic and terrestrial) and coarse organic detritus from headwaters to habitats downstream as an important attribute of productivity. The movement of prey items and organic detritus among habitats has a strong influence on fish populations, food webs, community dynamics, and ecosystem processes (Wipfli and Gregovich 2002).

Composition:

The plan includes benthic macroinvertebrate composition as an important indicator of aquatic invertebrates in streams. Benthic macroinvertebrate assemblages in streams reflect overall biological integrity of the benthic community. Because benthic communities respond to a wide array of stressors in different ways, it is often possible to determine the type of stress that has affected a macroinvertebrate community.

7.2 Physical/Environmental Variables

The physical/environmental variables that will be measured in the Upper Columbia Basin can be grouped into seven general categories: water quality, habitat access, habitat quality, channel condition, riparian condition, flow/hydrology, and watershed condition. Each of these categories consists of one or more indicator variables (Table 9). In sum, these categories and their associated indicators address watershed process and "input" variables (e.g., artificial physical barriers, road density, and other anthropogenic disturbances) as well as "outcome" variables (e.g., temperature, sediment, woody debris, pools, riparian habitat, etc.), as outlined in Hillman and Giorgi (2002) and the Action Agencies/NOAA Fisheries RME Plan.

What follows is a brief description of each physical/environmental indicator variable. Section 8 identifies recommended methods for measuring each indicator. Unless indicated otherwise, most of the information presented below has been summarized in Meehan (1991), MacDonald et al. (1991), Armantrout (1998), Bain and Stevenson (1999), OPSW (1999), Hillman and Giorgi (2002), and the Action Agencies/NOAA Fisheries RME Plan (2003).

Water Quality

Water Temperature:

The plan includes two temperature metrics that will serve as specific indicators of water temperature: maximum daily maximum temperature (MDMT) and maximum weekly maximum temperature (MWMT). MDMT is the single warmest daily maximum water temperature recorded during a given year or survey period. MWMT is the mean of daily maximum water temperatures measured over the warmest consecutive seven-day period. MDMT is measured to establish compliance with the short-term exposure to extreme temperature criteria, while MWMT is measured to establish compliance with mean temperature criteria.

Turbidity:

The plan includes turbidity as the one sediment-related specific indicator under water quality. Turbidity refers to the amount of light that is scattered or absorbed by a fluid. Suspended particles of fine sediments often increase turbidity of streams. However, other materials such as finely divided organic matter, colored organic compounds, plankton, and microorganisms can also increase turbidity of streams.

Contaminants and Nutrients:

The plan includes five specific indicators associated with contaminants and nutrients: conductivity, pH, dissolved oxygen (DO), nitrogen, and phosphorus. Most of these indicators are commonly measured because of their sensitivity to land-use activities, municipal and industrial pollution, and their importance in aquatic ecosystems.

Table 9. A "core" list of physical/environmental indicator variables to be monitored within subbasins in the Upper Columbia Basin. Table is modified from Action Agencies/NOAA Fisheries RME Plan (2003).

General characteristics	Specific indicators[1]
Water Quality	MWMT and MDMT
	Turbidity
	Conductivity
	pH
	Dissolved oxygen
	Nitrogen
	Phosphorus
Habitat Access	Road crossings
	Diversion dams
	Fishways
Habitat Quality	Dominant substrate
	Embeddedness
	Depth fines
	LWD (pieces/km)
	Pools (pools/km)
	Residual pool depth
	Fish cover
	Side channels and backwaters
Channel condition	Stream gradient
	Width/depth ratio
	Wetted width
	Bankfull width
	Bank stability
Riparian Condition	Riparian structure
	Riparian disturbance
	Canopy cover
Flows and Hydrology	Streamflow
Watershed Condition	Watershed road density
	Riparian-road index
	Land ownership
	Land use

[1] Other indicators can be measured depending on the objectives of the study. For example, various metals and pollutants, herbicides and pesticides, thalweg profile, presence of livestock, artificial instream structures, bedload, etc. can be measured at each sampling site.

The plan included conductivity, pH, and DO because these parameters are often incorporated into water quality monitoring programs (e.g., OPSW 1999; Bilhimer et al. 2003). Conductivity (or specific conductance) refers to the ability of water to conduct an electric current. The conductivity of water is a function of water temperature and the concentration of dissolved ions. It is measured as micromhos/centimeter (µmhos/cm).[35]

pH is defined as the concentration of hydrogen ions in water (moles per liter). It is a measure of how acidic or basic water is—it is not a measure of acidity or alkalinity (acidity and alkalinity are measures of the capacity of water to neutralize added base or acid, respectively). The logarithmic pH scale ranges from 0 to 14. Pure water has a pH of 7, which is the neutral point. Water is acidic if the pH value is less than 7 and basic if the value is greater than 7.

DO concentration refers to the amount of oxygen dissolved in water. Its concentration is usually measured in mg per liter (mg/L). The capacity of water to hold oxygen in solution is inversely proportional to the water temperature. Increased water temperature lowers the concentration of DO at saturation. Respiration (both plants and animals) and biochemical oxygen demand (BOD) are the primary factors that reduce DO in water. Photosynthesis and dissolution of atmospheric oxygen in water are the major oxygen sources.

The plan includes nitrogen and phosphorus as indicators of nutrient loading in streams. Nitrogen in aquatic ecosystems can be partitioned into dissolved and particulate nitrogen. Most water quality monitoring programs focus on dissolved nitrogen, because it is more readily available for both biological uptake and chemical transformations. Both dissolved and particulate nitrogen can be separated into inorganic and organic components. The primary inorganic forms are ammonia (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-). Nitrate is the predominant form in unpolluted waters. This plan calls for the measurement of ammonia, nitrate/nitrites, and total nitrogen.

Phosphorus can also be separated into two fractions, dissolved and particulate. Dissolved phosphorus is found almost exclusively in the form of phosphate ions (PO_4^{-3}), which bind readily with other chemicals. There are three main classes of phosphate compounds: orthophosphates, condensed phosphates, and organically-bound phosphates. Each can occur as dissolved phosphorus or can be bound to particulate matter. In general, biota use only orthophosphates. Total phosphorus and orthophosphates will be measured under this plan.

Habitat Access

Artificial Physical Barriers:

The plan includes three specific indicators associated with artificial physical barriers: road crossings (culverts), dams, and fishways. Roads and highways are common in the Upper Columbia River Basin and where they intersect streams they may block fish passage. Culverts can block passage of fish particularly in an upstream direction (WDFW 2000). In several

[35] Conductivity may also be reported in millisiemens/meter, where 1 millisiemen/m equals 0.1 µmhos/cm.

cases, surveys have shown a difference in fish populations upstream and downstream from existing culverts, leading to the conclusion that free passage is not possible (Clay 1995). Dams and diversions that lack fish passage facilities can also block fish passage. Unscreened diversions may divert migrating fish into ditches and canals. Entrained fish can end in irrigated fields and orchards. Fishways are man-made structures that facilitate passage of fish through or over a barrier. Although these structures are intended to facilitate passage, they may actually impede fish passage (Clay 1995; WDFW 2000).

Habitat Quality

Substrate:

The Plan includes three specific indicators of substrate: dominant substrate, embeddedness, and depth fines. Dominant substrate refers to the most common particle size that makes up the composition of material along the streambed. This indicator describes the dominant material in spawning and rearing areas. Embeddedness is a measure of the degree to which fine sediments surround or bury larger particles. This measure is an indicator of the quality of over-wintering habitat for juvenile salmonids. Depth fines refer to the amount of fine sediment (<0.85 mm) within the streambed. Depth fines will be estimated at a depth of 15-30 cm (6-12 inches) within spawning gravels.

Large Woody Debris:

The plan includes the number of pieces of large woody debris (LWD) per stream kilometer as the one specific indicator of LWD in streams. LWD consists of large pieces of relatively stable woody material located within the bankfull channel and appearing to influence bankfull flows. LWD is also referred to as large organic debris (LOD) and coarse woody debris (CWD). LWD can occur as a single piece (log), an aggregate (two or more clumped pieces, each of which qualifies as a single piece), or as a rootwad.

The definition of LWD differs greatly among institutions. For example, NMFS (1996) defined LWD east of the Cascade Mountains as any log with a diameter greater than 30 cm (1 ft) and a length greater than 10.6 m (35 ft). Armantrout (1998) and BURPTAC (1999) defined LWD as any piece with a diameter >10 cm and a length > 1 m. Schuett-Hames et al. (1994) defined it as any piece with a diameter >10 cm and a length >2 m, while Overton et al. (1997) defined LWD as any piece with a diameter >10 cm and a length >3 m or two-thirds of the wetted stream width. Crews on the Wenatchee National Forest currently define LWD as any piece with a diameter >15 cm and a length >6 m. Because of the wide range of definitions, this plan recommends that LWD be placed within three size categories: >10-cm diameter x >1 m long; >15-cm diameter x >6 m long; and >30-cm diameter x >3 m long. By counting the number of pieces of LWD within each category, the plan will satisfy the requirements of the Forest Service, PIBO, and other institutional needs. This will also allow one to assess the association between different size categories of wood and fish production.

Pool Habitat:

The plan includes two specific indicators associated with pool habitat: number of pools per kilometer and residual pool depth. A pool is slow-water habitat with a gradient less than 1% that is normally deeper and wider than aquatic habitats upstream and downstream from it (Armantrout 1998). To be counted, a pool must span more than half the wetted width, include the thalweg, be longer than it is wide, and the maximum depth must be at least 1.5 times the crest depth. Plunge pools are included in this definition even though they may not be as long as they are wide. Residual pool depth refers to the maximum depth of a pool if there is little or no flow in the channel. It is calculated as the difference between the maximum pool depth and the maximum crest depth (Overton et al. 1997).

Fish Cover:

Fish cover consists of such things as algae, macrophytes, woody debris, overhanging vegetation, undercut banks, large substrate, and artificial structures that offer concealment cover for fish and macroinvertebrates. This information is used to assess habitat complexity, fish cover, and channel disturbance.

Off-Channel Habitat:

Off-channel habitat consists of side-channels, backwater areas, alcoves or sidepools, off-channel pools, off-channel ponds, and oxbows. A side channel is a secondary channel that contains a portion of the streamflow from the main or primary channel. Backwater areas are secondary channels in which the inlet becomes blocked but the outlet remains connected to the main channel. Alcoves are deep areas along the shoreline of wide and shallow stream segments. Off-channel pools occur in riparian areas adjacent to the stream channels and remain connected to the channel. Off-channel ponds are not part of the active channel but are supplied with water from over bank flooding or through a connection with the main channel. These ponds are usually located on flood terraces and are called wall-based channel ponds when they occur near the base of valley walls. Finally, oxbows are bends or meanders in a stream that become detached from the stream channel either from natural fluvial processes or anthropogenic disturbances.

Channel Condition

Stream gradient:

Stream gradient is the slope (change in vertical elevation per unit of horizontal distance) of the water surface within a site or reach. Although gradient is not usually affected by land-use activities, it is a major classification variable that indicates potential water velocities and stream power, which in turn control aquatic habitat and sediment transport within the reach. It is also an index of habitat complexity, as reflected in the diversity of water velocities and sediment sizes within the stream reach.

Width/Depth Ratio:

The width/depth ratio is an index of the cross-section shape of a stream channel at bankfull level. The ratio is a sensitive measure of the response of a channel to changes in bank conditions. Increases in width/depth ratios, for example, indicate increased bank erosion, channel widening, and infilling of pools. Because streams almost always are several times wider than they are deep, a small change in depth can greatly affect the width/depth ratio.

Wetted Width:

Wetted width is the width of the water surface measured perpendicular to the direction of flow. Wetted width is used to estimate water surface area, which is then used to calculate the density (i.e., number of fish divided by the water surface area sampled)[36] of fish within the site or reach.

Bankfull Width:

Bankfull width is the width of the channel (water surface) at the bankfull stage, where bankfull stage corresponds to the channel forming discharge that generally occurs within a return interval from 1.4 to 1.6 years and may be observed as the incipient elevation on the bank where flooding begins. There are several indicators that one can use to identify bankfull stage. The active floodplain is the best indicator of bankfull stage. It is the flat, depositional surface adjacent to many stream channels. These are most prominent along low-gradient, meandering reaches, but are often absent along steeper mountain streams. Where floodplains are absent or poorly defined, other useful indicators may serve as surrogates to identify bankfull stage (Harrelson et al. 1994). Those include:

- The height of depositional features (especially the top of the pointbar, which defines the lowest possible level for bankfull stage;
- A change in vegetation (especially the lower limit of perennial species);
- Slope or topographic breaks along the bank;
- A change in the particle size of bank material, such as the boundary between coarse cobble or gravel with fine-grained sand or silt;
- Undercuts in the bank, which usually reach an interior elevation slightly below bankfull stage; and
- Stain lines or the lower extent of lichens on boulders.

Streambank Condition:

The plan includes streambank stability as the one specific indicator of streambank condition. Streambank stability is an index of firmness or resistance to disintegration of a bank based on the percentage of the bank showing active erosion (alteration) and the presence of protective

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36 By definition, the measure of the number of fish per unit area is called "crude density" (Smith and Smith 2001). However, not all of the water surface area provides suitable habitat for fish. Density measured in terms of the amount of area suitable as living space is "ecological density."

vegetation, woody material, or rock. A stable bank shows no evidence of breakdown, slumping, tension cracking or fracture, or erosion (Overton et al. 1997). Undercut banks are considered stable unless tension fractures show on the ground surface at the bank of the undercut.

Riparian Condition

Riparian structure:

Riparian structure describes the type and amount of various types of vegetation within the riparian zone. Information on riparian structure can be used to evaluate the health and level of disturbance of the stream corridor. In addition, it provides an indication of the present and future potential for various types of organic inputs and shading.

Riparian disturbance:

Riparian disturbance refers to the presence and proximity of various types of human land-use activities within the riparian area. Activities include such things as walls, dikes, riprap, dams, buildings, pavement, roads and railroads, pipes, trash, parks, lawns, mining, agriculture, pastures, and logging. All these activities have an effect on the riparian vegetation, which in turn affects the quantity and quality of aquatic habitat for listed fish species.

Canopy cover:

Riparian canopy cover over a stream is important not only in its role in moderating stream temperatures through shading, but it also serves to control bank stability and provides inputs of coarse and fine particulate organic materials. Organics from riparian vegetation become food for stream organisms and structure to create and maintain complex channel habitat.

Flows and Hydrology

Streamflows:

The plan includes three specific indicators of streamflows: change in peak flow, change in base flow, and change in timing of flow. Peak flow is the highest or maximum streamflow recorded within a specified period of time. Base flow is the streamflow sustained in a stream channel and is not a result of direct runoff. Base flow is derived from natural storage (i.e., outflow from groundwater, large lakes, or swamps), or sources other than rainfall. Timing of flow refers to the time when peak and base flows occur and the rate of rises and falls in the hydrograph. These indicators are based on “annual” flow patterns.

Watershed Conditions

Road Density:

A road is any open way for the passage of vehicles or trains. The plan includes both road density and the riparian-road index (RRI) as indicators of roads within watersheds. Road density is an index of the total miles of roads within a watershed. It is calculated as the total length of all roads (km) within a watershed divided by the area of the watershed (km^2). The RRI is expressed as the total mileage of roads (km) within riparian areas divided by the total number of stream kilometers within the watershed (WFC 1998). For this index, riparian areas are defined as those falling within the federal buffers zones; that is, all areas within 300 ft of either side of a fish-bearing stream, within 150 ft of a permanent nonfish-bearing stream, or within the 100-year floodplain.

Watershed Disturbance:

The plan includes land ownership and land use as the two indicators of watershed disturbance. Land ownership describes the surface status of the basin. That is, it delineates the portions of the basin owned by federal, state, county, tribal, and private entities. Land use, on the other hand, delineates the portions of the basin that are subject to specific land uses, such as urban, agriculture, range, forest, wetlands, etc.

*7.3 **Recommended Indicators***

As noted earlier, the biological and physical/environmental indicators identified in this section represent a "core" list of variables that will be measured in subbasins in the Upper Columbia Basin. This plan does not preclude the investigator from measuring other indicator variables. Which variables will be measured depends on the type of monitoring (status/trend vs. effectiveness), the target fish species, and the type of tributary action implemented. Identified below are the appropriate indicators for each type of monitoring.

Effectiveness Monitoring—This plan does not recommend that all indicators listed in Tables 8 and 9 be measured for each tributary action. Different biological indicators will be measured depending on the fish species of interest (Table 10). All biological indicators identified in Table 8 will be measured for actions that affect anadromous species (spring chinook, summer/fall chinook, steelhead, and sockeye salmon). For resident species (bull trout and cutthroat trout), however, indicators related to smolts and fecundity will not be measured.

The plan recommends that only those physical/environmental indicators that are linked directly to the proposed action be measured. In other words, the most useful indicators are likely to be those that represent the first links of the cause-and-effect chain. Because different projects have different objectives and desired effects, the investigator only needs to measure those indicators directly influenced on the chain of causality between the habitat action and the effect (Table 11). This approach differs from the Action Agencies/NOAA Fisheries Plan, which requires all indicators be measured, regardless of the type of habitat action implemented.

<u>Status/Trend Monitoring</u>—All physical/environmental indicators identified in Table 9 will be measured as part of status/trend monitoring within the five monitoring zones (see Section 2) in the Upper Columbia Basin. In contrast, different biological indicators will be measured depending on the target fish species (Table 10). As with effectiveness monitoring, all biological indicators identified in Table 8 will be measured for anadromous species. Indicators related to smolts and fecundity will not be measured for resident species.

Table 10. Biological indicator variables that will be measured (marked with an "X") for anadromous (spring chinook, summer/fall chinook, steelhead, and sockeye salmon) and resident (bull trout and cutthroat trout) fish species during status/trend and effectiveness monitoring in subbasins in the Upper Columbia Basin.

General characteristics	Specific indicators	Anadromous species	Resident species
Adults	Escapement/Number	X	X
	Age structure	X	X
	Size	X	X
	Sex ratio	X	X
	Origin (hatchery or wild)	X	X
	Genetics	X	X
	Fecundity	X	
Redds	Number	X	X
	Distribution	X	X
Parr/Juveniles	Abundance	X	X
	Distribution	X	X
	Size	X	X
Smolts	Number	X	
	Size	X	
	Genetics	X	
Macroinvertebrates	Transport	X	X
	Composition	X	X

Table 11. Rankings of the usefulness of physical/environmental indicators to monitoring effects of different tributary habitat actions. Rankings vary from 1 = highly likely to be useful; 2 = moderately likely to be useful; and 3 = unlikely to be useful or little relationship, although the indicator may be useful under certain conditions or may help interpret data from a primary indicator. Table is modified from Hillman and Giorgi (2002). The different classes of habitat actions are from the Action Agencies/NOAA Fisheries RME Plan.

General characteristics	Specific indicators	Different classes of habitat actions							
		Diversion screens	Barrier removal	Sediment reduction	Water quality improvement	Nutrient enhancement	Instream flows	Riparian habitat	Instream structure
Water quality	MWMT/MDMT	3	2	3	1	2	1-2	1	3
	Turbidity	3	1-2	1	1	1	1-2	2	3
	Conductivity	3	2	2	1	1	2	2	3
	pH	3	3	3	1	1	3	2-3	3
	DO	3	2-3	2-3	1	1	1-2	2-3	3
	Nitrogen	3	3	3	1	1	3	2	3
	Phosphorus	3	3	3	1	1	3	2	3
Habitat access	Road crossings	3	1	3	3	3	3	3	3
	Diversion dams	1-2	1	3	3	3	2	3	3
	Fishways	2-3	1	3	3	3	3	3	3
Habitat quality	Dominant substrate	3	2	1	3	3	1-2	2	1-2
	Embeddedness	3	1-2	1	1-2	3	1-2	2	1-2
	Depth fines	3	1-2	1	1-2	2	2	2	1-2
	LWD	3	3	3	3	3	2	1	1
	Pools	3	1-2	1-2	3	3	1-2	1-2	1
	Residual pool depth	3	1-2	1	3	3	1	1-2	1
	Fish cover	3	2	1	1-2	1-2	1	1-2	1
	Off-channel habitat	3	2	2	3	3	1	1-2	1
Channel condition	Stream gradient	2	2	2	2	2	2	2	2
	Width/depth	3	1-2	1-2	3	3	1-2	1-2	1
	Wetted width	3	1-2	1-2	3	3	1-2	1-2	1
	Bankful width	3	1-2	1-2	3	3	1-2	1-2	1
	Bank stability	3	2	1-2	3	3	2	1	1
Riparian condition	Riparian structure	3	3	2	2-3	3	2	1	1-2
	Riparian disturbance	3	3	2	2-3	3	2	1	1-2
	Canopy cover	3	3	2	2-3	3	2	1	1-2
Flows/hydrology	Streamflows	3	1-2	3	3	3	1	2	1-2
Watershed condition	Road density	3	3	1-2	2	3	2-3	2-3	2
	Riparian-road index	3	3	1-2	2	3	2-3	1	2
	Land ownership	2	2	1	1	2-3	1	1	2
	Land use	1-2	1-2	1	1	2-3	1	1	2

SECTION 8: MEASURING PROTOCOLS

An important component of all regional monitoring strategies (ISAB, Action Agencies/NOAA Fisheries, and SRFB) is that the same measurement method be used to measure a given indicator. The reason for this is to allow comparisons of biological and physical/environmental conditions within and among watersheds and basins.[37] This section identifies methods to be used to measure biological and physical/environmental indicators. The methods identified in this plan are consistent with those described in the Action Agencies/NOAA Fisheries RME Plan and, for the most part, consistent with EMAP and SRFB protocols.

The Action Agencies/NOAA Fisheries monitoring group reviewed several publications, including the work of Johnson et al. (2001) that describe methods for measuring indicators. Not surprisingly, there can be several different methods for measuring the same variable. For example, channel substrate can be described using surface visual analysis, pebble counts, or substrate core samples (either McNeil core samples or freeze-core samples). These techniques range from the easiest and fastest to the most involved and informative. As a result, one can define two levels of sampling methods. Level 1 (extensive methods) involves fast and easy methods that can be completed at multiple sites, while Level 2 (intensive methods) includes methods that increase accuracy and precision but require more sampling time. The Action Agencies/NOAA Fisheries monitoring group selected primarily Level 2 methods, which minimize sampling error.

Before identifying measuring protocols, it is important to define a few terms. These terms are consistent with the Action Agencies/NOAA Fisheries RME Plan.

Reach (effectiveness monitoring) – for effectiveness monitoring, a stream reach is defined as a relatively homogeneous stretch of a stream having <u>similar</u> regional, drainage basin, valley segment, and channel segment characteristics and a repetitious sequence of habitat types. Reaches are identified by using a list of classification (stratification) variables (from Table 4). Reaches may contain one or more sites. The starting point and ending point of reaches will be measured with Global Positioning System (GPS) and recorded as Universal Transverse Mercator (UTM).

Reach (status/trend monitoring) – for status/trend monitoring, a reach is a length of stream (20 times the mean bankfull width, but not less than 150-m long or longer than 500 m)[38] selected with a systematic randomized process (GRTS design). GRTS selects a point on the "blue-line" stream network represented on a 1:100,000 scale USGS map. This point is referred to as the "X-site." The X-site identifies the midpoint of the reach. That is, the sampling reach extends a distance of 10 times the average bankfull

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[37] Bonar and Hubert (2002) and Hayes et al. (2003) review the benefits, challenges, and the need for standardized sampling.

[38] This reach length differs from Simonson et al. (1994) and Reynolds et al. (2003), which use 40x the wetted width. The use of 20x the bankfull width is consistent with AREMP and PIBO protocols. This protocol also allows one to assess channel conditions even if the channel is dry. There are naturally dry channels within the project area.

width upstream and downstream from the X-site, measured along the thalweg[39]. Biological and physical/environmental indicators are measured within the reach. The X-site and the upstream and downstream ends of the reach will be measured with GPS and recorded as UTM. For purposes of re-measurements, these points will also be photographed, marked with permanent markers (e.g., orange plastic survey stakes), and carefully identified on maps and site diagrams. Reach lengths and boundaries will be "fixed" the first time they are surveyed and they will not change over time even if future conditions change.

Site (effectiveness monitoring) – a site is an area of the effectiveness monitoring stream reach that forms the smallest sampling unit with a defined boundary. Site length depends on the width of the stream channel. Sites will be 20 times the average bankfull width with a minimum length of 150 m and a maximum length of 500 m. Site lengths are measured along the thalweg. The upstream and downstream boundaries of the site will be measured with GPS and recorded as UTM. For purposes of re-measurements, these points will also be photographed, marked with permanent markers (e.g., orange plastic survey stakes), and carefully identified on maps and site diagrams. Site lengths and boundaries will be "fixed" the first time they are surveyed and they will not change over time even if future conditions change.

Transect – a transect is a straight line across a stream channel, perpendicular to the flow, along which habitat features such as width, depth, and substrate are measured at pre-determined intervals. Effectiveness monitoring sites and status/trend monitoring reaches will be divided into 11 evenly-spaced transects by dividing the site into 10 equidistant intervals with "transect 1" at the downstream end of the site or reach and "transect 11" at the upstream end of the site or reach.

Habitat Type – Habitat types, or channel geomorphic units, are discrete, relatively homogenous areas of a channel that differ in depth, velocity, and substrate characteristics from adjoining areas. This plan recommends that the investigator identify the habitat type under each transect within a site or reach following the Level II classification system in Hawkins et al. (1993). That is, habitat will be classified as turbulent fast water, non-turbulent fast water, scour pool, or dammed pool (see definitions in Hawkins et al. 1993). By definition, for a habitat unit to be classified, it should be longer than it is wide. Plunge pools, a type of scour pool, are the exception, because they can be shorter than they are wide.

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39 "Thalweg" is defined as the path of a stream that follows the deepest part of the channel (Armantrout 1998).

8.1 Biological Indicators

This section identifies the methods and instruments that should be used to measure biological indicators. Table 12 identifies indicator variables, example protocols, and sampling frequency. The reader is referred to the cited documents for a more detailed description of each method.

Table 12. Recommended protocols and sampling frequency for biological indicator variables.

General characteristics	Specific indicators	Recommended protocol	Sampling frequency
Adults	Escapement/Number	Dolloff et al. (1996); Reynolds (1996); Van Deventer and Platts (1989)	Annual
	Age structure	Borgerson (1992)	Annual
	Size	Anderson and Neumann (1996)	Annual
	Sex ratio	Strange (1996)	Annual
	Origin (hatchery or wild)	Borgerson (1992)	Annual
	Genetics	WDFW Genetics Lab	Annual
	Fecundity	Cailliet et al. (1986)	Annual
Redds	Number	Mosey and Murphy (2002)	Annual
	Distribution	Mosey and Murphy (2002)	Annual
Parr/Juveniles	Abundance/Distribution	Dolloff et al. (1996); Reynolds (1996); Van Deventer and Platts (1989)	Annual
	Size	Anderson and Neumann (1996)	Annual
Smolts	Number	Murdoch et al. (2000)	Annual
	Size	Anderson and Neumann (1996)	Annual
	Genetics	WDFW Genetics Lab	Annual
Macroinvertebrates	Transport	Wipfli and Gregovich (2002)	Annual/Monthly
	Composition	Peck et al. (2001)[1]	Annual

[1]The Peck et al. (2001) report is a draft document, which states that it should not be cited or quoted. However, it provides an appropriate method for estimating benthic macroinvertebrate composition.

Adults

Escapement:

The plan includes escapement/number of mature adults as an important biological indicator of population health. "Total escapement" of anadromous fish into subbasins within the Upper Columbia Basin can be estimated roughly as the number of fish counted at mainstem Columbia River dams. For example, escapement of spring chinook into the Wenatchee Basin can be estimated as the difference between fish counts at Rock Island Dam and Rocky Reach

Dam (with some correction for fallback). Counts at dams should be made with video operated continuously during the upstream migration of anadromous salmonids. Counts of adults at weirs are more accurate and should be used whenever possible. This method is recommended if accurate estimates of escapements into specific watersheds are necessary.

"Spawning escapement" can be estimated as the number of redds times a "fish-per-redd" estimate. WSRFB (2003) uses 2.2 chinook per redd, assuming one redd per female. For steelhead, they assume 1.23 redds per female. A more accurate method currently used by WDFW in the Upper Columbia Basin is based on the sex ratio of broodstock (not recovered carcasses) collected randomly over the run (A. Murdoch, personal communication, WDFW). For example, if the sex ratio of a random sample of the run is 1.5:1.0, the expansion factor for the run would be 2.5 fish/redd. This method is used for all supplemented stocks within the Upper Columbia Basin. Another method, which can be used if the sex ratio is unknown, is the "Modified Meekin Method" (A. Murdoch, WDFW, personal communication). This method takes the 2.2 adults/redd (from Meekin 1967) and increases it by the proportion of jacks in the run. For example, if jacks make up 10% of the run, the modified adults/redd would be 2.42 (2.2 x 1.1 = 2.42 adults/redd). This plan recommends that spawning escapement be estimated based on sex ratios. Both total and spawning escapement will be reported as "whole" numbers.

Numbers of resident adult fish should be estimated within status/trend monitoring reaches and effectiveness monitoring sites using underwater observations (snorkeling) and electrofishing surveys. Snorkeling, which is a quick, nondestructive method that is not restricted by deep water and low conductivities,[40] is the "primary" sampling method in this plan. Snorkel surveys will follow the protocols identified in Dolloff et al. (1996). Accurate estimates of adult bull trout may require nighttime snorkeling. However, Hillman and Chapman (1996) counted more adult bull trout during the day than at night in the Blackfoot River, Montana, because adult bull trout were unable to conceal themselves, making them readily visible to snorkelers. Both daytime and nighttime surveys should be conducted for at least two years to see which survey time (daytime or nighttime) provides the best estimate of resident adult fish. For each fish observed during day or night surveys, snorkelers will estimate fish size to the nearest 2 cm and report numbers as fish/ha.

Electrofishing is the "secondary" method and will be used within a sub-sample of snorkel sites. The plan recommends that at least five randomly-selected sites (10% of the status/trend sites sampled annually) within each monitoring zone be sampled with both snorkeling and electrofishing.[41] The purpose for this is to establish a relationship between the methods and to collect fish for assessment of condition (length and weight), age, gender, and genetics.[42]

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40 Hillman and Miller (2002) reported that snorkel estimates were more accurate than electrofishing estimates in the Chiwawa River, a Wenatchee River tributary, because low conductivity (35 µmhos) in the river reduced the efficiency of electrofishing. They noted that electrofishing estimates were at best 68% of snorkel estimates.

41 Sampling within a site should occur within the same day and sites should be blocked to prevent movement into and out of the site during and between sampling.

42 Because ESA-listed species occur within monitoring areas in the Upper Columbia Basin, federal agencies may limit the amount of electrofishing that can be conducted within the basin. If electrofishing cannot be used, this plan recommends that

Electrofishing will follow the protocols outlined in Reynolds (1996). For salmonids, fork length (anterior tip to the median caudal fin rays) will be measured to the nearest 1 mm and weighed to the nearest 1 g. For all other fish, total length (anterior tip to the longest "compressed" caudal fin rays) will be measured to the nearest 1 mm and weighed to the nearest 1 g. This plan recommends the removal-depletion method of electrofishing, with at least three complete passes. Population numbers and 95% confidence intervals can be estimated with the maximum-likelihood formula (Van Deventer and Platts 1989). Numbers of fish will be reported as fish/ha.

Spawners:

The plan includes six indicators associated with the characteristics of the spawning populations: age structure, size, sex ratio, origin, genetics, and fecundity. For anadromous fish, most of these characteristics will be collected from live fish trapped at weirs or from carcasses sampled during spawning surveys. Scales will be pulled from live fish and carcasses. Scales will be read to determine age structure and origin (wild or hatchery). Presence or absence of an adipose fin will also determine origin. Age analysis will be completed following methods described by Borgerson (1992). Size will be measured to the nearest 1 mm and reported as both fork length (anterior tip to the median caudal fin rays) and hypural length (mid-eye to hypural plate) (Anderson and Neumann 1996). The latter is necessary because some carcasses will have decomposed to a point where fork length cannot be measured accurately. The gender of each fish sampled will be recorded (Strange 1996). Fecundity (total number of eggs produced by a given size female) will be estimated for fish collected for hatchery broodstock and from dead pre-spawn females collected during spawning surveys (Cailliet et al. 1986). Finally, genetic samples will be collected and analyzed according to the protocols being refined at the WDFW Genetics Lab. To avoid resampling the same carcass, the head of all sampled carcasses will be removed.

Many of the characteristics identified above for anadromous fish will be collected from resident fish during electrofishing surveys (or nighttime dip netting), collection at weirs, and during spawning surveys. Characteristics such as age structure (from scales), size (fork length or total length; mm), weight (g), origin, and genetic samples can be collected from adults trapped at weirs and during electrofishing (or nighttime dip netting) surveys. Origin can be assessed by examining fins, with hatchery fish tending to have deformed or eroded fins. Gender can be recorded for those fish found dead during spawning surveys. The protocols identified above can be used to measure characteristics of resident fish.

Redds

Abundance/Distribution:

This plan includes abundance and distribution of salmonid redds as indicators of population health. The plan calls for a complete census of redds of fall-spawning anadromous fish (e.g.,

snorkelers collect fish at night with hand-held dip nets. Using an appropriate sampling design, fish can be selected so as to not bias the sample.

chinook and sockeye salmon). For other species (e.g., steelhead and bull trout), numbers of redds will be counted annually within already-established index areas and in reaches that will be selected using probabilistic sampling (GRTS; see Section 4.4). At least 25 reaches, each 1.6-km long (1.0 mile), will be surveyed throughout the spawning period within all monitoring zones, except in the Entiat Basin. Because the spawning distribution of fish in the Entiat Basin is relatively small, each survey reach there will be 1.0-km long. As in other monitoring zones, 25 reaches will be surveyed in the Entiat Basin each year.

To assess changes in spawning distribution, a five-year rotating panel design with 25 reaches per year will be implemented (see Section 3.2). Thus, a different set of 25 reaches will be sampled each year during the first five years. Throughout the spawning period, investigators will conduct weekly redd surveys following the example of Mosey and Murphy (2002). Each week new redds will be counted, mapped, and marked.[43] Marking is needed to avoid recounting redds during subsequent surveys. Abundance of redds will be reported as the number of redds within a population or subpopulation. Abundance will also be reported as the number of redds per km within each population or subpopulation.

Parr

Abundance/Distribution:

The plan includes the abundance and distribution of juvenile fish as an indicator of population health. Juvenile numbers will be estimated with snorkeling and electrofishing within status/trend monitoring reaches and effectiveness monitoring sites. Snorkeling is the "primary" sampling method in this plan and will follow the protocols identified in Dolloff et al. (1996). Accurate estimates of juvenile bull trout may likely require nighttime snorkeling. Therefore, both daytime and nighttime surveys should be conducted for at least two years to see which survey time (daytime or nighttime) provides the best estimate of juvenile fish. For each fish observed during day or night surveys, snorkelers will estimate fish size to the nearest 2 cm and report numbers as fish/ha.

Electrofishing is the "secondary" method and will be used within a sub-sample of snorkel sites (same five sites within each monitoring zone used to sample adult fish). Electrofishing will follow the protocols outlined in Reynolds (1996). This plan recommends the removal-depletion method of electrofishing, with a minimum of three complete passes. Population numbers and 95% confidence intervals can be estimated with the maximum-likelihood formula (Van Deventer and Platts 1989). Numbers will be reported as fish/ha.

Juvenile fish collected during electrofishing (or nighttime dip netting) will be measured (see below) and at least 5,000 juvenile chinook and 5,000 steelhead within each population will be implanted with PIT tags. The sample size of 5,000 for anadromous populations in the Upper Columbia Basin was estimated by the Action Agencies/NOAA Fisheries Monitoring Group.

[43] Because of inclement weather and high streamflows, surveys for steelhead redds may not be made on regularly timed intervals. Adjusting surveys to fit environmental conditions may be necessary.

This is a very rough estimate of the minimum number needed to estimate life-stage survival rates.

Condition:

The plan includes Fulton-type condition as the metric for well-being of juvenile fish. Juvenile fish collected during electrofishing and with rotary traps (or other appropriate traps) will be measured (fork length for salmonids and total length for all other fish; mm) and weighed (g). Fulton-type condition will be estimated with methods described in Anderson and Neumann (1996).

Smolts

Abundance:

Abundance of smolts is an estimate of the total number of smolts produced within a watershed or basin. Investigators will use floating screw traps (or other appropriate traps depending on stream conditions) to collect downstream migrating smolts. Traps will operate for at least the entire period of the smolt migration. Trapping efficiency, based on mark/recapture will be estimated throughout the trapping period. Methods for operating the trap, estimating efficiency, and the frequency at which efficiency tests are conducted are described in Murdoch et al. (2000). Numbers of smolts will be reported for populations or subpopulations.

Condition:

The Fulton-type condition factor describes the well-being of smolts within a population or subpopulation. Smolts collected with traps will be measured (fork length; mm) and weighed (g). Fulton-type condition will be estimated with methods described in Anderson and Neumann (1996).

Genetics:

Genetic characterization (via DNA microsatellites) describes within- and between-population genetic variability of smolts. DNA samples from a systematic sample of smolts[44] will be collected and analyzed according to the protocols being refined at the WDFW Genetics Lab.

Macroinvertebrates

Transport:

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44 The total number of smolts needed to characterize within and between-population genetic variability is presently unknown. Therefore, "**k**" (i.e., the k^{th} smolt sampled) remains undefined.

The plan includes export of invertebrates (aquatic and terrestrial) and coarse organic detritus from headwaters to downstream habitats as an attribute of freshwater productivity. Investigators will follow the methods described in Wipfli and Gregovich (2002) to assess energy sources for downstream food webs. The method requires the placement of sampling stations near tributary junctions of fishless and fish-bearing streams. Specially-modified drift nets (Wipfli and Gregovich 2002) will capture invertebrates and particulate organic matter. Invertebrate transport will be reported as numbers per day and dry mass (mg) per day. Debris transport will be reported as dry mass (g) per m^3 water and dry mass (g) per day. This work will be conducted monthly.

Compostion:

The plan also includes benthic macroinvertebrate composition as an attribute of freshwater productivity. Investigators will follow the "targeted-riffle-sample" method described in Peck et al. (2001). This method requires at least eight independent kick-net[45] samples from riffles within sites or reaches. The eight samples are combined, sieved to remove debris and sediments, and then processed in a lab. Samples will be analyzed according to the River InVertebrate Prediction And Classification System (RIVPACS) (Hawkins et al. 2001).

8.2 <u>Physical/Environmental Indicators</u>

This section identifies the methods and instruments needed to measure physical/environmental indicators. Table 13 identifies indicator variables, example protocols for measuring indicators, and sampling frequency. There is no space here to describe each method in detail; therefore, the reader is referred to the cited documents for detailed descriptions of methods and measuring instruments. Importantly, and for obvious reasons, all habitat sampling would follow fish sampling (snorkeling and electrofishing) within status/trend monitoring reaches and effectiveness monitoring sites.

Water Quality

Water Temperature:

The plan includes two temperature metrics that will serve as specific indicators of water temperature: maximum daily maximum temperature (MDMT) and maximum weekly maximum temperature (MWMT). Data loggers can be used to measure MWMT and MDMT. Zaroban (2000) describes pre-placement procedures (e.g., selecting loggers and calibration of loggers), placement procedures (e.g., launching loggers, site selection, logger placement, and locality documentation), and retrieval procedures. This manual also provides standard methods for conducting temperature-monitoring studies associated with land-management activities and for characterizing temperature regimes throughout a watershed.

[45] The kick net is a D-frame sampler with a 30.5-cm wide base, a muslin bottom panel, a net with a mesh size of 500 µm, and a detachable bucket with a 500-µm mesh end (see Figure 11-1 in Peck et al. 2001).

The number of loggers used will depend on the number of reaches and treatment and control sites. For monitoring the effectiveness of actions that affect water temperatures, at a minimum, at least one logger will measure water temperatures at the downstream end and one at the upstream end of each reach that contains treatment or control sites. Additional measurements may be needed within reaches (at treatment sites) depending on the objectives and scope of the study. For status/trend monitoring, one logger will be placed at the downstream end of the distribution of each population or subpopulation.

Data loggers will record temperatures hourly to the nearest 0.1˚C throughout the year. Investigators will also measure water temperatures with a calibrated thermometer at each site or reach sampled for fish. These snap-shot measurements will be used to assess the reliability of fish sampling techniques.[46]

Turbidity:

The plan includes turbidity as the one sediment-related specific indicator under water quality. Investigators will measure turbidity with monitoring instruments calibrated on the nephelometric turbidity method (NTUs). Chapter 11 in OPSW (1999) provides a standardized method for measuring turbidity, data quality guidelines, equipment, field measurement procedures, and methods to store and analyze turbidity data.

For monitoring the effectiveness of actions that affect turbidity, at a minimum, turbidity will be measured at the downstream end and at the upstream end of each reach that contains treatment or control sites. Additional instruments may be needed to measure turbidity at treatment sites within reaches depending on objectives and scope of the study. For status/trend monitoring, one instrument will be placed at the downstream end of the distribution of each population or subpopulation.

Monitoring instruments will measure turbidity hourly to the nearest 1 NTU throughout the year. Investigators will also measure turbidity with a portable turbidimeter within each site or reach sampled for fish. Because both electrofishing and snorkeling are affected by turbidity, these snap-shot measurements will be used to assess the reliability of the fish sampling techniques.

[46] Both electrofishing and snorkeling are affected by water temperature. Hillman et al. (1992) demonstrated that snorkel counts are less reliable at cold water temperatures.

Table 13. Recommended protocols and sampling frequency of physical/environmental indicator variables. Table is modified from Action Agencies/NOAA Fisheries RME Plan.

General characteristics	Specific indicators	Recommended protocols	Sampling frequency
Water Quality	MWMT/MDMT	Zaroban (2000)	Annual/Continuous (hourly)
	Turbidity	OPSW (1999)	Annual/Continuous (hourly)
	Conductivity	OPSW (1999)	Annual/Continuous (hourly)
	pH	OPSW (1999)	Continuous (hourly)
	DO	OPSW (1999)	Continuous (hourly)
	Nitrogen	OPSW (1999)	Seasonal (4/yr)
	Phosphorus	OPSW (1999)	Seasonal (4/yr)
Habitat Access	Road crossings	Parker (2000); WDFW (2000)	Annual
	Diversion dams	WDFW (2000)	Annual
	Fishways	WDFW (2000)	Annual
Habitat Quality	Dominant substrate	Peck et al. (2001)	Annual
	Embeddedness	Peck et al. (2001)	Annual
	Depth fines	Schuett-Hames (1999)	Annual
	LWD (pieces/km)	BURPTAC (1999)	Annual
	Pools per kilometer	Hawkins et al. (1993); Overton et al. (1997)	Annual
	Residual pool depth	Overton et al. (1997)	Annual
	Fish cover	Peck et al. (2001)	Annual
	Off-channels habitats	WFPB (1995)	Annual
Channel condition	Stream gradient	Peck et al. (2001)	Annual
	Width/depth ratio	Peck et al. (2001)	Annual
	Wetted width	Peck et al. (2001)	Annual
	Bankfull width	Peck et al. (2001)	Annual
	Bank stability	Moore et al. (2002)	Annual
Riparian Condition	Structure	Peck et al. (2001)	Annual
	Disturbance	Peck et al. (2001)	Annual
	Canopy cover	Peck et al. (2001)	Annual
Flows and Hydrology	Streamflow	Peck et al. (2001)	Continuous
Watershed Condition	Watershed road density	WFC (1998); Reeves et al. (2001)	5 years
	Riparian-road index	WFC (1998)	5 years
	Land ownership	n/a	5 years
	Land use	Parmenter et al. (2003)	5 years

Contaminants and Nutrients:

The plan includes five specific indicators associated with contaminants and nutrients: conductivity, pH, dissolved oxygen (DO), nitrogen, and phosphorus. OPSW (1999) identifies standard methods for measuring conductivity (Chapter 9), pH (Chapter 8), DO (Chapter 7)[47], and nitrate/nitrites, ammonium, total nitrogen, total phosphorous, and orthophosphates (Chapter 10). OPSW (1999) also includes criteria for data quality guidelines, equipment, field-measurement procedures, and methods to store and analyze water quality data.

For monitoring the effectiveness of actions that affect these parameters, at a minimum, conductivity, pH, and DO will be measured hourly at the downstream end and upstream end of each reach that contains treatment or controls sites. At a minimum, nitrogen and phosphorus will be measured seasonally (four times per year; February, May, August, and November) at both ends of a reach. Additional measurements (both in time and space) may be needed at treatment and control sites depending on objectives and scope of the study. For status/trend monitoring, conductivity, pH, and DO will be collected hourly and nitrogen and phosphorus seasonally (February, May, August, and November) at the downstream end of the distribution of each population or subpopulation.

Water quality instruments can be used to monitor conductivity, pH, and DO. These indicators will be measured hourly throughout the year. Conductivity will be measured to the nearest 0.1 µmhos/cm, pH to the nearest 0.1 unit, and DO to the nearest 0.1 mg/L. Indicators associated with nitrogen and phosphorus will be collected as grab samples at least four times per year (February, May, August, and November). Ammonia is recorded in mg NH_3-N/L, nitrite in mg NO_2^--N/L, nitrate in mg NO_3^--N/L, and total nitrogen in mg N/L. Both total phosphorus and orthophosphates are recorded in mg P/L. Because conductivity affects electrofishing success, a portable conductivity meter will be used to measure conductivity within each site or reach sampled for fish.

Habitat Access:

Artificial Physical Barriers:

The plan includes three specific indicators associated with artificial physical barriers: road crossings (culverts), dams, and fishways. Remote sensing (aerial photos, LANDSAT ETM+, or both) will be used as a first cut to identify possible barriers. Investigators will then conduct field surveys using the WDFW (2000) protocols to evaluate possible barriers. The WDFW (2000) manual provides guidance and methods on how to identify, inventory, and evaluate culverts, dams, and fishways that impede fish passage. WDFW (2000) also provides methods for estimating the potential habitat gained upstream from barriers, allowing prioritization of restoration projects. The manual by Parker (2000) focuses on culverts and assesses

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[47] Although OPSW (1999) indicates that the Winkler Titration Method is the most accurate method for measuring DO concentration, this plan recommends the use of an electronic recording device with an accuracy of at least ±0.2 mg/L.

connectivity of fish habitats on a watershed scale. These manuals can be used to identify all fish passage barriers within monitoring reaches. Assessment of fish passage barriers will occur once annually during base-flow conditions.

Habitat Quality

Substrate:

The plan includes three specific indicators of substrate: dominant substrate, depth fines, and embeddedness. Peck et al. (2001) provides a method for describing substrate composition within each site or reach. Substrate composition will be assessed within the bankfull width (not wetted width) along the "channel bottom" in the site or reach, regardless if the channel is wet or dry. Investigators will measure substrate at five equidistant points along each of the 11 "regular" transects, plus along an additional 10 transects placed mid-way between each of the 11 transects. The investigator will visually estimate the size of a particle at each of the points along the 21 transects (total sample size of 105 particles). Classification of bed material by particle size will follow Table 14. For each sampling site or reach, the investigators will report the dominant substrate size. Additionally, investigators can calculate reach-level means, standard deviations, and percentiles for substrate size classes (see methods in Kaufmann et al. 1999). Substrate will be characterized annually during base-flow conditions.

Table 14. Classification of stream substrate channel materials by particle size. Table is from Peck et al. (2001).

Class name	Size range (mm)	Description
Bedrock (smooth)	>4,000	Smooth surface rock larger than a car
Bedrock (rough)	>4,000	Rough surface rock larger than a car
Hardpan		Firm, consolidated fine substrate
Boulders	>250-4,000	Basketball to car size
Cobbles	>64-250	Tennis ball to basketball size
Gravel (coarse)	>16-64	Marble to tennis ball size
Gravel (fine)	>2-16	Ladybug to marble size
Sand	>0.06-2	Smaller than ladybug size, but visible as particles
Fines	<0.06	Silt, clay, muck (not gritty between fingers)

Investigators will measure depth fines with McNeil core samplers.[48] Methods for conducting core sampling can be found in Schuett-Hames et al. (1999). For effectiveness monitoring,

48 Core sampling can be conducted in streams with shallow spawning areas. Spawning areas that are too small or too deep cannot be sampled effectively with core samplers (see Schuett-Hames et al. 1999). In addition, because of the extensive

four randomly-selected samples (subsamples) will be taken from each spawning area (pool tailout or riffle) within each site (samples will not be taken from sites that lack spawning areas). For status/trend monitoring, four subsamples from one randomly-selected spawning area within "accessible" (see footnote 48) reaches will be collected. Where possible, core samples will also be collected in spawning areas at or near the long-term, water-quality monitoring sites. These long-term monitoring sites will be located at the downstream end of the distribution of populations or subpopulations. The volumetric method will be used for processing samples sorted via a standard set of sieves. The volumetric method measures the milliliters (to the nearest 1 ml) of water displaced by particles of different size classes. At a minimum, the following sieves will be used to sort particles: 64.0 mm, 16.0 mm, 6.4 mm, 4.0 mm, 1.0 mm, 0.85 mm, 0.50 mm, 0.25 mm, and 0.125 mm. Fines will be measured once annually during base-flow conditions.

Peck et al. (2001) also provides methods for measuring embeddedness. As with substrate composition, embeddedness will be assessed within the bankfull width (not wetted width) along the "channel bottom," regardless if the channel is dry or wet. Embeddedness will be estimated at five equidistant points along the 11 "regular" transects (total sample size of 55). At each sampling point along a transect, all particles larger than sand within a 10-cm diameter circle will be examined for embeddedness. Embeddedness is the fraction of particle surface that is surrounded by sand or finer sediments. By definition, sand and fines are embedded 100%, while bedrock is embedded 0%. Investigators will record the average percent (%) embeddedness of particles in the 10-cm circle. Embeddedness will be measured once annually during base-flow stream conditions.

Large Woody Debris:

Large woody debris (LWD) consists of large pieces of relatively stable woody material located within the bankfull channel and appearing to influence bankfull flows. Investigators will simply count the number of LWD pieces within sites or reaches (wet or dry) in forested streams (e.g., see BURPTAC 1999). Pieces are counted throughout the entire reach or site, not just along transects. LWD will be divided into three size categories: >10 cm x >1 m; >15 cm x >6 m; and >30 cm x >3 m (diameter x length, respectively). Investigators will record the count of LWD pieces within each size category. This indicator will be measured once annually during base-flow conditions.

Pool Habitat:

The plan includes two indicators associated with pool habitat: number of pools per km and residual pool depth. Investigators will count the number of pools throughout a monitoring reach or site. To be counted, a pool must span more than half the wetted width, include the thalweg, be longer than it is wide, and the maximum depth must be at least 1.5 times the crest depth. Plunge pools are included in this definition even though they may not be as long as they are wide. Hawkins et al. (1993) and Overton et al. (1997) provide good descriptions of

equipment needed to conduct substrate core sampling, core sampling within sites located long distances from access points (>0.75-1.0 km) may be skipped. Every effort, however, should be made to collect the data.

the various types of pools and how to identify them. Pools are counted throughout the entire reach or site, not just along transects.

Overton et al. (1997) describe methods for measuring residual pool depth. Residual pool depth is simply the difference between the maximum pool depth and the crest depth. Measurements differ, however, depending on the type of pool. For dammed pools, residual depth is the difference between maximum pool depth and maximum crest depth at the head of the pool. For scour pools, on the other hand, residual pool depth is the difference between maximum pool depth and maximum crest depth at the tail of the pool. Depths are measured to the nearest 0.01 m. For effectiveness monitoring, residual pool depth will be measured in all pools within treatment and control sites. For status/trend monitoring, residual pool depth will be measured in all pools within a reach. Both pool per km and residual pool depth will be measured once annually during base-flow conditions.

Fish Cover:

Fish cover is measured within the wetted width of a site or reach. Fish cover is not measured in dry side channels. It is visually estimated at 5 m upstream and 5 m downstream (10-m total length) at each of the 11 transects following procedures described in Peck et al. (2001). Cover types consist of filamentous algae, aquatic macrophytes (including wetland grasses), large woody debris, brush and small woody debris, in-channel live trees or roots, overhanging vegetation (within 1 m of the water surface but not in the water), undercut banks, boulders, and artificial structures (e.g., concrete, cars, tires, rip-rap, etc.). For each cover type, the investigator will record areal cover as: 0 (zero cover), 1 (<10% cover), 2 (10-40% cover), 3 (40-75% cover), and 4 (>75% cover). Fish cover will be estimated annually during base-flow conditions.

Off-Channel Habitat:

Off-channel habitat consists of side-channels, backwater areas, alcoves or sidepools, off-channel pools, off-channel ponds, and oxbows. Following the definitions for each off-channel habitat type (see Section 7), the investigator will enumerate the number of each type of off-channel habitat within a monitoring reach or site. Off-channel habitats will be enumerated throughout the entire site or reach, not just along transects. In addition, investigators will measure the lengths of side channels in the site or reach. Investigators will record the number of off-channel habitat types and the lengths of side channels (measured to the nearst 0.5 m) within the site or reach. Sampling will occur once annually during base-flow conditions.

Channel Condition

Stream Gradient:

The water surface gradient or slope is an indication of potential water velocities and stream power. Water surface slope will be reported as a percentage[49] and will be measured according to the protocol described in Peck et al. (2001) with some modifications. Rather than measure percent slope directly with a clinometer or Abney level, as recommended in Peck et al. (2001), this plan calls for the measurement of water surface elevations with a hand level. That is, water surface elevation will be measured between each of the 11 "regular" transects using a hand level (5X magnifying level recommended) and a telescoping leveling rod (graduated in cm). Beginning at the downstream-end of the reach or site, water surface elevation is measured by "backsighting" downstream between transects (results in at least 10 measurements per reach or site). If a meander bend, vegetation, or some other object blocks your line-of-sight along the channel[50], it will be necessary to establish a "supplemental" point between transects. The investigator records the elevation (measured to the nearest cm) and horizontal distance between transects or supplementary points (measured to the nearest cm). Percent water surface slope is then calculated as the fall per unit distance (rise over run), times 100. Sampling will occur once annually during base-flow conditions.

Width/Depth Ratio:

The width/depth ratio is an index of the cross-section shape of a stream channel at bankfull level. The ratio is expressed as bankfull width (geomorphic term) divided by the mean cross-section bankfull depth. Peck et al. (2001) offer the recommended protocol for measuring bankfull widths and depths. This indicator will be measured at the 21 transects (includes the 11 "regular" and 10 "additional" transects) within each reach (for status/trend monitoring) or treatment and control sites (for effectiveness monitoring), regardless if the channel is wet or dry. Width and depth will be recorded to the nearest 0.1 m. Sampling will occur once annually during base-flow conditions.

Wetted Width:

Wetted width is the width of the water surface measured perpendicular to the direction of flow. Peck et al. (2001) describes the recommend method for measuring this indicator. Wetted width will be measured to the nearest 0.1 m at the 21 transects (11 "regular" and 10 "additional" transects) in each reach or treatment and control sites. Sampling will occur once annually during base-flow conditions.

Bankfull Width:

Bankfull width is the width of the channel (water surface) at bankfull stage. Peck et al. (2001) describe methods for measuring bankfull width. Bankfull width will be measured to the nearest 0.1 m at the 21 transects in each reach (for status/trend monitoring) or treatment

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49 Although this plan recommends reporting slope as a percentage, one can easily convert between percentage, decimal, and degrees with the following formulas: (1) Percent slope = slope (in decimal form) x 100; (2) Slope (in decimal form) = tan (slope in degrees); and (3) Slope (in degrees) = $\tan^{-1}$ (slope in decimal form).

50 If you have to sight across land to measure surface elevation between two transects, then you need to make supplementary measurements (do not "short-circuit" meander bends).

and control sites (for effectiveness monitoring), regardless if the channel is wet or dry. Sampling will occur once annually during base-flow conditions.

Streambank Condition:

The plan includes streambank stability as the one specific indicator of streambank condition. Moore et al. (2002) describe the recommended method for assessing stream bank stability. The method estimates the percent (%) of the lineal distance that is actively eroding at the active channel height on both sides of the transect regardless if the channels is wet or dry. 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 will be measured once annually during base-flow conditions at the 11 evenly-spaced transects within each reach (for status/trend monitoring) or treatment and control site (for effectiveness monitoring).

Riparian Condition

Structure:

Riparian structure identifies the type and amount of various kinds of riparian vegetation. Peck et al. (2001) offer methods for describing riparian structure. Riparian structure will be assessed within a 10 m x 10 m plot on both ends of each of the 11 transects, regardless if the channel is wet or dry. Within each riparian plot, the investigator will divide the vegetation into three layers: canopy layer (>5-m high), understory layer (0.5-5-m high), and the ground-cover layer (<0.5-m high). Areal cover will be estimated within each of the three vegetation layers. Aerial cover is recorded as "0" if no cover; "1" if <10% cover; "2" if 10-40%; "3" if 40-75%; or "4" if >75% cover. The type of vegetation will be described in both the canopy and understory layers. Vegetation types include deciduous, coniferous, broadleaf evergreen, mixed, and none. Kaufmann et al. (1999) describes methods for analyzing riparian structure data. This indicator will be measured once annually during base-flow conditions.

Disturbance:

Riparian disturbance will be measured as the presence and proximity of various types of human land-use activities in the riparian area. Peck et al. (2001) provide the recommended method for assessing this indicator. The presence/absence and proximity of 11 categories of human influences will be described within 5 m upstream and 5 m downstream from each of the 11 transects, regardless if the channel is wet or dry. Human influences include: (1) walls, dikes, revetments, riprap, and dams; (2) buildings; (3) pavement/cleared lot; (4) roads or railroads; (5) inlet or outlet pipes; (6) landfills or trash; (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, hay fields, or evidence of livestock, (10) logging; and (11) mining. Proximity classes include: (1) present within the defined 10 m stream segment and located in the stream or on the stream bank; (2) present within the 10 x 10 m riparian plot but away from the bank; (3) present but outside the riparian plot; and (4) not present within or adjacent to the 10 m stream segment or the riparian plot area at the transect. Kaufmann et al. (1999) describes methods for analyzing riparian disturbance data. Riparian disturbance will be measured once annually during base-flow conditions.

Canopy Cover:

Peck et al. (2001) describe the recommended method for measuring canopy cover. Canopy cover will be measured at each of the 11 equally-spaced transects in wet or dry channels using a Convex Spherical Densiometer (model B). Six measurements are collected at each transect (four measurements in four directions at mid-channel and one at each bank). The mid-channel measurements estimate canopy cover over the channel, while the two bank measurements estimate cover within the riparian zone. The two bank measurements are particularly important in wide streams, where riparian canopy may not be detected at mid-channel. The investigator records the number of grid intersection points (0-17) that are covered by vegetation at the six points along each transect. Mean densiometer readings and standard deviations are calculated according to methods described in Kaufmann et al. (1999). Canopy cover will be measured once annually during base-flow conditions.

Flows and Hydrology

Streamflows:

Changes in streamflows will be assessed by collecting flow data at the downstream end of monitoring reaches and/or at the downstream end of the distribution of each population or subpopulation. Investigators will use USGS or WDOE flow data where available to assess changes in peak, base, and timing of flows. For those streams with no USGS or State stream-gauge data, investigators will use the velocity-area method described in Peck et al. (2001) to estimate stream flows. Water velocities will be measured to the nearest 0.01 m/s with a calibrated water-velocity meter rather than the float method. Wetted width and depth will be measured to the nearest 0.1 m. Flows will be reported as m^3/s.[51]

Watershed Conditions

Road Density:

The plan includes road density and the riparian-road index (RRI) as indicators of roads within watersheds. Using remote sensing, investigators will measure the road density and riparian-road index within each watershed in which monitoring activities occur. Road density will be calculated with GIS as the total length (km) of roads within a watershed divided by the area (km^2) of the watershed. The riparian-road index will be calculated with GIS as the total kilometers of roads within riparian areas divided by the total number of stream kilometers within the watershed. WFC (1998) provides an example of calculating the riparian-road index

[51] The following formula can be used to convert cfs (cubic feet per second) to cms (cubic meters per second): cms = cfs x 0.02832.

in the Umpqua Basin. Both road density and the riparian-road index will be updated once every five years.

Watershed Disturbance:

The plan includes both land ownership and land use as the two indicators of watershed disturbance. Using remote sensing techniques and available GIS layers, the investigator will map the spatial extent of land ownership and land uses within each watershed that includes monitoring reaches or sites. These indicators will be updated once every five years.

8.3 Recommendations

This plan requires that the protocols identified above be used to measure biological and physical/environmental indicators. It is understood that some of these methods will differ from those currently used by entities that will be implementing this plan. Indeed, some of the entities that will implement this plan may have collected data for several years with protocols different from those identified in this plan. It is not the intent of this plan to have those entities immediately switch protocols. Rather, this plan encourages entities to use both methods for a few years.[52] This will allow them to compare the performance of different methods and to develop relationships between different protocols. As noted in Section 4.4, at least 10% of the sites within each subbasin (Wenatchee, Entiat, Methow, and Okanogan) will be used to compare sampling protocols. This means that five sites in each of the subbasins will be sampled with more than one protocol.

The precision (repeatability) of measurements will be assessed by repeatedly sampling the same sites with independent crews. As noted in Section 4.4, 10% of the sites within each subbasin (same sites used to compare protocols) will be sampled by two independent crews each year for five years. Sampling by the two independent crews will be no more than two-days apart. This will minimize the effects of site changes on estimates of precision.

As noted earlier, water quality and quantity indicators will be measured continuously[53] at permanent, long-term monitoring locations and some (temperature, turbidity, and conductivity) will be measured during each visit to a monitoring site or reach for the purpose of evaluating fish sampling methods. For status/trend monitoring, at a minimum, permanent locations occur at the downstream end of the distribution of target populations or subpopulations. For effectiveness monitoring, if the intent of the management action (treatment) is to affect water quality, then continuous water quality sampling occurs at the upstream and downstream ends of reaches that contain treatment or control sites. As outlined in Section 8.2, this plan recommends that water quality indicators be measured with instruments that continuously record water quality conditions. Hydrolab® has a water quality

52 The number of years needed to compare performance and to develop relationships between methods will be determined as data are collected. At a minimum, entities implementing this plan should expect to use both methods for at least five years (n = 5).

53 Strictly speaking, water quality indicators are not measured "continuously." Instruments that measure these indicators take recordings at timed intervals, which, on the scale of a year, are close enough to be considered continuous.

instrument (DataSonde 4a)[54] that measures most of the water quality indicators identified in this plan (Table 15). Other instruments that continuously record water quality indicators could be used provided they achieve the same (or better) accuracy standards as the DataSonde. This plan recommends that the instruments record water quality indicators at hourly intervals (all recordings taken at the top of the hour).

Table 15. Water quality indicators, range, accuracy, and resolution of the DataSonde 4a developed by Hydrolab.

Indicator	Range	Accuracy	Resolution
Temperature	-5˚ to 50˚C	±0.10˚C	0.01˚C
Turbidity	0 to 1000 NTU	±5% of range	0.1 to 1 NTU
Conductivity	0 to 100 mS/cm	±0.001 mS/cm	4 digits
pH	0 to 14 units	±0.2 units	0.01 units
Dissolved oxygen	0 to 50 mg/L	±0.2 mg/L	0.01 mg/L

As a final note, the protocols identified in this section for measuring physical/environmental indicators were designed for sampling wadeable streams. Because the sampling frame for subbasins within the Upper Columbia Basin include first through fifth-order streams, sites in large, non-wadeable rivers such as the Wenatchee and Methow rivers will be included in the sample. Most of the protocols identified in Table 13 can be used in non-wadeable streams with some creative modifications. For example, dominant substrate and embeddedness can be assessed using snorkel or SCUBA gear.[55] Measurements of widths and depths can be collected from boats or rafts. Depth fines is the only indicator that cannot be collected in most non-wadeable streams.

54 Information on Hydrolab and the DataSonde 4a can be found at http://www.hydrolab.com. As noted earlier, the use of trade names in this paper is for reader information only and does not imply endorsement by an agency of any product.

55 Water clarity during base-flow conditions within the Wenatchee, Methow, and Entiat rivers is suitable for underwater observation work.

SECTION 9: IMPLEMENTATION

The preceding sections serve notice that considerable care must be put into the appropriate methods and logic structure of a status/trend and effectiveness monitoring plan. The intent of this section is to distill the information presented in this document into a concise outline that an investigator can follow to develop a statistically-valid monitoring plan. For convenience, this summary is offered as a checklist of steps that will aid the investigator in developing a valid monitoring program. Although these steps are generic, the investigator should address each one in order to demonstrate complete understanding of status/trend and effectiveness monitoring.

This section consists of three parts. The first part outlines the steps needed to setup and implement the monitoring plan. The second and third parts outline the steps needed to design status/trend monitoring studies and effectiveness monitoring studies, respectively.

9.1 Program Setup

In order to setup the monitoring program, it is important to follow a logical sequence of steps. By proceeding through each step, the investigator will better understand the goals of monitoring and its strengths and limitations. These steps should aid the investigator in implementing a valid monitoring program that reduces duplication of sampling efforts, and thus overall costs, but still meets the needs of the different entities. The plan assumes that all entities involved with implementing the plan will cooperate and freely share information.

Setup Steps:

1. Identify the populations and/or subpopulations of interest (e.g., spring chinook, steelhead, bull trout).
2. Identify the geographic boundaries (areas) of the populations or subpopulations of interest.
3. Describe the purpose for selecting these populations or subpopulations (what are the concerns?).
4. Identify the objectives for monitoring.
5. Select the appropriate monitoring approach (status/trend or effectiveness monitoring or both) for addressing the objectives.
6. Identify and review existing monitoring and research programs in the area of interest.
7. Determine if those programs satisfy the objectives of the proposed program.
8. If data gaps exist, implement the appropriate monitoring approach by following the criteria outlined below.
9. Classify the landscape and streams in the area of interest (see Section 6).
10. Describe how data collection efforts will be shared among the different entities.
11. Identify a common database for storing biological and physical/environmental data.
12. Estimate costs of implementing the program.
13. Identify cost-sharing opportunities.

9.2 Status/Trend Monitoring

If the objective of the monitoring program is to assess the current status of populations and/or environmental conditions, or to assess long-term trends in these parameters, then the following steps will help the investigator design a valid status/trend monitoring program.

Problem Statement and Overarching Issues:

1. Identify and describe the problem to be addressed.
2. Identify boundaries of the study area.
3. Describe the goal or purpose of the study.
4. List hypotheses to be tested.

Statistical Design (see Section 3):

1. Describe the statistical design to be used (e.g., EMAP design).
2. List and describe potential threats to external validity and how these threats will be addressed.
3. If this is a pilot test, explain why it is needed.
4. Describe descriptive and inferential statistics to be used and how precision of statistical estimates will be calculated.

Sampling Design (see Sections 4 & 5):

1. Describe the statistical population(s) to be sampled.
2. Define and describe sampling units.
3. Identify the number of sampling units that make up the sampling frame.
4. Describe how sampling units will be selected (e.g., random, stratified, systematic, etc.).
5. Describe variability or estimated variability of the statistical population(s).
6. Define Type I and II errors to be used in statistical tests (the plan recommends no less than 0.80 power).

Measurements (see Sections 7 & 8):

1. Identify indicator variables to be measured.
2. Describe methods and instruments to be used to measure indicators.
3. Describe precision of measuring instruments.
4. Describe possible effects of measuring instruments on sampling units (e.g., core sampling for sediment may affect local sediment conditions). If such effects are expected, describe how the study will deal with this.
5. Describe steps to be taken to minimize systematic errors.
6. Describe QA/QC plan, if any.
7. Describe sampling frequency for field measurements.

Results:

1. Explain how the results of this study will yield information relevant to management decisions.

9.3 Effectiveness Monitoring

If the objective of the monitoring program is to assess the effects of tributary habitat actions (e.g., improve stream complexity), then the following steps will help the investigator design a valid effectiveness monitoring program (these steps are modified from Paulsen et al. 2002). Because effectiveness monitoring encompasses the essence of cause-and-effect research (i.e., attempts to control for sources of invalidity), the steps below are more extensive and intensive than those in the status/trend monitoring program.

Problem Statement and Overarching Issues:

1. Identify and describe the problem to be improved or corrected by the action being monitored.
2. Describe current environmental conditions at the project site.
3. Describe factors contributing to current conditions (e.g., road crossing causing increased siltation).
4. Identify and describe the habitat action(s) (treatments) to be undertaken to improve existing conditions.
5. Describe the goal or purpose of the habitat action(s).
6. Identify the hypotheses to be tested.
7. Identify the independent variables in the study.

Statistical Design (see Section 3):

1. Describe the statistical design to be used (e.g., BACI design).
2. Describe how treatments (habitat actions) and controls will be assigned to sampling units (e.g., random assignment).
3. Show whether or not the study will include "true" replicates or subsamples.
4. Describe how temporal and spatial controls will be used and how many of each type will be sampled.
5. Describe the independence of treatment and control sites (are control sites completely unaffected by habitat actions?).
6. Identify covariates and their importance to the study.
7. Describe potential threats to internal and external validity and how these threats will be addressed.
8. If this is a pilot test, explain why it is needed.
9. Describe descriptive and inferential statistics to be used and how precision of statistical estimates will be calculated.

Sampling Design (see Sections 4 & 5):

1. Describe the statistical population(s) to be sampled.
2. Define and describe sampling units.
3. Describe the number of sampling units (both treatment and control sites) that make up the sampling frame.
4. Describe how sampling units will be selected (e.g., random, stratified, systematic, etc.).
5. Define "practical significance" (e.g., environmental or biological effects of the action) for this study.
6. Describe how effect size(s) will be detected.
7. Describe the variability or estimated variability of the statistical population(s).
8. Define Type I and II errors to be used in statistical tests (the plan recommends no less than 0.80 power).

Measurements (see Sections 7 & 8):

1. Identify and describe the indicator (dependent) variables to be measured.
2. Describe methods and instruments to be used to measure indicators.
3. Describe the precision of measuring instrument(s).
4. Describe possible effects of measuring instruments on sampling units (e.g., core sampling for sediment may affect local sediment conditions). If such effects are expected, describe how the study will deal with this.
5. Describe steps to be taken to minimize systematic errors.
6. Describe QA/QC plan, if any.
7. Describe sampling frequency for field measurements.

Results:

1. Explain how the results of this study will yield information relevant to management decisions.

These steps should be carefully considered when designing a monitoring plan to assess the effectiveness of any habitat action, regardless of how simple the proposed action may be. Even monitoring the effectiveness of irrigation screens requires careful consideration of all steps in the checklist. In some cases, the investigator may not be able to address all steps with a high degree of certainty, because adequate information does not exist. For example, the investigator may lack information on population variability, effect size, "practical significance," or instrument precision, which makes it difficult to design studies and estimate sample sizes. In this case the investigator can address the statements with the best available information, even if it is based on professional opinion, or design a pilot study to answer the questions.

SECTION 10: REFERENCES

Action Agencies (Bonneville Power Administration, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers) and NOAA Fisheries. 2003. Draft research, monitoring and evaluation plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion. Bonneville Power Administration, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and NOAA Fisheries, Portland, OR. Web link: http://www.nwr.noaa.gov/1hydrop/hydroweb/fedrec.htm

Anderson, R. O. and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in*: B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Bain, M. B. and N. J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, MD.

Bailey, R. G. 1978. Description of ecoregions of the United States. U.S. Forest Service, Intermountain Region, Ogden, UT.

Bailey, R. G. 1998. Ecoregions map of North America: explanatory note. U.S. Forest Service, Miscellaneous Publication 1548, Washington, D.C.

Bayley, P. B. 2002. A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest. Report to the Washington State Independent Science Panel, Olympia, WA.

Bevenger, G. S. and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. Research Paper RM-RP-319, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Bilhimer, D., J. Carroll, S. O'Neal, and G. Pelletier. 2003. Draft quality assurance project plan: Wenatchee River temperature, dissolved oxygen, pH, and fecal coliform total maximum daily load year 2 technical study. Washington State Department of Ecology, Olympia, WA.

Bisson, P. A. and D. R. Montgomery. 1996. Valley segments, stream reaches, and channel units. Pages 23-52 *in*: R. R. Hauer and G. A. Lamberti, editors. Methods in stream ecology. Academic Press, New York, NY.

Bjornn T. C. and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Bonar, S. A. and W. A. Hubert. 2002. Standard sampling of inland fish: benefits, challenges, and a call for action. Fisheries 27:10-16.

Borgerson, L. A. 1992. Scale analysis. Oregon Department of Fish and Wildlife, Fish Research Project F-144-R-4, Annual Progress Report, Portland, OR.

Box, G. E. P. and G. M. Jenkins. 1976. Time-series analysis: forecasting and control. Holden-Day, San Francisco, CA.

Browne, R. H. 2001. Using the sample range as a basis for calculating sample size in power calculations. The American Statistician 55:293-298.

BURPTAC (Beneficial Use Reconnaissance Project Technical Advisory Committee). 1999. 1999 beneficial use reconnaissance project workplan for wadable streams. Idaho Division of Environmental Quality, Boise, ID. Web link: http://www.deq.state.id.us/water/surface_water/99_burp_workplan.pdf

Cailliet, G. M., M. S. Love, and A. W. Ebeling. 1986. Fishes, a field and laboratory manual on their structure, identification, and natural history. Wadsworth Publishing Company, Belmont, CA.

Clay, C. H. 1995. Design of fishways and other fish facilities. Second edition. Lewis Publishers, Boca Raton, Florida.

Cohen, J. 1988. Statistical power analysis for the behavioral sciences. Lawrence-Erlbaum, Hillsdale, NJ.

Cook, T. D. and D. T. Campbell. 1979. Quasi-experimentation: design and analysis issues for field settings. Houghton Mifflin Company, Boston, MA.

Cupp, C. E. 1989a. Identifying spatial variability of stream characteristics through classification. Master's thesis. University of Washington, Seattle, WA.

Cupp, C. E. 1989b. Valley segment type classification for forested lands of Washington. Washington State Timber/Fish/Wildlife Agreement, TFW-AM-89-001, Department of Natural Resources, Olympia, WA.

Currens, K. P., H. W. Li, J. D. McIntyre, D. R. Montgomery, and D. W. Reiser. 2000. Recommendations for monitoring salmonid recovery in Washington State. Independent Science Panel Report 2000-2, Olympia, WA.

Currens, K. P., H. W. Li, J. D. McIntyre, D. R. Montgomery, and D. W. Reiser. 2002. Responses of salmon and trout to habitat changes. Independent Science Panel Technical Memorandum 2002-2, Olympia, WA.

Diaz-Ramos, S., D. L. Stevens, and A. R. Olsen. 1996. EMAP statistical methods manual. U.S. Environmental Protection Agency, EPA/620/R-96/XXX, Corvallis, OR.

Dolloff, A., J. Kershner, and R. Thurow. 1996. Underwater observation. Pages 533-554 *in*: B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification; viewing streams in a watershed context. Environmental Management 10:199-214.

Gordon, N. D., T. A. McMahon, and B. L. Finlayson. 1992. Stream hydrology an introduction for ecologists. John Wiley and Sons, New York, NY.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, Inc., New York, NY.

Green, R. H. 1994. Aspects of power analysis in environmental monitoring. Pages 173-182 *in*: D. J. Fletcher and B. F. J. Manly, editors. Statistics in ecology and environmental monitoring. University of Otago Press, Dunedin.

Gregory, S. V. and P. A Bisson. 1997. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. Pages 277-314 in: D. J. Stouder, P. A. Bisson, and R. J. Naiman, editors. Pacific salmon and their ecosystems, status and future options. Chapman and Hall, New York, NY.

Hadley, R. F. and S. A. Schumm. 1961. Sediment sources and drainage basin characteristics in upper Cheyenne River basin. U.S. Geological Survey, Water-Supply Paper 1531-B, Reston, Virginia.

Hairston, N. G. 1989. Ecological experiments: purpose, design, and execution. Cambridge University Press, New York, NY.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-245, Fort Collins, CO.

Hawkins, C. P., and ten others. 1993. Hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

Hawkins, C., J. Ostermiller, M. Vinson, and J. Stevenson. 2001. Steam algae, invertebrate, and environmental ssampling associated with biological water quality assessments: field protocols. Utah State University, Logan, UT.
Web link: http://www.usu.edu/buglab/monitor/USUproto.pdf

Hayes, D. and 14 others. 2003. Developing a standardized sampling program: the Michigan experience. Fisheries 28:18-25.

Hicks, L. L., J. Light, G. Watson, B. Sugden, T. W. Hillman, and D. Berg. 1999. Adaptive management: concepts and applications to Plum Creek's Native Fish Habitat Conservation Plan. Native Fish Habitat Conservation Plan Technical Report No. 13, Plum Creek Timber Company, Seattle, WA.

Hillman, T. W., J. W. Mullan, and J. S. Griffith. 1992. Accuracy of underwater counts of juvenile chinook salmon, coho salmon, and steelhead. North American Journal of Fisheries Management 12:598-603.

Hillman, T. W. and D. W. Chapman. 1996. Comparison of underwater methods and electrofishing for estimating fish populations in the Upper Blackfoot River Basin. BioAnalysts, Inc. Report to the Seven-Up Pete Joint Venture, Lincoln, MT.

Hillman, T. W. and A. E. Giorgi. 2002. Monitoring protocols: effectiveness monitoring of physical/environmental indicators in tributary habitats. BioAnalysts, Inc. Report to Bonneville Power Administration, Portland, Or. Web link: http://www.efw.bpa.gov/cgi-bin/FW/welcome.cgi?ViewMode=External

Hillman, T. W. and M. D. Miller. 2002. Abundance and total numbers of chinook salmon and trout in the Chiwawa River Basin, Washington. BioAnalysts, Inc. Report to Chelan County Public Utility District, Wenatchee, WA.

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 2:423-432.

Hunt, C. B. 1967. Physiography of the United States. W. H. Freeman, San Francisco, CA.

Hurlbert, S. J. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-211.

ICBTRT (Interior Columbia Basin Technical Recovery Team). 2003. Independent populations of chinook, steelhead, and sockeye for listed evolutionarily significant units within the interior Columbia River domain. Working draft. NOAA Fisheries Northwest Fisheries Science Center, Seattle, WA.

Idea Works, Inc. 1997. Methodologists toolchest. Version 1.2. Distributed by Scolari, Sage Publications Software, Beverly Hills, CA.

ISAB (Independent Scientific Advisory Board). 2003. A review of strategies for recovering tributary habitat. Independent Scientific Advisory Board for the Northwest Power Planning Council, ISAB 2003-2, Portland, OR. Web link:

http://www.nwppc.org/library/isab/Default.htm

Johnson, D. H., and nine others. 2001. Inventory and monitoring of salmon habitat in the Pacific Northwest—directory and synthesis of protocols for management/research and volunteers in Washington, Oregon, Montana, Idaho, and British Columbia. Review draft. Washington Department of Fish and Wildlife, Olympia, WA. Web link: http://www.wa.gov/wdfw/hab/sshiap/dataptcl.htm

Kaufmann, P. R., P. Levine, E. G. Robinson, C. Seeliger, and D. V. Peck. 1999. Quantifying physical habitat in wadeable streams. EPA/620/R-99/003, U.S. Environmental Protection Agency, Washington, D.C. Web link: http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/phyhab.html

Krebs, C. J. 1999. Ecological methodology. Second edition. Benjamin/Cummings, Menlo Park, CA.

Lazorchak, J. M., D. J. Klemm, and D. V. Peck (editors). 1998. Environmental monitoring and assessment program—surface waters: field operations and methods for measuring the ecological condition of wadeable streams. EPA/620/R-94/004F, U.S. Environmental Protection Agency, Washington, D.C. Web link: http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ws_abs.html

Lee, K. N. 1993. Compass and gyroscope: integrating science and politics for the environment. Island Press, Washington, D.C.

Lipsey, M. W. 1990. Design sensitivity: statistical power for experimental research. Sage Publications, Beverly Hills, CA.

MacDonald, L. H., A. W. Smart, and R. C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, EPA/910/9-91-001, Seattle, WA.

Manly, B. F. J. 1992. The design and analysis of research studies. Cambridge University Press, New York, NY.

Manly, B. F. J. 2001. Statistics for environmental science and management. Chapman and Hall, New York, NY.

Mapstone, B. D. 1995. Scalable decision rules for environmental impact studies: effect size, Type I, and Type II errors. Ecological Applications 5:401-410.

Meehan, W. R., editor. 1991. Influences of forest and range management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, MD.

Meekin, T. K. 1967. Report on the 1966 Wells Dam chinook tagging study. Washington Department of Fisheries report to Douglas County Public Utility District, Contract Number 001-01-022-4201.

Montgomery, D. R. and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington State Timber/Fish/Wildlife Agreement, TFW-SH10-93-002, Department of Natural Resources, Olympia, WA. Web site: http://www.nwifc.wa.gov/cmerdoc/TFW_SH10_93_002.pdf

Montgomery, D. R. and J. M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of American Bulletin 109:596-611.

Moore, K., K. Jones, and J. Dambacher. 2002. Methods for stream habitat surveys; aquatic inventory project. Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Natural Production Program, Corvallis, OR. Web link: http://oregonstate.edu/Dept/ODFW/freshwater/inventory/methods.html

Moore, K. 2002. Draft Oregon plan for salmon and watersheds monitoring strategy. Oregon Plan, Salem, OR.

Mosey, T. R. and L. J. Murphy. 2002. Spring and summer chinook spawning ground surveys on the Wenatchee River Basin, 2001. Chelan County Public Utility District, Wenatchee, WA.

Mullan, J. W., K. R. Williams, G. Rhodus, T. W. Hillman, and J. D. McIntyre. 1992. Production and habitat of salmonids in Mid-Columbia River tributary streams. U.S. Fish and Wildlife Service Monograph I, Leavenworth, WA.

Murdoch, A., K. Petersen, T. Miller, M. Tonseth, and T. Randolph. 2000. Freshwater production and emigration of juvenile spring chinook salmon from the Chiwawa River in 1998. Report No. SS99-05, Washington Department of Fish and Wildlife, Olympia, WA.

Naiman, R. J., D. G. Lonzarich, T. J. Beechie, and S. C. Ralph. 1992. General principles of classification and the assessment of conservation potential in rivers. Pages 93-123 *in*: P. J. Boon, P. Calow, and G. E. Petts, editors. River conservation and management. John Wiley and Sons, New York, NY.

Nawa, R. K., C. A. Frissell, and W. J. Liss. 1988. Life history and persistence of anadromous fish stocks in relation to stream habitats and watershed classification. Annual progress report to Oregon Department of Fish and Wildlife, Portland, OR.

NCSS (Number Cruncher Statistical Systems). 2000. Pass 2000 power analysis and sample size for Windows. NCSS, Kaysville, UT.

NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. The National Marine

Fisheries Service Environmental and Technical Services Division, Habitat Conservation Branch, Seattle, WA.

NRC (National Research Council). 1992. Restoration of aquatic ecosystems: science, technology, and public policy. National Academy Press, Washington, D.C.

Omernik, J. M. 1987. Aquatic ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

OPSW (Oregon Plan for Salmon and Watersheds). 1999. Water quality monitoring, technical guide book. Version 2.0. Corvallis, OR. Web link: http://www.oweb.state.or.us/publications/index.shtml

Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) fish and fish habitat standard inventory procedures handbook. USDA Forest Service General Technical Report INT-GTR-346, Ogden, UT.

Overton, W. S., D. White, and D. L. Stevens. 1990. Design report for EMAP environmental monitoring and assessment program. U.S. Environmental Protection Agency, EPA/600/3-91/053, Corvallis, OR.

Parker, M. A. 2000. Fish passage – culvert inspection procedures. Watershed Restoration Technical Circular No. 11. Ministry of Environment, Lands and Parks and Ministry of Forest, British Columbia.

Parker, R. A. and N. G. Berman. 2003. Sample size: more than calculations. The American Statistician 57:166-170.

Parmenter, A. W., A. Hansen, R. E. Kennedy, W. Cohen, U. Langener, R. Lawrence, B. Maxwell, A. Gallant, and R. Aspinall. 2003. Land use and land cover in the greater Yellowstone ecosystem: 1975-1995. Ecological Applications 13:687-703.

Paulsen, C., S. Katz , T. Hillman, A. Giorgi, C. Jordan, M. Newsom, and J. Geiselman, 2002 Guidelines for Action Effectiveness Research Proposals for FCRPS Offsite Mitigation Habitat Measures. Bonneville Power Administration, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and NOAA Fisheries, Portland, OR. Web link: http://www.efw.bpa.gov/cgiin/FW/welcome.cgi?ViewMode=ExternalView.

Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001. Environmental monitoring and assessment program—surface waters: western pilot study field operations manual for wadeable streams. Draft Report. EPA/XXX/X-XX/XXX, U.S. Environmental Protection Agency, Washington, D.C. Web link: http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ewwsm01.html *[Although this draft document states that it should not be cited or quoted, some of the material in the report is an important improvement to Lazorchak et al. (1998). By not citing* *the document, it may give the appearance that I improved some of the methods outlined in the Lazorchak et al. report. To avoid this, I feel it necessary to offer credit where credit is due.]*

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47:2-15.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report INT-138, Ogden, UT.

Platts, W. S. and twelve others. 1987. Methods for evaluating riparian habitats with applications to management. USDA Forest Service General Technical Report INT-221, Ogden, UT.

Reeves, G. H., and nine others. 2001. Aquatic and riparian effectiveness monitoring plan for the Northwest Forest Plan. USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR.

Reynolds, J. B. 1996. Electrofishing. Pages 221-253 *in*: B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Reynolds, L., A. T. Herlihy, P. R. Kaufmann, S. V. Gregory, and R. M. Hughes. 2003. Electrofishing effort requirements for assessing species richness and biotic integrity in Western Oregon streams. North American Journal of Fisheries Management 23:450-461.

Roni, P., L. Weitkamp, and J. Scordino. 1999. Identification of essential fish habitat for salmon in the Pacific Northwest: initial efforts, information needs, and future direction. American Fisheries Society Symposium 22:93-107.

Roper, B. B., J. L. Kershner, and R. C. Henderson. 2003. The value of using permanent sites when evaluating stream attributes at the reach scale. Journal of Freshwater Ecology 18:585-592.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, CO.

Royce, W. F. 1996. Introduction to the practice of fishery science. Revised edition. Academic Press, New York, NY.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1990. Elementary survey sampling. Fourth edition. PWS-KENT Publishing Company, Boston, MA.

Schuett-Hames, D., J. Ward, M. Fox, A. Pleus, and J. Light. 1994. Large woody debris survey module. Section 5 *in*: D. Schuett-Hames, A. Pleus, L. Bullchild, and S. Hall, editors. Ambient monitoring program manual. Timber-Fish-Wildlife TFW-AM9-94-001, Northwest Indian Fisheries Commission, Olympia, WA. Web link: http://www.nwifc.wa.gov/TFW/documents.asp

Schuett-Hames, D., A. E. Pleus, E. Rashin, and J. Matthews. 1999a. Method manual for the stream temperature survey. Timber-Fish-Wildlife TFW-AM9-99-005, Northwest Indian Fisheries Commission, Olympia, WA. Web link: http://www.nwifc.wa.gov/TFW/documents.asp

Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999b. Method manual for the salmonid spawning gravel composition survey. Timber-Fish-Wildlife TFW-AM9-99-006, Northwest Indian Fisheries Commission, Olympia, WA. Web link: http://www.nwifc.wa.gov/TFW/documents.asp

Simonson, T., J. Lyons, and P. Kanehl. 1994. Quantifying fish habitat in streams: transect spacing, sample size, and a proposed framework. North American Journal of Fisheries Management 14:607-615.

Skalski, J. R. and D. S. Robson. 1992. Techniques for wildlife investigations, design and analysis of capture data. Academic Press, New York, NY.

Smith, E. P., D. R. Orvos, and J. Cairns. 1993. Impact assessment using the before-after-control-impact (BACI) model: concerns and comments. Canadian Journal of Fisheries and Aquatic Sciences 50:627-637.

Smith, R. L. and T. M. Smith. 2001. Ecology and field biology. Sixth edition. Benjamin Cummings, New York, N.Y.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, and R. P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057, Management Technology, Corvallis, OR.

Stevens, D. L. 1997. Variable density grid-based sampling designs for continuous spatial populations. Environmetrics 8:167-195.

Stevens, D. L. 2002. Sampling design and statistical analysis methods for the integrated biolgocial and physical monitoring of Oregon streams. Report No. OPSW-ODFW-2002-07, The Oregon Plan for Salmon and Watersheds, Oregon Department of Fish and Wildlife, Corvallis, OR.

Stevens, D. L. and A. R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics 4:415-428.

Stevens, D. L. and N. S. Urquhart. 2000. Response designs and support regions in sampling continuous domains. Environmetrics 11:13-41.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: “pseudoreplication” in time? Ecology 67:929-940.

Stewart-Oaten, A., J. R. Bence, and C. W. Osenberg. 1992. Assessing effects of unreplicated perturbations: no simple solutions. Ecology 73:1396-1404.

Strahler, A. N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Bulletin of the Geological Society of America 63:1117-1142.

Strange, R. J. 1996. Field examination of fishes. Pages 433-446 *in*: B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Underwood, A. J. 1994. Things environmental scientists (and statisticians) need to know to receive (and give) better statistical advice. Pages 33-61 *in*: D. J. Fletcher and B. F. J. Manly, editors. Statistics in ecology and environmental monitoring. University of Otago Press, Dunedin.

USFWS (U.S. Fish and Wildlife Service). 2000. Biological Opinion, effects to listed species from operations of the Federal Columbia River Power System. U.S. Fish and Wildlife Service, Regions 1 and 6, Portland, OR.

Van Deventer, J. S. and W. S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data—user's guide for MicroFish 3.0. USDA Forest Service General Technical Report INT-254, Ogden, UT.

WDFW (Washington Department of Fish and Wildlife). 2000. Fish passage barrier and surface water diversion screening assessment and prioritization manual. Washington Department of Fish and Wildlife Habitat Program, Environmental Restoration Division, Olympia, WA. Web link: http://www.wa.gov/wdfw/hab/engineer/fishbarr.htm

Wertz, W. A. and J. F. Arnold. 1972. Land systems inventory. U.S. Forest Service, Intermountain Region, Ogden, UT.

WFC (World Forestry Center). 1998. Pilot study report, Umpqua land exchange project. World Forestry Center, Portland, OR. Web link: http://www.or.blm.gov/umpqua/documents.htm

WFPB (Washington Forest Practices Board). 1995. Washington forest practices board manual: standard methodology for conducting watershed analysis under Chapter 222-22 WAC. Version 3.0. Washington Forest Practices Board, Olympia, WA. Web link: http://www.dnr.wa.gov/forestpractices/watershedanalysis/

Whittier, T. R., R. M. Hughes, and D. P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Sciences 45:1264-1278.

Wipfli, M. S. and D. P. Gregovich. 2002. Export of invertebrates and detritus from fishless headwater streams in southeastern Alaska: implications for downstream salmonid production. Freshwater Biology 47:957-969.

WSRFB (Washington Salmon Recovery Funding Board). 2003. Draft 5/16/2003 monitoring and evaluation strategy for habitat restoration and acquisition projects. Washington Salmon Recovery Funding Board, Olympia, WA. Web link: http://www.iac.wa.gov/srfb/docs.htm

Zaroban, D. W. 2000. Protocol for placement and retrieval of temperature data loggers in Idaho streams. Idaho Division of Environmental Quality, Boise, ID. Web link: http://www.deq.state.id.us/water/tlp.htm

APPENDIX A—WENATCHEE BASIN

APPENDIX B—ENTIAT BASIN

APPENDIX C—METHOW BASIN

APPENDIX D—OKANOGAN BASIN

APPENDIX E—CHELAN RIVER AND SMALL TRIBUTARIES

Appendix C
Entiat Subbasin Plan

EFFECTS OF HYDROELECTRIC DAMS
ON VIABILITY OF WILD FISH
BioAnalysts
April 2004

The existence and operation of the Columbia River Hydrosystem poses risks to wild populations of anadromous salmonids. Run-of river dams present passage obstacles to both adult and juvenile migrants, and the water management of storage reservoirs for hydropower production has reshaped the seasonal hydrograph. Both of these elements have had deleterious effects on salmon resources in the basin. This section focuses on Upper Columbia River populations, but in some cases refers to data from the Snake River or lower Columbia to illustrate basic principles.

Effects on Juvenile Life Stages

Migrating smolts of all species traverse the impounded mainstem Columbia during their seaward journey, most notably the two ESUs of Upper Columbia spring chinook and summer steelhead. Also, egg-through-smolt life stages of ocean-type summer/fall chinook incubate, rear, and migrate through the upper and lower Columbia River segments. During downstream migration, smolts encounter two general classes of effects, those associated with passage at the dams and those experienced within the reservoirs.

Smolt travel time and survival through a series of projects (dam and pool) are two key indices used to assess the effects of the hydrosystem on the performance of salmon populations. Typically PIT-tagged hatchery fish or a mixture of hatchery and wild fish are used as indicator stocks. In the Snake River, known wild fish are used on a regular basis, but in the Upper Columbia there has been no concerted effort to tag known wild fish. Therefore, in the Upper Columbia, managers must rely on hatchery and mixed populations to generate performance indices. However, the hatchery and mixed populations have generally proved to be adequate surrogates for representing the migratory characteristics of wild populations within the impounded Columbia-Snake River system (FCRPS BiOp 2000). Herein, this section relies on the same complex of populations for representing wild stocks from the Upper Columbia.

Salmon Migration and Survival

As noted elsewhere in this plan, both Mullan et al. (1992) and Chapman et al. (1994, 1995) identified the construction and operation of the Columbia River hydrosystem as a primary agent contributing to the decline of spring chinook and steelhead populations in the upper Columbia. Chapman et al. (1994, 1995) arrived at the same conclusion for sockeye and summer/fall chinook as well. These discussions focus on spring chinook and steelhead, but in most cases will apply to sockeye as well. Ocean-type summer/fall chinook populations that migrate during the summer face unique conditions. We do not discuss details for ocean-type chinook at his time.

Smolts

Dam Passage Effects

Smolts passing each dam incur effects that result in elevated mortality. Survival rates differ among passage routes and dams. In the Snake River, spillways provide the safest routes, followed by bypasses, with turbines being the most injurious (Muir et al. 2001). In a meta-analysis of smolt survival data, Bickford and Skalski (2000) affirmed that spillways generally provide a safer route of passage than do Kaplan turbines. Their study included dams in the Columbia and Snake rivers.

Smolt passage survival though one or more projects (reservoir and dam) provides a more complete index of total hydropower impacts, since it reflects mortality incurred passing the dam and that within the reservoir. Predation on smolts by fish and birds is the primary agent causing mortality in the impoundments. During the 1980s, system survival studies were conducted through the Upper Columbia from Pateros to Priest Rapids tailrace. The mean per-project survival ranged from 84 to 87.5% for steelhead (FPC 1985, 1986; McConnaha and Basham 1985). For spring chinook, McKenzie et al. (1983 and 1984) reported mean per-project survival estimates that ranged from 83.4 to 88.7%.

Today, passage survival at certain dams appears to have improved with the implementation of contemporary configurations and operations. For example, recent project survival estimates from Rocky Reach and Rock Island dams indicate that smolt survival is improved over historical conditions. Skalski et al. (2003) summarized data for Rock Island Dam and Skalski et al. (2001) did so for Rocky Reach Dam . They considered all project survival estimates obtained since 1998, using all tag types (radio, PIT, and acoustic).

Species/life stage	Rocky Reach	Rock Island
Yearling Chinook	90.3% (4.0)	93.2% (0.6)
Steelhead	96.4% (0.3)	94.6% (0.9)

Estimates for Rocky Reach are limited, particularly for yearling chinook where PIT and radio estimates were averaged for one year, 1998. Prototype surface collectors of various configurations and operations were in place at Rocky Reach during all years. Thus current survival may differ since the production-scale surface collector has been completed and in full operations. Future evaluations will provide an evaluation of the effects on project survival.

Also, the predator-control program directed at removing adult northern pikeminnow has been in place since the mid-1990s. This has no doubt contributed to increasing survival through reservoirs, which would be reflected in project survival estimates. Although quantifying the effectiveness of that program alone, in terms of improved smolt survival, has been technically difficult to accomplish.

Migration Rate Effects

The emplacement of nine dams on the mainstem Columbia has slowed river velocities considerably. This has resulted in slower migration rates through the impounded system. To illustrate this, Ebel and Raymond (1976) and Bentley and Raymond (1976), for example, estimated that after dam emplacement, travel times of yearling chinook salmon and steelhead increased at least two-fold over pre-impoundment conditions. Slower migration seaward can affect smolt survival inriver and perhaps at seawater entry. Inriver, smolts have increased exposure time to predatory species and changing water conditions. Both of these can result in higher mortality than realized under pre-impoundment conditions. A protracted migration may result in suboptimal development and compromise seawater adaptation and survival, although this remains to be definitively demonstrated. Clearly, evidence for steelhead indicates that exposure to warming inriver temperatures depresses the smoltification process and promotes recidivism when temperatures exceed 12-13˚C.

Slower migration may also result in other types of delayed effects that could be manifested in the form of poor marine survival. Congleton et al. (2002) monitored the physiological condition of stream type spring/summer chinook salmon migrating from Lower Granite Dam to Bonneville Dam during 1998-2002. They found that body lipid and protein masses decreased significantly and with increased travel time. Slower migration forces juveniles to use caloric reserves beyond levels expected to occur under a free-flowing river, yielding swift migration speed. Such a tax on body reserves could compromise smolt survival, particularly during early seawater residence.

The flow augmentation program adopted by the fisheries agencies and Tribes is meant to offset deleterious effects associated with impoundment. However, recently the ISAB (2003) has questioned the effectiveness of that program.

Adults

Chief Joseph Dam lacks an adult fishway and has permanently blocked passage to spawning and rearing areas upstream from that site since 1961, when the dam was completed. All other dams from Wells to Bonneville are equipped with adult fishways that permit upstream passage. Although these dams are obstacles, they do provide effective fish passage ways in most cases. Some fishways have been found to be problematic because their specific location or configuration exacerbates fallback. The Bradford Island Fishway at Bonneville Dam is a good example of such a problem site.

Survival Estimates

Accurate estimates of adult passage survival do not exist, because thus far they have proved impractical to obtain. Typically, survival indices are reported, which are best characterized as minimum survival estimates. Most survival indices have been obtained using radio-telemetry methods. Fish are tagged at the foot of the reach and monitored as they pass dams to some terminal sampling location. Survival through the reach of interest is a minimum survival estimate because certain fish fates have not been accurately accounted for in many studies. These include tag failure, tag regurgitation, tributary turnoff (some cases), all harvest removals, and for some species cessation of migration associated with mainstem spawning. Thus the survival index based on tagged fish arriving at the uppermost dam represents an estimate of minimum survival through the reach. Recently the installation of an adult PIT detection system at Wells Dam has provided the opportunity to generate estimates similar to those obtained using radio telemetry.

Adult survival through portions of the Upper Columbia has been estimated in some years over the last decade. In general, survival rates of both steelhead and spring chinook are high. This has been demonstrated using a number of approaches.

Steelhead—English et al. (2001, 2003) estimated that a minimum of 93.3% and 94.2% of the steelhead arriving at Rocky Reach Dam survived to known spawning areas, or remained upstream from the dam. These estimates are consistent with estimates from the Snake River and lower Columbia, which generally average near 96.8% per project (Rocky Reach BiOp 2003). Also, as reported in that BiOp, PIT tag-based survival estimates from McNary to Wells Dam averaged 97% per project.

Yearling Chinook—In 2002, PIT tag-based estimates indicate that the minimum survival of spring chinook ranged from 95.8% to 100% for two stocks tracked from McNary to Wells Dam. That range is consistent with values reported for Federal Columbia River Power System projects, which average a loss near 2.4% for spring chinook (Rocky Reach BiOp 2003).

Overall, these collective estimates comport with estimates obtained for adults migrating through some free-flowing rivers. In fact, NOAA Fisheries concluded, "[f]urthermore, based on the observed ranges of mortality estimates for un-impounded river systems, which often exceed that observed in impounded reaches of the Columbia River, NOAA Fisheries concludes that there is a high likelihood that mortality as a result of direct, indirect, or delayed effects of passing the Project does not exceed 2% for any Permit Species" (Rocky Reach BiOp 2003, p.6-9).

Literature Cited

Bickford, S. and J. Skalski. 2000. Reanalysis and interpretation of 25 years of Snake-Columbia River juvenile salmonid survival studies. North American Journal of Fisheries Management 20:53-68.

Congleton, J., T. Wagner, D. Jones, J. Evavold, D. Fryer, and B. Sun. (2002). Evaluation of physiological changes in migrating chinook salmon and effects on performance and survival. Abstract. Anadromous Fish Evaluation Program, USACE, Portland OR.

English, K., C. Sliwinski, B. Nass, and J. Stevenson. 2001. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 1999-2000.

English, K., C. Sliwinski, B. Nass, and J. Stevenson. 2001. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 2001-2002.

ISAB. 2003. Review of Flow Augmentation: Update and Clarification. Report to NPCC, Portland, OR.

Muir, W., S. Smith, J. Williams, and B. Sandford. 2001. Survival of juvenile salmonids passing though bypass systems, turbines, and spillways with and without flow deflectors at Snake River dams. North American Journal of Fisheries Management 21:135-146.

Skalski, J, and six other authors. 2003. Estimation of survival of yearling Chinook salmon smolts at the Rock Island Dam, Pool, and project in 2003 using acoustic and PIT-tag release-recapture methods. Research report to Chelan PUD. 87 p., plus appendices.

Skalski, J. R. Townsend, and R. McDonald. 2001. Estimation of Rock Island project yearling Chinook smolts in 2001 using PIT-tag release-recapture methods. Report to Chelan County PUD. 74 p.

Appendix
Summary of Artificial Production
In the Entiat Subbasin

I. Introduction

Various processes are underway within the Columbia Basin that direct hatchery program implementation. The listing of certain populations of fish under the ESA has also dictated hatchery program modifications and reform.

Some of the principal processes are:

Federal:

Hatchery and Genetic Management Plans:
The Hatchery and Genetic Management Plan (HGMP) process was initiated to identify offsite mitigation opportunities associated with operation of the Federal Columbia River Power System. The HGMP process is designed to describe existing propagation programs, identify necessary or recommended modifications of those programs, and help achieve consistency of those programs with the Endangered Species Act. The HGMP process only addresses anadromous salmon and steelhead programs.

Hatchery and Genetic Management Plans are described in the final salmon and steelhead 4(d) rule (July 10, 2000; 65 FR 42422) as a mechanism for addressing the take of certain listed species that may occur as a result of artificial propagation activities. NOAA Fisheries will use the information provided by HGMPs in evaluating impacts on anadromous salmon and steelhead listed under the ESA. In certain situations, the HGMPs will apply to the evaluation and issuance of section 10 take permits. Completed HGMPs may also be used for regional fish production and management planning by federal, state, and tribal resource managers.

The primary goal of the HGMP process is to devise biologically-based artificial propagation management strategies that ensure the conservation and recovery of listed Evolutionarily Significant Units (ESUs). The HGMP process also seeks to document and implement hatchery reform in the Columbia Basin. Much of the initial work on the HGMP process was coordinated and combined with efforts to complete the Artificial Production Review and Evaluation (APRE – see below)) analysis, which looked at the same sorts of information.

Artificial Production Review and Evaluation (APRE):

The APRE process seeks to document progress toward hatchery reform in the Columbia Basin. The NPCC used consultants and representatives of the Columbia Basin fishery managers to analyze existing programs and recommend reforms; a draft report that will go to the Council and the region has been prepared. The APRE process includes both anadromous and non-anadromous fish in its analysis.

Pacific Coastal Salmon Recovery Fund

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established in FY2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to Endangered Species Act (ESA) listings of West Coast salmon and steelhead populations. The PCSRF supplements existing state, tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation; promotes efficiencies and effectiveness in recovery efforts through enhanced sharing and pooling of capabilities, expertise and information. The goal of the Pacific Coastal Salmon Recovery Fund is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat.

The PCSRF's enhancement objective is*: To conduct activities that enhance depressed stocks of wild anadromous salmonids through hatchery supplementation, reduction in fishing effort on depressed wild stocks, or enhancement of Pacific salmon fisheries on healthy stocks in Alaska. This includes supplementation and salmon fishery enhancements.*

US v. OR

United States v Oregon, originally a combination of two cases, Sohappy v. Smith and U.S. v. Oregon, legally upheld the Columbia River treaty tribes reserved fishing rights. Specifically the decision acknowledged the treaty tribes reserved rights to fish at "all usual and accustomed" places whether on or off the reservation, and were furthermore entitled to a "fair and equitable share" of the resource. Although the Sohappy case was closed in 1978, U.S. v. Oregon remains under the federal court's continuing jurisdiction serving to protect the tribes treaty reserved fishing rights. This case is tied closely to U.S. v. Washington, which among other things defined "fair and equitable share" as 50 percent of all the harvestable fish destined for the tribes' traditional fishing places, and established the tribes as co-managers of the resource.

In 1988, under the authority of U.S. v. Oregon, the states of Washington, Oregon and Idaho, federal fishery agencies, and the treaty tribes agreed to the Columbia River Fish Management Plan (CRFMP), which was a detailed harvest and fish production process. There are no financial encumbrances tied to the process. Rather, the fish production section reflects current production levels for harvest management and recovery purposes, since up to 90% of the Columbia River harvest occurs on artificially produced fish. This Plan expired in 1998, and has had subsequent annual rollover of portions in which agreement has been reached. However, a newly negotiated CRFMP is forthcoming.

Hatchery production programs in the upper Columbia sub-basins are included in the management plans created by the fishery co-managers identified in the treaty fishing rights case *United States v Oregon*. The parties to *U.S. v Oregon* include the four Columbia River Treaty Tribes – Yakama Nation, Warm Springs, Umatilla, and Nez Perce tribes, NOAA-Fisheries, U.S. Fish and Wildlife Service, and the states of Oregon, Washington, and Idaho. The Shoshone-Bannock Tribe is admitted as a party for purposes of production and harvest in the upper Snake River only. These parties jointly develop harvest sharing and hatchery management plans that are entered as orders of the court that are binding on the parties. The "relevant co-managers" described in the *U.S. v Orego*n management plans are, for the mid-Columbia sub-basins, the federal parties, Yakama Nation, and Washington Department of Fish and Wildlife.

Hatchery programs are viewed by the Yakama Nation as partial compensation for voluntary restrictions to treaty fisheries imposed by the tribe to assist in rebuilding upriver populations of naturally-spawning salmonids. Because treaty and non-treaty fisheries are restricted on the basis of natural stock abundance, the tribal priority is to use hatcheries in a manner that supplements natural spawning and increases average population productivity. Perspectives on the appropriate use of hatchery-origin fish for supplementation vary between federal, state, and tribal fish co-managers. Federal and, to a lesser degree, state co-managers place a higher priority on managing the genetic risks of hatchery supplementation of natural populations, while the tribe sees the demographic threats of habitat loss and degradation as the greater risk to natural populations. In general, however, all parties agree that hatcheries can and should be operated as integral components of natural populations where the survival benefits of the hatchery can result in a significant increase in net population productivity.

ESA

Current ESA Section 10 Permits for listed summer steelhead (Permit #1395); listed spring chinook (Permit #1196) and non-listed anadromous fish (Permit # 1347) also direct artificial production activities associated with the habitat conservation plans. Douglas PUD, Chelan PUD and WDFW are co-permittees, therefore provisions within the permits and associated Biological Opinions are incorporated into the hatchery programs undertaken in the HCP's.

State:

The state, along with the federal government have various forums in which they are active. All have some role in determining or balancing artificial production programs, as well as the ones that follow under "other". Essentially no specific action would occur until the action is determined to be warranted in the already established processes.

Other:

<u>FERC processes:</u>

Under current settlement agreements and stipulations, the three mid-Columbia PUDs pay for the operation of hatchery programs within the Columbia Cascade Province. These programs determine the levels of hatchery production needed to mitigate for the construction and continued operation of the PUD dams.

Habitat Conservation Plans:
In 2002, habitat conservation plans (HCPs) were signed by Douglas and Chelan PUDs, WDFW, USFWS, NOAA Fisheries, and the Colville Confederated Tribes. The overriding goal of the HCPs are to achieve no-net impact[1] on anadromous salmonids as they pass Wells (Douglas PUD), Rocky Reach, and Rock Island (Chelan PUD) dams. One of the main objectives of the hatchery component of NNI is to provide species specific hatchery programs that may include contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest.

Biological Assessment and Management Plan:
The biological assessment and management plan (BAMP) was developed by parties negotiating the HCPs in the late 1990s. The BAMP was developed to document guidelines and recommendations on methods to determine hatchery production levels and evaluation programs. It is used within the HCP as a guiding document for the hatchery programs.

All of these processes affect the hatchery programs within the Entiat River Basin in one way or another.

Historic programs

Historically, fish have been released as part of the GCFMP beginning in the 1940s. Chinook, sockeye, steelhead and some coho were released as part of that program. Until about 8 years ago, steelhead were also released as part of a state program that was funded by Chelan PUD for mitigation for the operation of Rocky Reach and Rock Island dams.

Current programs

Current program overview: Currently, the Entiat NFH is the only hatchery program within the Entiat Basin. The BAMP identifies the Entiat as a potential reference stream, where no hatcheries would be directly influencing the population dynamics.

Facility description: The hatchery, 6.7 miles upstream from the confluence with the Columbia River, has 2 – 16 x 120 foot adult holding ponds, 30 – 8 x 80 raceways, and 32 starter tanks. Fish returning to Entiat NFH must travel about 491 river miles and negotiate passage through eight Columbia River hydroelectric dams.

[1] NNI refers to achieving a virtual 100% survival of anadromous salmonids as they pass the mainstem projects. This is achieved through 91% survival of adults and juveniles (or 93% for juveniles) passing the projects, and 7% compensation through hatchery programs and 2% contribution through a tributary fund, which will fund projects to improve salmonid habitat in the tributaries.

In the past, the primary water source for the hatchery was the Entiat River. The current program utilizes ground water as the primary source. In 1996, the water rights for the river source (surface) and wells (ground) were combined for a total allotment of 22.5 cfs. The water right for Limekiln Spring is 7 cfs or 3,142 gpm. The hatchery water intake is located at river mile 7.2, approximately 1/3 mile upstream of the hatchery. The intake structure consists of a diversion dam, intake well, and bar trash-racks. Screening for the system is in compliance with current standards.

Surface water is used on a limited basis. It has been determined that Entiat River water contains high organic loads and detrimental parasites *(Myxobolus sp.)* which have been shown to have a negative impact on hatchery fish production. Since 1990, hatchery production has relied primarily on ground and spring water for fish production. The availability of said ground water determines fish production numbers at ENFH.

II. Program Goals and Objectives

Federal program

Grand Coulee Fish Maintenance Project (GCFMP)

The USFWS operates the Leavenworth NFH Complex in the CCP region constructed by the U.S. Bureau of Reclamation (BOR) to replace fish losses that resulted from construction of Grand Coulee Dam. These programs were authorized as part of the Grand Coulee Fish Maintenance Project (GCFMP) on April 3, 1937, and re-authorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. The complex consists of three hatchery facilities, Leavenworth, Entiat, and Winthrop NFHs, with the following mission:

*"To produce high quality spring Chinook salmon and summer steelhead smolts commensurate with the production goals established by the Columbia River Fisheries Management Pla*n" (USFWS 2002a)

Objectives originally established for the Leavenworth Hatchery Complex, as part of the GCFMP were (from Calkins et al. 1939):

1) . . . *to bring, by stream rehabilitation and supplemental planting, the fish populations in the 677 miles of tributary streams between Grand Coulee Dam and Rock Island Dam, up to figures commensurate with the earlier undisturbed conditions and with the natural food supply in the streams.*

2) . . . *to produce in addition, by the combination of artificial spawning, feeding, rearing and planting in these streams, a supplemental downstream migration equivalent to that normally produced by the 1,245 miles of streams and tributaries above Grand Coulee Dam.*

Current objectives of the USFWS hatcheries are outlined in USFWS (1986a, b). In the USFWS Statement of Roles and Responsibilities, the broad roles of the hatcheries are,

. . . to seek and provide for mitigation of fishery resource impairment due to Federal water-related developments . . . the Fishery Resource Program goal, in fulfilling its mitigative responsibilities, is to ensure that established and future fishery resource mitigation requirements are fully and effectively discharged. Implicit in this goal is the replacement of fishery resource losses caused by specific Federal projects . . . and another responsibility of the Leavenworth Hatchery . . . is to restore depleted Pacific salmon and steelhead stocks of national significance in accord with statutory mandates such as the Pacific Northwest Electric Power Planning and Conservation Act, Mitchell Act, Salmon and Steelhead Conservation Act, Pacific Salmon Treaty Act of 1985 and Indian Treaties and related Court decisions.

Shelldrake (1993) updated the objectives of the mid-Columbia NFHs:

- *Hatchery production* [specific to each facility].
- *Minimize interaction with other fish populations through proper rearing and release strategies.*
- *Maintain stock integrity and genetic diversity of each unique stock through proper management of genetic resources.*
- *Maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens.*
- *Conduct environmental monitoring to ensure that hatchery operations comply with water quality standards and to assist in managing fish health.*
- *Communicate effectively with other salmon producers and managers in the Columbia River Basin.*

The initial plan for the operation of the Leavenworth Hatchery Complex (Leavenworth, Entiat and Winthrop NFHs) called for the collection of adult salmon and steelhead at Rock Island Dam and transport to the hatchery for holding and spawning. Eggs and juveniles would subsequently be shipped to the satellite facilities. Sockeye (*O. nerka*), Chinook, and steelhead were the species of emphasis, and later coho were added. Sockeye production ended in the 1960s because of low survival, and disease problems (USFWS 1986a). Coho production also ended in the 1960s

The hatcheries built as part of the GCFMP began operation in the early 1940s at Leavenworth (Icicle Creek, a tributary of the Wenatchee River), Entiat, and Winthrop (Methow River). The Leavenworth facility was built as the main hatchery site, and the Entiat and Winthrop hatcheries as substations. These hatcheries were built as part of the program to relocate populations of salmon and steelhead that formerly ascended the Columbia River upstream from the Grand Coulee Dam site.

III. Program Operations

Entiat NFH released Spring Chinook that originated from commingled upriver stocks intercepted at Rock Island Dam in 1942 and 1944. Annual reports dating from 1945-

1974, indicate that the facility produced summer Chinook, spring Chinook, sockeye, coho, rainbow and steelhead trout either as smolts, fry releases, catchables, and/or eyed egg transfers. Racks were installed across the river as a barrier to deflect returning adult salmonids into the facility. This practice of blocking the river began when water flows permitted work to be done in the river, typically late May early June. Racks were removed usually in November before ice became a problem.

On March 15th, 1951, Entiat NFH was transferred to the Branch of Fishery Biology to serve as a salmon cultural laboratory headed by Roger E. Burrows. Both experimental and production operations were performed. Studies included feeding trials, pituitary, hydraulic, development, and incubation experiments.

In 1953 an electric weir was installed on an experimental basis across the Entiat River to block upstream migration and to ensure adult brood stock collection. The weir was designed similar to electric weirs used in the Great Lakes to control sea lampreys. It consisted of 50, 1.5" pipe electrodes, suspended vertically at 3 foot intervals at an angle across the river. A 1.5"pipe ground line was also installed 15 feet below the electrodes following the contour of the river and parallel to the electrode line. The weir was charged by 110 volt, 60 cycle alternating current. Steelhead, Dolly Varden and other trout were passed above the weir when captured in the holding pond. In 1954, due to the effectiveness of the electric weir at higher water flows some spring Chinook were capture and spawned in August. Of the 903,410 Chinook eggs taken in 1954, 35% were derived from spring Chinook. Sockeye eggs were also taken that year and subsequently shipped to Leavenworth NFH for further rearing. In 1954, the state of Washington negotiated an escapement of 50% for Chinook returning to the Entiat. In 1955, an estimated 200 adults reached spawning grounds above the facility. In 1956, escapement was believed to be over 1000 spring and summer Chinook. The goal at that time was to allow all returning spring Chinook to pass while retaining the summer run for artificial propagation.

On March 1st, 1961 the Entiat NFH was no longer a "Salmon Cultural Laboratory" and was returned to a production facility. The hatchery began to rear rainbow trout as well as Chinook salmon. Rainbow trout were distributed to areas on the Yakama Indian Reservation, Nason and Icicle Creeks, juvenile ponds in Cashmere, WA and the Entiat River. Planting areas expanded in 1963 to include areas on the Warm Springs Reservation, Peshastin and Douglas creeks, and Lilly and Clear Lakes. Distributions of Cutthroat trout were also made. Annual reports do not specify whether or not the electric weir was in operation. Reports do state that the State of Washington was trapping Chinook at Rocky Reach Dam for the Chinook program at Turtle Rock.
Releases of coho salmon smolts began in 1965 and continued until 1970. It appears from the records that the eggs for the Coho program were shipped from Little White Salmon NFH. Records do not indicate why programs started and/or stopped. There were comments about significant trapping taking place at the newly constructed Rocky Reach Dam in the 60's.

In 1974, Spring Chinook salmon smolt production resumed with eggs from several locations; Cowlitz River (1974), Carson NFH (1975-1982), Little White Salmon NFH

(1976, 1978, 1979, 1981), Leavenworth NFH (1979-1981, 1994) and Winthrop NFH (1988). Returning adults have voluntarily entered the fish trap at the facility and have been the primary brood stock for the station in 1980, and from 1982 to 2002 (Cooper et. al. 2002).

Adult spring Chinook salmon return to the hatchery beginning in early to mid-May. The escapement goal for the hatchery is 350 adults for a subsequent release of 400,000 smolts. Extra adults are spawned because of an aggressive program to cull diseased eggs. Bacterial Kidney Disease (BKD) is prevalent at this facility, and highly infected eggs are taken out of production. Spawning begins in mid-August and can continue into mid-September. The ENFH stock of spring Chinook salmon is not listed under the Endangered Species Act (ESA).

All brood stock used for production are volunteers to the facility. Adults swim up the collection ladder and into one of two holding ponds. The holding ponds measure 16 x 120 feet and are supplied with a mixture of surface and ground water for attraction and operation of the ladder.

The ladder operates throughout the entire run spectrum. The goal is to collect all returning hatchery adults so they don't mix and spawn with the listed natural stock found in upriver areas. Excess adults are periodically donated to various tribes for subsistence and ceremonial purposes.

All adult crosses (matings) are randomly made, no selection occurs. Spawning occurs once per week and all females that are ripe on that day are spawned.

Juveniles are released as yearlings annually, in early to mid-April. The yearlings are "force" released directly into the Entiat River when the majority is in a smolt or pre-smolt stage. All juveniles released from ENFH are adipose fin-clipped. With 100% marking of released juveniles, the potential for harvest increases while also strengthening our ability to evaluate ecological affects.

Throughout the years, the spring Chinook release goal at ENFH has varied considerably. The current goal is 400,000 smolts annually. For years 1976 to 2001, the average yearling release was 576,660 fish.

As previously mentioned, the stock of spring Chinook propagated at ENFH is not listed under the ESA. All other stocks found in the Entiat River Basin are listed as "endangered". Therefore, the potential is greater that the program may have a negative influence on the listed stocks present. Potential genetic and ecological affects to the natural population includes; predation, competition, residualism, genetic introgression to natural stocks, and transmission of diseases or parasites. For a description of these effects, please refer to the Hatchery and Genetic Management Plan (HGMP) for this hatchery.

Current evaluation practices include: bio-sampling of returning adults, 100% external marking of all juveniles released, application of PIT tags, assessment of stray rates, travel-time of released juveniles through the Columbia corridor, assessment of potential for hatchery fish to transfer diseases to wild fish, success/failure of hatchery adults spawning naturally, use of NATURE's type rearing,[2] raceway density studies, genetic comparison of hatchery and wild stocks, and feed (fish food) evaluations, among others.

The Leavenworth NFH Complex (Leavenworth, Entiat, and Winthrop NFH's) has a team comprised of staff from the hatcheries, Fish Health, and Mid-Columbia River Fishery Resource Office. This team (Hatchery Evaluation Team) meets twice annually and part of its charge is to evaluate data obtained from on- and off-station studies. If the team decides that the data warrants a change, their request is elevated to supervisors for review or is simply implemented.

IV. Program Success

Entiat NFH was constructed to mitigate for lost habitat due to the construction of Grand Coulee Dam. The primary objective of this facility is to provide fish for harvest. The hatchery stock, although not ESA listed, is a healthy and viable population. Although in some years excess adults were available for harvest, the spring Chinook fishery in the Entiat River has been closed since the mid-1980's. Although few in numbers, some ENFH adults are captured in the lower Columbia River fishery.

Average escapement for years 1980 to 2001 is 677 adults (range = 80 to 2,666). Although no harvest has been allowed in many years, several tribes periodically receive excess adults for subsistence and ceremonial purposes. With 100% marking of released juveniles, the potential for a fishery may increase.

Due to the ESA listing of three species of salmonids in the upper-Columbia region, the USFWS was required to complete a HGMP and numerous Biological Assessments (BA's) describing potential hatchery affects on these populations. The resulting Biological Opinion's (BiOp) are an analysis of the BA's, in which Conservation Recommendations, contained within, direct the USFWS to conduct various assessments. Some of these assessments were mentioned previously in the Monitoring and Evaluation section.

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[2] NATURE's rearing is a "hands off" approach where artificial substrate and woody debris is added to the raceways. Automatic feeders are utilized, negating the need to "hand feed".

Appendix E
Entiat Subbasin Plan

Hatchery Information for Subbasin Planning

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April, 2004

Wenatchee Subbasin

I. Introduction

Various processes are underway within the Columbia Basin that direct hatchery program implementation. The listing of certain populations of fish under the ESA has also dictated hatchery program modifications and reform.

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The Hatchery and Genetic Management Plan (HGMP) process was initiated to identify offsite mitigation opportunities associated with operation of the Federal Columbia River Power System. The HGMP process is designed to describe existing propagation programs, identify necessary or recommended modifications of those programs, and help achieve consistency of those programs with the Endangered Species Act. The HGMP process only addresses anadromous salmon and steelhead programs.

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The primary goal of the HGMP process is to devise biologically-based artificial propagation management strategies that ensure the conservation and recovery of listed Evolutionarily Significant Units (ESUs). The HGMP process also seeks to document and implement hatchery reform in the Columbia Basin. Much of the initial work on the HGMP process was coordinated and combined with efforts to complete the Artificial Production Review and Evaluation (APRE – see below)) analysis, which looked at the same sorts of information.

Artificial Production Review and Evaluation (APRE)
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salmon and steelhead populations. The PCSRF supplements existing state, tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation; promotes efficiencies and effectiveness in recovery efforts through enhanced sharing and pooling of capabilities, expertise and information. The goal of the Pacific Coastal Salmon Recovery Fund is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat.

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Hatchery production programs in the upper Columbia sub-basins are included in the management plans created by the fishery co-managers identified in the treaty fishing rights case *United States v Oregon*. The parties to *U.S. v Oregon* include the four Columbia River Treaty Tribes – Yakama Nation, Warm Springs, Umatilla, and Nez Perce tribes, NOAA-Fisheries, U.S. Fish and Wildlife Service, and the states of Oregon, Washington, and Idaho. The Shoshone-Bannock Tribe is admitted as a party for purposes of production and harvest in the upper Snake River only. These parties jointly develop harvest sharing and hatchery management plans that are entered as orders of the court that are binding on the parties. The "relevant co-managers" described in the *U.S. v Orego*n management plans are, for the mid-Columbia sub-basins, the federal parties, Yakama Nation, and Washington Department of Fish and Wildlife.

Hatchery programs are viewed by the Yakama Nation as partial compensation for voluntary restrictions to treaty fisheries imposed by the tribe to assist in rebuilding upriver populations of naturally-spawning salmonids. Because treaty and non-treaty fisheries are restricted on the basis of natural stock abundance, the tribal priority is to use hatcheries in a manner that supplements natural spawning and increases average population productivity. Perspectives on the appropriate use of hatchery-origin fish for supplementation vary between federal, state, and tribal fish co-managers. Federal and, to a lesser degree, state co-managers place a higher priority on managing the genetic risks of hatchery supplementation of natural populations, while the tribe sees the demographic threats of habitat loss and degradation as the greater risk to natural populations. In general, however, all parties agree that hatcheries can and should be operated as integral components of natural populations where the survival benefits of the hatchery can result in a significant increase in net population productivity.

Federal ESA

Current ESA Section 10 Permits for listed summer steelhead (Permit #1395); listed spring chinook (Permit #1196) and non-listed anadromous fish (Permit # 1347) also direct artificial production activities associated with the habitat conservation plans. Douglas PUD, Chelan PUD and WDFW are co-permittees, therefore provisions within the permits and associated Biological Opinions are incorporated into the hatchery programs undertaken in the HCP's.

State:
The state, along with the federal government has various forums in which they are active. All have some role in determining or balancing artificial production programs, as well as the ones that follow under "other". Essentially no specific action would occur until the action is determined to be warranted in the already established processes.

Other:

<u>FERC processes:</u>
Under current settlement agreements and stipulations, the three mid-Columbia PUDs pay for the operation of hatchery programs within the Columbia Cascade Province. These programs determine the levels of hatchery production needed to mitigate for the construction and continued operation of the PUD dams.

<u>Habitat Conservation Plans:</u>
In 2002, habitat conservation plans (HCPs) were signed by Douglas and Chelan PUDs, WDFW, USFWS, NOAA Fisheries, and the Colville Confederated Tribes. The overriding goal of the HCPs are to achieve no-net impact[1] on anadromous salmonids as they pass Wells (Douglas PUD), Rocky Reach, and Rock Island (Chelan PUD) dams. One of the main objectives of the hatchery component of NNI is to provide species specific hatchery programs that may include contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest.

<u>Biological Assessment and Management Plan:</u>

[1] NNI refers to achieving a virtual 100% survival of anadromous salmonids as they pass the mainstem projects. This is achieved through 91% survival of adults and juveniles (or 93% for juveniles) passing the projects, and 7% compensation through hatchery programs and 2% contribution through a tributary fund, which will fund projects to improve salmonid habitat in the tributaries.

The biological assessment and management plan (BAMP) was developed by parties negotiating the HCPs in the late 1990s. The BAMP was developed to document guidelines and recommendations on methods to determine hatchery production levels and evaluation programs. It is used within the HCP as a guiding document for the hatchery programs.

All of these processes affect the hatchery programs within the Upper Columbia Basin in one way or another.

Historic and current programs and facilities

Historic programs

The first hatchery that released salmonids in the Wenatchee Basin began operation in 1899 on the Wenatchee River (Chiwaukum Creek). This hatchery was built to replenish the salmon (primarily Chinook, and coho) runs, which had virtually been eliminated by the 1890s (Gilbert and Evermann 1895; WDFG 1898). The Wenatchee facility was closed from 1904 to 1913 because of severe weather, logistics of the location, but primarily because it lacked adequate brood stock.

The biggest problems encountered in the early years of the hatcheries were lack of fish for broodstock, and because of irrigation diversions that entrained large numbers of juveniles (both naturally- and artificially produced).

Most of the fish planted from the Wenatchee facility in the first few years of production were probably coho (WDFG 1904-1920; Craig and Suomela 1941). For the first few years, species were not differentiated, with almost 8 million fry planted per year from the Wenatchee facility. Beginning in 1904, when species were differentiated, by far the majority of fish released were coho. After the Wenatchee hatchery was moved downstream near the town of Leavenworth in 1914, Chinook production began again, with supplementation of eggs from other hatcheries as far away as the Willamette and McKenzie rivers of Oregon (WDFG 1914; Craig and Suomela 1941).

Success of the releases of fish from these hatcheries is unknown, but not thought to have been large.

Current programs

Current program overview:

Artificial production of anadromous fish in the Wenatchee Subbasin includes spring Chinook, summer Chinook, summer steelhead, sockeye, and reintroduction of coho salmon (Table 1). Spring Chinook and summer steelhead are currently ESA-listed as endangered through the Endangered Species Act of 1973. Summer Chinook are considered a depressed population. Once extirpated from the Wenatchee Subbasin, small numbers of coho salmon have been reintroduced, and plans are currently in the feasibility stage for larger scale reintroduction. Hatchery intervention in the Wenatchee Subbasin is guided by a two-pronged approach that encourages local adaptation, preservation and enhancement of specific populations while simultaneously spreading the risk through selection of several artificial production alternatives.

Table 1. Artificial anadromous fish production in the Wenatchee Subbasin

Fish Species	Facility	Funding Source	Production level goals
Spring Chinook	Eastbank Fish Hatchery Complex (Chiwawa acclimation pond) (Operated by WDFW)	Chelan County PUD	672,000
	Leavenworth National Fish Hatchery (Operated by USFWS)	Bureau of Reclamation	1,625,000
Steelhead	Eastbank Fish Hatchery Complex (Operated by WDFW)	Chelan County PUD	400,000
Summer Chinook	Eastbank Fish Hatchery Complex (Dryden acclimation pond) (Operated by WDFW)	Chelan County PUD	864,000
Sockeye	Eastbank Hatchery (Operated by WDFW)	Chelan County PUD	200,000
Coho	Leavenworth NFH, Enitat NFH, Peshastin Incubation Facility (Operated by USFWS and YN) Cascade Fish Hatchery (Operated by ODFW) Willard NFH (Operated by USFWS)	BPA (Fish & Wildlife Program)	> 500,000
	Acclimation sites at Nason Creek, Beaver Creek and Icicle Creek (YN)	BPA (Fish & Wildlife Program)	> 500,000

Federal programs

Grand Coulee Fish Maintenance Project (GCFMP)

The USFWS operates the Leavenworth NFH Complex in the CCP region constructed by the U.S. Bureau of Reclamation (BOR) to replace fish losses that resulted from construction of Grand Coulee Dam. These programs were authorized as part of the Grand Coulee Fish Maintenance Project (GCFMP) on April 3, 1937, and re-authorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. The complex consists of three hatchery facilities, Leavenworth, Entiat, and Winthrop NFHs.

Leavenworth NFH

Leavenworth National Fish Hatchery (NFH) was originally authorized by the Grand Coulee Fish Maintenance Project (GCFMP) on April 3, 1937, and reauthorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. It began operations in 1942. Leavenworth NFH is one of three mid-Columbia hatcheries constructed by the Bureau of Reclamation (BOR) as mitigation for the Grand Coulee Dam-Columbia Basin Project. It is currently used for adult collection, egg incubation and rearing of spring Chinook salmon. It also provides juveniles and/or adults for re-establishing spring Chinook runs in other Columbia River tributaries, as needed (e.g., Peshastin Creek adult out-plants). The hatchery complex (Complex) consists of Leavenworth, Entiat, and Winthrop NFH's.

Facility description: Leavenworth NFH is situated on Icicle Creek, 2.8 miles from its confluence with the Wenatchee River. Fish returning to LNFH must travel about 497 miles to and from the ocean, and must pass seven Columbia River hydroelectric dams on their migrations.

Rearing facilities include two – 15 x 150 foot adult holding ponds, 45 – 8 x 80 raceways, 14 – 10 x 100 covered raceways, 72 troughs, 108 starter tanks, plus 40 small and 22 large Foster-Lucas ponds (not used for hatchery production).

The primary water source for the hatchery is Icicle Creek. The water right allows for the diversion of up to 42 cubic feet per second (cfs) for production. During low flows in the summer, the hatchery water supply (Icicle Creek) is supplemented with water from Snow and Nada lakes (up to 16,000 acre feet; these lakes are located in the upper Icicle Creek watershed). The hatchery also has seven wells, with a total water right of 6,700 gallons per minute. The well water is mainly used for egg incubation and early rearing.

State programs

Rock Island Fish Hatchery Complex

The Rock Island Fish Hatchery Complex (RIFHC) began operation in 1989 as mitigation for salmonids lost as a result of operation of Rock Island Dam. The facility was constructed by, and operates under funding from, Chelan PUD originally through the Rock Island Settlement Agreement. Currently, Chelan PUD and fisheries agencies and the Colville Confederated Tribes have signed a habitat conservation plan (HCP). When the HCP is incorporated into Chelan PUD's FERC license, it will supersede the Settlement Agreement. Production levels and evaluation programs are outlined within the HCP (Table 1).

Facility description: The RIFHC has one main incubation and rearing hatchery (Eastbank) and five satellite rearing/acclimation facilities, and four broodstock trapping sites. The main hatchery, Eastbank, has two adult holding ponds, 70 half-stacks of vertical incubators equipped with a chilled water supply (4.5 gpm per half-stack), eight 3,750 cu. ft. raceways and five 22,200 cu. ft. raceways. Eastbank has four wells that supply 53 cfs. This water varies in temperature from a low of 46° F in May to a high of 57° F in December. Rearing space at Eastbank was designed to maintain maximum loading densities below the criteria of Piper et al. (1982), as modified by Wood (Chelan PUD and CH2MHILL 1988).

Three satellite facilities of the RIFHC are found within the Wenatchee River Basin; Lake Wenatchee net pens (sockeye), Chiwawa rearing ponds (spring Chinook), and the Dryden pond acclimation site (summer/fall Chinook). Steelhead are currently scatter planted in Nason Creek, and the Wenatchee and Chiwawa rivers.

At Lake Wenatchee, there are six floating net pens for juvenile rearing (about 20 x 20 x 20 ft) and two adult holding pens (about 16 x 16 x 20). The Chiwawa facility has two 50 x 150 x 5 ft ponds (water source from the Chiwawa and Wenatchee rivers), and the Dryden facility has one 864,000 ft^3 pond (water source from the Wenatchee River).

II. Program Goals and Objectives

Federal programs

Leavenworth National Fish Hatchery (NFH)**:**
Specific fishery objectives which were originally established for Leavenworth NFH were (from Calkins et al. 1939):

1) "…to bring, by stream rehabilitation and supplemental planting, the fish populations in the 677 miles of tributary streams between Grand Coulee Dam and Rock Island Dam, up to figures commensurate with earlier undisturbed conditions and with the natural food supply in the streams."

2) "…to produce, in addition, by the combination of artificial spawning, feeding, rearing and planting in these streams, a supplemental downstream migration equivalent to that normally produced by the 1,245 miles of streams and tributaries above Grand Coulee Dam."

Shelldrake (1993) updated the objectives of the mid-Columbia NFHs:

- *Hatchery production* [specific to each facility].
- *Minimize interaction with other fish populations through proper rearing and release strategies.*
- *Maintain stock integrity and genetic diversity of each unique stock through proper management of genetic resources.*
- *Maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens.*
- *Conduct environmental monitoring to ensure that hatchery operations comply with water quality standards and to assist in managing fish health.*
- *Communicate effectively with other salmon producers and managers in the Columbia River Basin.*

The USFWS's current mission for the Leavenworth complex is (USFWS 2002a):

> *"To produce high quality spring Chinook salmon and summer steelhead smolts commensurate with the production goals established by the Columbia River Fisheries Management Pla*n"

Original production consisted of Chinook salmon trapped at Rock Island Dam (1940 – 43), but since then has included several resident and anadromous salmonid species, including spring, summer, and fall Chinook, coho, sockeye, summer steelhead, rainbow trout, and kokanee.

Early spring Chinook salmon stocks used for the program came from several lower Columbia River locations. These include McKenzie River, OR (1941); Willamette River, OR (1965); Eagle Creek NFH (1966); Cowlitz River (1974, 76); Little White Salmon NFH (1974, 77-79), and the current stock originated from Carson NFH (1970-73, 75-81, 85). The Carson stock developed from adults, trapped at large, from Bonneville Dam in the 1950's. No eggs or fry have been imported into LNFH for almost 20 years.

State programs

Rock Island Fish Hatchery Complex

The goal of the RIFHC is to use artificial production to replace adult production lost due to smolt mortality at mainstem hydroelectric projects, while not reducing the natural production or long-term fitness of salmonid stocks in the area (WDF 1993). Specific goals of the WDFW hatcheries (WDF 1993) are:

- *Hatchery production* [in terms of number of fish released from each site],
- *minimize interactions with other fish populations through rearing and release strategies, maintain stock integrity and genetic diversity of each population or unique stock through proper management of genetic resources.*
- *maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens,*
- *conduct environmental monitoring to ensure that the hatchery operations comply with water quality standards and to assist in managing fish health,*
- *communicate effectively with other salmon producers and managers in the Columbia River basin, and with implementers of local and regional flow and spill programs, and*
- *develop a Conservation Plan and conduct a comprehensive monitoring/evaluation program to determine that the program meets mitigation obligations, estimate survival to adult, evaluate effects of the program on local naturally producing populations, and evaluate downstream migration rates in regards to size and timing of fish released.*

Yakama Nation Program

The long-term goal of the YN/BPA Mid-Columbia Coho Reintroduction Feasibility Project is to reestablish naturally reproduction coho salmon populations in mid-Columbia river basins (Wenatchee, Entiat, and Methow), with numbers at or near carrying capacity that provide opportunities for harvest (YN et.al. 2002). The long-term goal is closely tied to the vision of reintroduction of coho in the Yakima basin and other areas from which the species has been eliminated. Mid-Columbia coho reintroduction is identified as a priority in the *Wy-Kan-Ush-Mi-Wa-Kish-Wit* document (Tribal Restoration Plan) and by the four Columbia River Treaty Tribes and has been affirmed as a priority by the Northwest Power Planning Council.

The short term goals of the feasibility phase, expected to last through 2004, is to determine whether a broodstock can be developed from Lower Columbia River coho stocks, whose progeny can survive in increasing numbers to return as adults to the mid-Columbia region, and to initiate natural reproduction in areas of low risk to sensitive species and in other select areas to study the risks and interactions with sensitive species (YN et al. 2002). Studies completed during the feasibility phase will inform future decisions about whether the long-term vision can be achieved.

III. Program Operations

Federal

Leavenworth National Fish Hatchery

<u>Brood stock collection and spawning:</u>
Adult spring Chinook salmon return to the hatchery beginning in late April – early May. The adult escapement goal for the hatchery (number of adults needed to meet the production goal) is 1,000. Beginning in 2001, an additional 350 adults have been collected for transfer and release into Peshastin Creek for natural spawning.

All brood stock used for production are volunteers to the facility. Adults swim up the collection ladder and into one of two holding ponds. The holding ponds measure 15 x 150 feet, and are joined in the middle by an adjustable slide-gate. The gate is opened and adults are allowed to enter the second pond during sorting, counting, etc. The holding ponds supply attraction water for the ladder. Adults are secured from throughout the run spectrum, which results in excess brood. Excess fish are periodically donated to various tribes and a local non-profit group (TU).

The ladder typically operates from May into July. Because of limited space in the holding ponds, coupled with the desire to keep surplus adults in the river for harvest, the ladder in some years is "pulsed" (opened a few days per week).

The adult pre-spawning survival goal is 98%, and for years 1993 to 2002, averaged just over 95% (87-97%; D. Davies, pers. comm.).

Spawning usually begins in mid-August, and can continue into early-September. Approximately two weeks prior to initial spawning, all adult females are injected with an antibiotic (erythromycin), to help combat the vertical transmission of Bacterial Kidney Disease (BKD) from the mother to the eggs.

Pathogen and disease monitoring start with adult testing of captured populations for all reportable aquatic viruses and bacteria at the minimum assumed pathogen prevalence level of 5% (i.e. 50 individuals). Since approximately 1994, the actual sampling has been a minimum of 210 adults (60 males and 150 females) for these pathogens. In addition, all females spawned are specifically and individually tested for *Renibacterium salmoninarum*, the causative agent of BKD. This is essential to determine the pathogen levels and eliminate or segregate the resulting eggs from different risk levels. This process greatly reduces the likelihood of transmitting the disease from infected females to progeny. All eggs and accompanying containers are disinfected with iodine solution during the water hardening process following fertilization.

<u>Juvenile releases:</u> Juveniles are released annually as yearlings in mid-April. The yearlings are forced from the ponds, directly into Icicle Creek, when the majority is in a smolt or pre-smolt

stage. Timing of release is coordinated with Columbia mainstem project operations to help maximize downstream migration survival. All juveniles released from LNFH are adipose fin-clipped. With 100% marked juveniles, subsequent adult harvest can be maximized while also strengthening the ability to evaluate ecological effects. The current release goal is 1,625,000 smolts annually. From 1971 to 2001, annual releases of spring Chinook from LNFH have averaged 1,649,074 fish.

<u>Hatchery Barrier:</u> Built in 1938 – 1940, the barrier was designed to exclude ascending adults from areas upstream of the hatchery and to help insure sufficient adults for brood. In recent years, the USFWS, along with other entities, have investigated the potential of providing passage for certain fish species to areas above the barrier. The effects of, and potential solutions to the barrier issue are currently being addressed in a Final Environmental Impact Statement (FEIS) that has been drafted and issued. Current plans are to provide passage in the next few years (2005 or 2006).

<u>Hatchery water intake system:</u> The hatchery's water delivery system consists of three major components and conveyance systems: 1) the gravity intake on Icicle Creek, 2) the Snow Lake Supplementation Water Supply Project and, 3) the well system on hatchery property.

The intake is located at RM 4.5, approximately 1.5 miles upstream of the hatchery. Water is conveyed to the hatchery through a buried 31-inch pipe system. This water enters a sand-settling basin and on through two screen chambers prior to its arrival at the hatchery. The water intake structure consists of a diversion dam, fish ladder, wide bar trash rack (6 inch spacing) and another narrower bar trash rack (1 1/2 inch spacing) located in a building. This structure is currently not properly screened, but plans are underway to bring it into compliance.

Entrained fish in the system can return to the river several ways: 1) the Cascade irrigation diversion, which branches off the system below the intake, has a drum screen to divert fish into a sluiceway back to the river, 2) the overflow area at the sand-settling basin can pass fish back to the river via effluent and, 3) the two screen chambers. One is within a building and is equipped with 1/8 inch x 1/8 inch plastic coated screens which divert fish into a bypass pipe to the river. The other screen chamber is covered and is equipped with 3/32-inch round-holed screens, which divert fish into an overflow channel leading back to the river. From both screen chambers, water is delivered to the rearing ponds and back to the river. Both screen chambers meet the standards for screening criteria described in the *1994 Policies and Procedures for Columbia Basin Anadromous Salmonid Hatcheries* developed by NMFS.

During construction of the hatchery, it was recognized that surface flow in Icicle Creek might at times be insufficient to meet production demands. A supplementary water supply project in Snow and Nada Lakes was therefore developed and a water right to 16,000 acre feet of Snow Lake was obtained. These lakes are located approximately 7 miles from the hatchery and about one-mile above it in elevation. A _ mile tunnel was drilled and blasted through granite to the bottom of Snow Lake and a control valve was installed at the outlet of the tunnel. Operation of the control valve is determined by Icicle Creek flow and water temperature. The control valve is typically opened mid-July or as soon as the creek water consistently reaches 58°F (D. Davies, USFWS, pers. comm.). Water drained from Snow Lake enters Nada Lake, which drains into

Snow Creek, a tributary to Icicle Creek that enters at RM 5.5. Thus, supplemental flows, ranging from 45 to 60 cfs from Snow Creek, enter Icicle Creek one-mile above LNFH's intake system.

During critical periods of the rearing cycle, well water is used to cool/warm stream water, and stream water to temper well water. The intake and water delivery systems are currently being addressed under a separate Biological Assessment and consultation process.

Evaluation: The Mid-Columbia River Fishery Resource Office (MCRFRO) provides monitoring, evaluation, and coordination services concerning Leavenworth NFH production. MCRFRO staff monitors hatchery returns, biological characteristics of the hatchery stock, fish marking, tag recovery, and other aspects of the hatchery program, and they maintain the database that stores this information. MCRFRO also cooperates with the hatchery, fish health and technology centers, and co-managers to evaluate fish culture practices, assess impacts to native species, and coordinate hatchery programs both locally and regionally.

The Leavenworth NFH Complex has a team comprised of staff from the hatcheries, Fish Health, and the MCRFRO (Hatchery Evaluation Team). Current evaluation practices/studies include: bio-sampling of returning adults, 100% external marking of released juveniles, application of PIT tags, assessment of stray rates, travel-time of released juveniles through the Columbia River corridor, assessment of potential of hatchery fish to transfer diseases to wild stocks, success/failure of hatchery produced adults to reproduce naturally, use of NATURE's type rearing[2], raceway density studies, genetic comparisons of hatchery and wild stocks, and feed (fish food) evaluations, among others. The sport harvest in Icicle Creek is also closely monitored to measure potential impacts to the listed stocks.

State program

Program operations for the various species raised under the RIFHC are as follows:

Sockeye

Broodstock is captured at Tumwater Dam on the Wenatchee River. Adults are hauled to Lake Wenatchee, where they are held and spawned. Eggs are then incubated and early reared at Eastbank Hatchery. The hatchery production level is currently 200,000 subyearlings, reared in net pens in Lake Wenatchee from July through November. Sockeye are released at two different times (August and November) in an effort to reduce post-release mortality.

Under the Chelan PUD's HCP, compensation for sockeye for the Wenatchee independent population could be increased, but not until 2013.

Spring Chinook

Returning spring Chinook adults are collected at a weir on the Chiwawa River and a ladder trap at Tumwater Dam. Fish are then hauled to Eastbank Hatchery, where they are spawned, incubated and reared until the following October.

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[2] NATURE's rearing is a "hands off" approach where artificial substrate and woody debris is added to the raceways. Automatic feeders are also utilized, negating the need to "hand feed".

Production at Eastbank Fish Hatchery has varied considerably since the program began with brood year 1989. The variability in production is a function of poor adult returns, inefficient traps, and different broodstock collection strategies stemming from adaptive management strategies for this population. Smolt production from the Eastbank Fish Hatchery has averaged 116,012 smolts annually, representing 17.3% of the interim production level (672,000) identified in the BAMP (1998). Under the Chelan PUD's HCP, compensation for spring Chinook for the Wenatchee independent population could be decreased, possibly prior to 2013.

Summer Chinook

Artificial production of summer Chinook for the Wenatchee Subbasin is run under the RIFHC. Summer Chinook production at Eastbank Hatchery is intended to mitigate for summer Chinook losses at Rock Island Dam. The production level for the Wenatchee River is a total of 864,000 yearling summer Chinook at 10 fish/lb (BAMP 1998).

Broodstock (492 adults) are collected at the left and right bank Dryden traps and Tumwater Dam trapping facility and transported to the Eastbank Hatchery. Incubation, spawning, and initial rearing of Wenatchee summer Chinook take place at the Eastbank facility. The fish are then transferred to the Dryden Acclimation Pond towards the end of their second winter, where they are volitionally released at smolt size (10fish/lb.) into the Wenatchee River in April-May.

Summer Steelhead

Adult Wenatchee River summer steelhead are collected for broodstock from the run-at-large at the right and left bank Dryden Dam traps and Tumwater Dam. The program goal is to collect a minimum of 50% natural origin adults and to exclude progeny of HxH matings in the hatchery component. Due to adult steelhead holding temperatures at Eastbank FH, steelhead are transferred to, held, and spawned at Wells FH. Incubation and final rearing occurs at Eastbank FH facilities.

The annual release goal For Eastbank FH is 400,000 smolts into the Wenatchee River, Nason Creek, and Chiwawa River basins however, smolt production from the Eastbank Fish Hatchery has averaged 266,632 smolts annually, representing 66.7% of the interim production level identified in the BAMP (1998).

Non-anadromous fish releases

Non anadromous fish have been planted within the Wenatchee Basin since the early 1900s. Rainbow trout, cutthroat trout, brook trout, and a few brown trout have all been planted at various times through multiple hatchery programs.

Following micro-habitat work in the 1980s that showed negative effects on pre-smolt steelhead from "catchable" releases of rainbow trout, all releases of rainbow were shifted from streams to various lakes within the basin which did not have connectivity to anadromous areas.

Yakama Nation Program

Coho

Adult coho salmon are collected by the Tribe from the run-at-large primarily from the right and left bank Dryden Dam traps. In years when insufficient numbers of coho are taken at Dryden Dam, supplemental broodstock may be collected at Tumwater Dam, Dam 5 on Icicle Creek, and/or the LNFH fishway. Currently the program collects naturally produced coho in the proportion in which they occur within the run. Adult coho are transferred to Entiat National Fish Hatchery where they are held and spawned by the YN and USFWS. Coho eggs are incubated at Entiat National Fish Hatchery, YN's Peshastin Incubation Facility, and in some years, Leavenworth NFH. Upon reaching between 500 and 600 temperature units, the coho eggs are transferred to Willard National Fish Hatchery and Cascade FH for rearing. Eagle Creek National Fish Hatchery was a rearing facility for coho released in mid-Columbia tributaries brood years 1998 and 2000. Eagle Creek National Fish Hatchery may be used as a rearing facility again in the future. Coho smolts produced from adult returns to the Methow River have been released in the Wenatchee Basin. Currently in the feasibility phase, changes in rearing, incubation, and acclimation facilities may continue to occur. Details on mating protocols, rearing and acclimation strategies, size at release and monitoring and evaluation can be found in the Yakama Nation's Mid-Columbia Coho HGMP (YN et al.2002).

Under the feasibility study, the Wenatchee River coho release goal is 1,000,000 smolts. Over one-half of smolts are currently released into Icicle Creek from Dam 5 and/or LNFH small Foster Lucas Ponds, for the purpose of broodstock development. The remainder of the coho smolts are acclimated and released from small natural ponds near suitable coho spawning and rearing habitat in Nason Creek, Beaver Creek, and the Little Wenatchee River. The actual numbers locations of coho release are re-evaluated annually.

<u>Conservation of the Species:</u> The capture of endangered UCR spring Chinook salmon and summer steelhead by WDFW for artificial propagation efforts are designed to benefit the species. The primary objectives of these efforts are to preserve extant spring Chinook and steelhead populations in the region, and to boost the abundance of remaining stocks. There are risks of ecological and genetic impacts to the ESA-listed juvenile and adult spring Chinook salmon and steelhead resulting from the proposed programs. However, the risk of extinction to natural populations is high enough that aggressive intervention is required.

<u>Genetic and Ecological Effects on Natural Populations:</u> The genetic risks to naturally produced populations from artificial propagation include reduction in the genetic variability (diversity) among and within populations, genetic drift, selection, and domestication which can contribute to a loss of fitness for the natural populations (Hard *et al.*1992; Cuenco *et al.* 1993; NRC 1996; and Waples 1996).

Disease interactions between hatchery fish and listed fish in the natural environment may be a source of pathogen transmission. Because the pathogens responsible for diseases are present in both hatchery and natural-origin populations, there is some uncertainty associated with determining the extent of disease transmission from hatchery fish (Williams and Amend 1976; Håstein and Lindstad 1991).

To address concerns of potential disease transmission from hatchery to natural fish, the Pacific Northwest Fish Health Protection Committee (PNFHPC) has established guidelines to ensure hatchery fish are released in good condition, thus minimizing impacts to natural fish (PNFHPC 1989). Also, the IHOT (1995) developed detailed hatchery practices and operations designed to prevent the introduction and/or spread of any fish diseases with the Columbia River Basin.

Direct competition for food and space between hatchery and listed fish may occur in spawning and/or rearing areas, the migration corridor, and ocean habitat. These impacts are assumed to be greatest in the spawning and nursery areas and at points of highest fish density (release areas) and to diminish as hatchery smolts disperse (USFWS 1994).

Competition for space and cover in the Wenatchee River probably occurs between hatchery and natural fish shortly after release and during downstream migration, but based on the smolt travel times the duration of interaction is minimal in the river (WDFW 1998a). Rearing and release strategies at all WDFW salmon and steelhead hatcheries are designed to limit adverse ecological interactions through minimizing the duration of interaction between newly liberated hatchery salmon and steelhead and naturally produced fish.

Hatchery fish may prey upon listed fish. Due to their location, size, and time of emergence, newly emerged Chinook salmon fry are likely to be most vulnerable to predation by hatchery released fish. Their vulnerability is believed to be greatest as they emerge and decreases somewhat as they move into shallow, shoreline areas (USFWS 1994). Emigration out of hatchery release areas and foraging inefficiency of newly released hatchery smolts may minimize the degree of predation on Chinook salmon fry (USFWS 1994).

Hatchery salmonids that do not emigrate after release are said to have residualized. These fish that residualize can adversely affect naturally produced fish through competition and predation. Chinook salmon do not tend to residualize (Groot and Margolis 1991), thus no effects are expected on natural UCR spring Chinook salmon or steelhead in the Wenatchee River.

<u>Harvest Management:</u> Fish harvest in the Columbia River basin affects the listed species by incidentally taking them in fisheries that target non-listed species. The largest potential impacts on UCR spring Chinook and steelhead come from treaty Indian and non-tribal fisheries in the Columbia River mainstem and potentially tributaries (Icicle Creek) (Myers *et al.* 1998).

A sport fishery for steelhead in the UCR has been authorized under Section 10 Permit 1395. In years when the escapement of hatchery origin steelhead is greater than expected (i.e., over-escapement) the fishery was specifically designed to remove excess hatchery fish from the spawning grounds with minimal impacts to the natural origin steelhead.

<u>Domestication of Hatchery Fish:</u> Another concern of the artificial propagation of salmon is domestication, which is the change in quantity, variety, and combination of alleles within a captive population or between a captive population and its source population in the wild that are

the result of selection in an artificial environment (Busack and Currens 1995). Domestication occurs because putting fish into an artificial environment for all or part of their lives imposes different selection pressures on them than does the natural environment. The concern is that domestication effects will decrease the performance of hatchery fish and their descendants in the wild. The concern is that hatchery fish selected to perform well in a hatchery environment tend to not perform well when released into the wild due to the difference between the hatchery and the wild environments. Potential impacts to the natural population occur when the hatchery fish spawns in the wild and the resulting performance of the natural population is reduced due to outbreeding depression (Busack and Currens 1995). The selection of broodstock is a common source of biased sampling. In general, broodstock selection should be random but bias occurs when selection is based on particular traits. Genetic changes due to unintentional selection can be caused by the hatchery environment, which allows more fish to survive compared to the natural environment. The elimination of all risks due to genetic diversity loss and domestication is not possible, but NOAA Fisheries believes that these risks can be minimized through the following measures proposed for the adult supplementation program:

- Address genetic concerns regarding selectivity, the collection of adult broodstock at traps for the supplementation program shall be representative of the run-at-large with respect to natural and hatchery parentage, migration timing, age class, morphology, and sex ratio;
- Provide that a proportion of each population that will not be subjected to artificial propagation and the associated potential risk of negative genetic effects, upstream escapement goal of approximately 80 adults per population will be maintained as a minimum level for natural spawning when escapement to Wells Dam is greater than 668 adults;
- An effective population size (N_e) of 500 fish per population per generation should be the *long-term* program production objective to maintain an adequate genetic base, even thought an N_e of at least 50 adults per generation is required to reduce the risk of inbreeding depression and genetic drift in the short term (fewer than 5 salmon generations) (BAMP 1998). If fewer adults are available, production can be scaled to ensure that hatchery-origin progeny do not overwhelm the population as a whole;
- Rear fish at minimum pond loading densities to reduce the risk of domestication effects and;
- Eliminate of Carson-stock spring Chinook (a highly domesticated stock) that will further reduce potential genetic effects.

Monitoring and Evaluation*:* The evaluation plan includes genetic monitoring of the hatchery and naturally produced fish, migration timing and survival of the hatchery releases, and studies to evaluate interaction between hatchery and naturally produced fish. Monitoring and evaluation of the hatchery programs in the Methow River is on-going. The plan for the adult-based supplementation program addresses three critical uncertainties associated with the program:

- whether the hatchery facilities can safely meet their production objectives;
- the effect of the programs on the long-term reproductive success of the population in the natural environment;
- the identification of ways to operate the facilities to reduce the short-term ecological impacts to the naturally produced fish (WDFW 1998a).

Adaptive Management
The monitoring and evaluation program will also provide data that can be used to change the program if the results suggest doing so. The monitoring and evaluation programs will also provide invaluable data on the use of supplementation to conserve and recover ESA-listed salmon species.

Tribal Harvest Allocations
All hatchery programs in the Methow Basin are currently included in the Columbia River Fish Management Plan (i.e., US *v.* Oregon).

IV. Program Success

Federal program

Adult returns: Chapman et al. (1995) compared the number of smolts[3] released to the number of adults returning to the Wenatchee, Entiat, and Methow rivers. For fish returning to the Wenatchee River, the smolt-to-adult survival averaged 0.45% (range: 0.14 - 0.99%, corrected for inter-dam loss, and incidental in-river and ocean harvest) between release year 1978 and 1990. Shelldrake (1993) lists the smolt-to-adult survival goal as 0.5%, which he shows as the five year average (range 0.12-0.92%). Mullan et al. (1992) report the mean smolt-to-adult survival of fish from Leavenworth NFH from 1976 - 1988 as 0.55% (range: 0.21-0.70%). They conclude,

> *The universal presence of bacterial kidney disease (BKD) in hatchery stocks is a prime suspect for the poor returns of Chinook salmon. Equally obvious is that the behavior of Chinook salmon in hatcheries is conditioned differently from that of wild fish. Large age-0 and yearling Chinook salmon smolts released to Icicle Creek were not cover-oriented, remained at the water surface and drifted downstream in the thalweg regardless of season or time of day, and had no apparent social structure, and were hyperactive . . . Recently hatched fry released to Icicle Creek, by contrast quickly removed themselves from the strong currents and mimicked the behavior of naturally produced Chinook . . . Behavior and BKD in hatchery Chinook is related . . .*

While the return per release of adult Chinook may be low, hatchery fish have still made up the majority of returning fish to the Wenatchee River in most years since the 1960s. Hatchery fish have made up greater than 50% of the run in practically every year since 1980. The percentage of hatchery fish in the spring Chinook run in the Wenatchee River appears to be increasing in recent years, probably as a result of increased smolt-to-adult survival in the early 1990s.

[3] They did not account for fry or parr releases in our estimates, or fish released in the fall or winter. While it is probable that these fish have made some contribution to the returning adults, they were unsure how to represent post release mortality (i.e., how many of the fish actually migrated downstream). Considering this, the estimates of smolt-to-adult survival that they derived should be considered biased upward.

The sport and tribal harvest in Icicle Creek, which is entirely attributed to LNFH, is the only fishery on spring Chinook in the upper-Columbia Region. For years 1984 to 2001, an average of 6,005 adults (range= 484 to 15,082) of LNFH origin have returned to the Wenatchee River Basin.

State program

Viable Populations:

Spring Chinook
Based on parr production, supplementation appears to be improving the Chiwawa spring Chinook population to some degree (Hillman and Miller 2002). However, it is difficult to quantify because the potential trends observed by Hillman and Miller need to be combined with population estimates and survival rates from reference areas before the total "picture" is known.

Summer Chinook
High escapements of summer Chinook in the Wenatchee Basin in recent years have been positively influenced in part by the hatchery program at Dryden Pond. A goal of a supplementation program is to increase the number of spawners by allowing hatchery fish to spawn naturally. Subsequent increases in the number of naturally produced fish on the spawning grounds would support the hypothesis that hatchery fish contributed to future adult returns.

Steelhead
An increase in the number of wild fish incorporated into the broodstock would reduce any potential genetic impacts to the wild fish. In the Wenatchee Basin, near equal proportions of hatchery and naturally produced adults allows for a broodstock composition that minimizes potential genetic impacts.

Sockeye
Poor post release survival (i.e., predation) likely reduced the survival rates of the Wenatchee sockeye program. Recent changes to the size and time of release have significantly increased the post release survival of the hatchery fish. Subsequent adult returns are not complete, but are expected to be much greater than previously reported.

Contribution of adults to recovery or harvest:
Returning adults from these programs are intended to increase to naturally spawning populations. The hatchery programs have successfully contributed adults to the naturally spawning populations. However, harvest does occur in years of high abundance on summer chinook and sockeye.

Smolt to adult return rates for Chiwawa spring chinook averaged 0.33 for brood years 1989 through 1997 (range: 0.04-0.96). For Wenatchee steelhead, smolt to adult returns averaged 0.47 for brood years 1996 through 2000 (range: 0.12-1.24). Wenatchee sockeye averaged 0.6 for brood years 1989 through 1997, ranging from 0.0-2.14. Wenatchee summer chinook have averaged 0.29 for brood years 1989 through 1997, ranging from 0.03-0.98.

Effects on Wild and Native Populations and Environment: Effects on the wild populations (target and non-target) will be assessed at the juvenile stage using smolt traps and when fish return as adults. The relative productivity of the spawning population will be monitored over time using smolt traps located within the Basin. Relationships between smolt production and spawner abundance (% hatchery fish on the spawning grounds) will provide information related to reproductive potential of the stocks and habitat. Relationships in productivity between stocks would also provide some information regarding competition in the freshwater environment. Smolt traps also provide information regarding trends in other species not directly associated with hatchery programs (i.e., non-target taxa of concern).

Spawning ground surveys will not only be used to develop smolt-to-adult return rates (SARs) for hatchery and wild fish, but provide information on spawn timing and distribution. Biological data collected from carcasses will also provide data concerning age and size at maturity.

Comparisons of any these parameters (juvenile or adult) between hatchery and wild fish would provide insight on the effects hatchery fish may have on wild populations. Any effects that are detected (greater than acceptable levels) would be addressed in subsequent changes in the respective hatchery program.

Yakama Nation

Coho Salmon

The first releases of coho salmon into the Wenatchee River under the YN's coho reintroduction project began in 1999. Smolt-to-Adult survival rates have ranged from 0.03% to 0.51%. The first significant adult returns of first generation mid-Columbia brood coho occurred in 2003 with the highest observed SAR (0.51%) since the projects inception.

Spawning ground surveys have been used to record naturally spawning coho in the Wenatchee Basin. As a direct result of the reintroduction effort, naturally spawning coho have been found in Nason Creek, Beaver Creek, Wenatchee River, Icicle Creek, Peshastin Creek, and Mission Creek. The population of naturally produced coho smolts emigrating from the Wenatchee River was estimated to be approximatelty17,054 in 2002 (BY 2000) and 36,678 in 2003 (BY 2001) (T. Miller WDFW, unpublished data).

Results of species interaction work have been equally promising. The YN has observed extremely low levels of predation by hatchery coho smolts on spring chinook fry as demonstrated through several predation evaluations in the Wenatchee and Yakima Rivers. Studies to evaluate predation by naturally produced coho on spring chinook fry are in the early stages. Two years of microhabitat and competition evaluations indicated that naturally reared coho parr selected different habitats than spring chinook parr or steelhead.

Entiat Subbasin

I. Introduction

Various processes are underway within the Columbia Basin that direct hatchery program implementation. The listing of certain populations of fish under the ESA has also dictated hatchery program modifications and reform.

Some of the principal processes are:

Federal:

Hatchery and Genetic Management Plans:
The Hatchery and Genetic Management Plan (HGMP) process was initiated to identify offsite mitigation opportunities associated with operation of the Federal Columbia River Power System. The HGMP process is designed to describe existing propagation programs, identify necessary or recommended modifications of those programs, and help achieve consistency of those programs with the Endangered Species Act. The HGMP process only addresses anadromous salmon and steelhead programs.

Hatchery and Genetic Management Plans are described in the final salmon and steelhead 4(d) rule (July 10, 2000; 65 FR 42422) as a mechanism for addressing the take of certain listed species that may occur as a result of artificial propagation activities. NOAA Fisheries will use the information provided by HGMPs in evaluating impacts on anadromous salmon and steelhead listed under the ESA. In certain situations, the HGMPs will apply to the evaluation and issuance of section 10 take permits. Completed HGMPs may also be used for regional fish production and management planning by federal, state, and tribal resource managers.

The primary goal of the HGMP process is to devise biologically-based artificial propagation management strategies that ensure the conservation and recovery of listed Evolutionarily Significant Units (ESUs). The HGMP process also seeks to document and implement hatchery reform in the Columbia Basin. Much of the initial work on the HGMP process was coordinated and combined with efforts to complete the Artificial Production Review and Evaluation (APRE – see below)) analysis, which looked at the same sorts of information.

Artificial Production Review and Evaluation (APRE):

The APRE process seeks to document progress toward hatchery reform in the Columbia Basin. The NPCC used consultants and representatives of the Columbia Basin fishery managers to analyze existing programs and recommend reforms; a draft report that will go to the Council and the region has been prepared. The APRE process includes both anadromous and non-anadromous fish in its analysis.

Pacific Coastal Salmon Recovery Fund

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established in FY2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to Endangered Species Act (ESA) listings of West Coast salmon and steelhead populations. The PCSRF supplements existing state, tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation; promotes efficiencies and effectiveness in recovery efforts through enhanced sharing and pooling of capabilities, expertise and information. The goal of the Pacific Coastal Salmon Recovery Fund is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat.

The PCSRF's enhancement objective is*: To conduct activities that enhance depressed stocks of wild anadromous salmonids through hatchery supplementation, reduction in fishing effort on depressed wild stocks, or enhancement of Pacific salmon fisheries on healthy stocks in Alaska. This includes supplementation and salmon fishery enhancements*.

US v. OR

United States v Oregon, originally a combination of two cases, Sohappy v. Smith and U.S. v. Oregon, legally upheld the Columbia River treaty tribes reserved fishing rights. Specifically the decision acknowledged the treaty tribes reserved rights to fish at "all usual and accustomed" places whether on or off the reservation, and were furthermore entitled to a "fair and equitable share" of the resource. Although the Sohappy case was closed in 1978, U.S. v. Oregon remains under the federal court's continuing jurisdiction serving to protect the tribes treaty reserved fishing rights. This case is tied closely to U.S. v. Washington, which among other things defined "fair and equitable share" as 50 percent of all the harvestable fish destined for the tribes' traditional fishing places, and established the tribes as co-managers of the resource.

In 1988, under the authority of U.S. v. Oregon, the states of Washington, Oregon and Idaho, federal fishery agencies, and the treaty tribes agreed to the Columbia River Fish Management Plan (CRFMP), which was a detailed harvest and fish production process. There are no financial encumbrances tied to the process. Rather, the fish production section reflects current production levels for harvest management and recovery purposes, since up to 90% of the Columbia River harvest occurs on artificially produced fish. This Plan expired in 1998, and has had subsequent annual rollover of portions in which agreement has been reached. However, a newly negotiated CRFMP is forthcoming.

Hatchery production programs in the upper Columbia sub-basins are included in the management plans created by the fishery co-managers identified in the treaty fishing rights case *United States v Oregon*. The parties to *U.S. v Oregon* include the four Columbia River Treaty Tribes – Yakama Nation, Warm Springs, Umatilla, and Nez Perce tribes, NOAA-Fisheries, U.S. Fish and Wildlife Service, and the states of Oregon, Washington, and Idaho. The Shoshone-Bannock Tribe is admitted as a party for purposes of production and harvest in the upper Snake River only. These parties jointly develop harvest sharing and hatchery management plans that are entered as orders of the court that are binding on the parties. The "relevant co-managers" described in the *U.S. v Orego*n management plans are, for the mid-Columbia sub-basins, the federal parties, Yakama Nation, and Washington Department of Fish and Wildlife.

Hatchery programs are viewed by the Yakama Nation as partial compensation for voluntary restrictions to treaty fisheries imposed by the tribe to assist in rebuilding upriver populations of naturally-spawning salmonids. Because treaty and non-treaty fisheries are restricted on the basis of natural stock abundance, the tribal priority is to use hatcheries in a manner that supplements natural spawning and increases average population productivity. Perspectives on the appropriate use of hatchery-origin fish for supplementation vary between federal, state, and tribal fish co-managers. Federal and, to a lesser degree, state co-managers place a higher priority on managing the genetic risks of hatchery supplementation of natural populations, while the tribe sees the demographic threats of habitat loss and degradation as the greater risk to natural populations. In general, however, all parties agree that hatcheries can and should be operated as integral components of natural populations where the survival benefits of the hatchery can result in a significant increase in net population productivity.

ESA

Current ESA Section 10 Permits for listed summer steelhead (Permit #1395); listed spring chinook (Permit #1196) and non-listed anadromous fish (Permit # 1347) also direct artificial production activities associated with the habitat conservation plans. Douglas PUD, Chelan PUD and WDFW are co-permittees, therefore provisions within the permits and associated Biological Opinions are incorporated into the hatchery programs undertaken in the HCP's.

State:
The state, along with the federal government have various forums in which they are active. All have some role in determining or balancing artificial production programs, as well as the ones that follow under "other". Essentially no specific action would occur until the action is determined to be warranted in the already established processes.

Other:

FERC processes:
Under current settlement agreements and stipulations, the three mid-Columbia PUDs pay for the operation of hatchery programs within the Columbia Cascade Province. These programs determine the levels of hatchery production needed to mitigate for the construction and continued operation of the PUD dams.

Habitat Conservation Plans:
In 2002, habitat conservation plans (HCPs) were signed by Douglas and Chelan PUDs, WDFW, USFWS, NOAA Fisheries, and the Colville Confederated Tribes. The overriding goal of the HCPs are to achieve no-net impact[4] on anadromous salmonids as they pass Wells (Douglas

[4] NNI refers to achieving a virtual 100% survival of anadromous salmonids as they pass the mainstem projects. This is achieved through 91% survival of adults and juveniles (or 93% for juveniles) passing the projects, and 7% compensation through hatchery programs and 2% contribution through a tributary fund, which will fund projects to improve salmonid habitat in the tributaries.

PUD), Rocky Reach, and Rock Island (Chelan PUD) dams. One of the main objectives of the hatchery component of NNI is to provide species specific hatchery programs that may include contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest.

Biological Assessment and Management Plan:
The biological assessment and management plan (BAMP) was developed by parties negotiating the HCPs in the late 1990s. The BAMP was developed to document guidelines and recommendations on methods to determine hatchery production levels and evaluation programs. It is used within the HCP as a guiding document for the hatchery programs.

All of these processes affect the hatchery programs within the Entiat River Basin in one way or another.

Historic programs

Historically, fish have been released as part of the GCFMP beginning in the 1940s. Chinook, sockeye, steelhead and some coho were released as part of that program. Until about 8 years ago, steelhead were also released as part of a state program that was funded by Chelan PUD for mitigation for the operation of Rocky Reach and Rock Island dams.

Current programs

Current program overview: Currently, the Entiat NFH is the only hatchery program within the Entiat Basin. The BAMP identifies the Entiat as a potential reference stream, where no hatcheries would be directly influencing the population dynamics.

Facility description: The hatchery, 6.7 miles upstream from the confluence with the Columbia River, has 2 – 16 x 120 foot adult holding ponds, 30 – 8 x 80 raceways, and 32 starter tanks. Fish returning to Entiat NFH must travel about 491 river miles and negotiate passage through eight Columbia River hydroelectric dams.

In the past, the primary water source for the hatchery was the Entiat River. The current program utilizes ground water as the primary source. In 1996, the water rights for the river source (surface) and wells (ground) were combined for a total allotment of 22.5 cfs. The water right for Limekiln Spring is 7 cfs or 3,142 gpm. The hatchery water intake is located at river mile 7.2, approximately 1/3 mile upstream of the hatchery. The intake structure consists of a diversion dam, intake well, and bar trash-racks. Screening for the system is in compliance with current standards.

Surface water is used on a limited basis. It has been determined that Entiat River water contains high organic loads and detrimental parasites *(Myxobolus sp.)* which have been shown to have a negative impact on hatchery fish production. Since 1990, hatchery production has relied primarily on ground and spring water for fish production. The availability of said ground water determines fish production numbers at ENFH.

While there have been no coho releases to date in the Entiat River basin, the Yakama Nation's coho reintroduction project includes future plans to reintroduce coho salmon to the Entiat River (Yakama Nation et al. 2002), and is identified as a priority in the *Wy-Kan-Ush-Mi-Wa-Kish-Wit* document (Tribal Restoration Plan). Reintroduction methods would likely be similar to efforts in the Wenatchee and Methow sub-basins (Yakama Nation et. al. 2002***),*** As a direct result of the current coho reintroduction efforts in the Wenatchee and Methow Rivers, some natural coho production has been documented in the Entiat River.

II. Program Goals and Objectives

Federal program

Grand Coulee Fish Maintenance Project (GCFMP)

The USFWS operates the Leavenworth NFH Complex in the CCP region constructed by the U.S. Bureau of Reclamation (BOR) to replace fish losses that resulted from construction of Grand Coulee Dam. These programs were authorized as part of the Grand Coulee Fish Maintenance Project (GCFMP) on April 3, 1937, and re-authorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. The complex consists of three hatchery facilities, Leavenworth, Entiat, and Winthrop NFHs, with the following mission:

*"To produce high quality spring Chinook salmon and summer steelhead smolts commensurate with the production goals established by the Columbia River Fisheries Management Pla*n" (USFWS 2002a)

Objectives originally established for the Leavenworth Hatchery Complex, as part of the GCFMP were (from Calkins et al. 1939):

1) *. . . to bring, by stream rehabilitation and supplemental planting, the fish populations in the 677 miles of tributary streams between Grand Coulee Dam and Rock Island Dam, up to figures commensurate with the earlier undisturbed conditions and with the natural food supply in the streams.*

2) *. . . to produce in addition, by the combination of artificial spawning, feeding, rearing and planting in these streams, a supplemental downstream migration equivalent to that normally produced by the 1,245 miles of streams and tributaries above Grand Coulee Dam.*

Current objectives of the USFWS hatcheries are outlined in USFWS (1986a, b). In the USFWS Statement of Roles and Responsibilities, the broad roles of the hatcheries are,

. . . to seek and provide for mitigation of fishery resource impairment due to Federal water-related developments . . . the Fishery Resource Program goal, in fulfilling its mitigative responsibilities, is to ensure that established and future fishery resource mitigation requirements are fully and effectively discharged. Implicit in this goal is the replacement of fishery resource losses caused by specific Federal projects . . . and another responsibility of the Leavenworth Hatchery . . . is to restore depleted Pacific salmon and steelhead stocks of national significance in accord with statutory mandates such as the Pacific Northwest Electric Power Planning and

Conservation Act, Mitchell Act, Salmon and Steelhead Conservation Act, Pacific Salmon Treaty Act of 1985 and Indian Treaties and related Court decisions.

Shelldrake (1993) updated the objectives of the mid-Columbia NFHs:

- *Hatchery production* [specific to each facility].
- *Minimize interaction with other fish populations through proper rearing and release strategies.*
- *Maintain stock integrity and genetic diversity of each unique stock through proper management of genetic resources.*
- *Maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens.*
- *Conduct environmental monitoring to ensure that hatchery operations comply with water quality standards and to assist in managing fish health.*
- *Communicate effectively with other salmon producers and managers in the Columbia River Basin.*

The initial plan for the operation of the Leavenworth Hatchery Complex (Leavenworth, Entiat and Winthrop NFHs) called for the collection of adult salmon and steelhead at Rock Island Dam and transport to the hatchery for holding and spawning. Eggs and juveniles would subsequently be shipped to the satellite facilities. Sockeye (*O. nerka*), Chinook, and steelhead were the species of emphasis, and later coho were added. Sockeye production ended in the 1960s because of low survival, and disease problems (USFWS 1986a). Coho production also ended in the 1960s

The hatcheries built as part of the GCFMP began operation in the early 1940s at Leavenworth (Icicle Creek, a tributary of the Wenatchee River), Entiat, and Winthrop (Methow River). The Leavenworth facility was built as the main hatchery site, and the Entiat and Winthrop hatcheries as substations. These hatcheries were built as part of the program to relocate populations of salmon and steelhead that formerly ascended the Columbia River upstream from the Grand Coulee Dam site.

Yakama Nation Program

The long-term goal of the YN/BPA Mid-Columbia Coho Reintroduction Feasibility Project is to reestablish naturally reproduction coho salmon populations in mid-Columbia river basins (Wenatchee, Entiat, and Methow), with numbers at or near carrying capacity that provide opportunities for harvest (YN et.al. 2002). This long-term goal is closely tied to the vision of reintroduction of coho to the Yakima basin and to other areas from which the species has been eliminated. Mid-Columbia coho reintroduction is identified as a priority in the *Wy-Kan-Ush-Mi-Wa-Kish-Wit* document (Tribal Restoration Plan) and by the four Columbia River Treaty Tribes and has been affirmed as a priority by the Northwest Power Planning Council.

The short term goals of the feasibility phase, expected to last through 2004, is to determine whether a broodstock can be developed from Lower Columbia River coho stocks, whose progeny can survive in increasing numbers to return as adults to the mid-Columbia Region, and to initiate natural reproduction in areas of low risk to sensitive species and in other select areas to study the risks and interactions with sensitive species (YN et al. 2002). Studies done in this phase will inform future decisions about whether the long-term vision can be achieved. Reintroduction of coho into the Entiat sub-basin may occur after 2004 as the YN is preparing a proposal which involves an initial release of up to 200,000 smolts in 2005 from yet-to-be-determined acclimation sites in the basin. Many of the studies regarding coho residualism, survival, species interactions, competition, and predation, which have been conducted in the Yakima, Wenatchee and Methow rivers are transferable and will be used to implement a long term program in the Entiat sub-basin.

III. Program Operations

Entiat NFH released Spring Chinook that originated from commingled upriver stocks intercepted at Rock Island Dam in 1942 and 1944. Annual reports dating from 1945-1974, indicate that the facility produced summer Chinook, spring Chinook, sockeye, coho, rainbow and steelhead trout either as smolts, fry releases, catchables, and/or eyed egg transfers. Racks were installed across the river as a barrier to deflect returning adult salmonids into the facility. This practice of blocking the river began when water flows permitted work to be done in the river, typically late May early June. Racks were removed usually in November before ice became a problem.

On March 15th, 1951, Entiat NFH was transferred to the Branch of Fishery Biology to serve as a salmon cultural laboratory headed by Roger E. Burrows. Both experimental and production operations were performed. Studies included feeding trials, pituitary, hydraulic, development, and incubation experiments.

In 1953 an electric weir was installed on an experimental basis across the Entiat River to block upstream migration and to ensure adult brood stock collection. The weir was designed similar to electric weirs used in the Great Lakes to control sea lampreys. It consisted of 50, 1.5" pipe electrodes, suspended vertically at 3 foot intervals at an angle across the river. A 1.5"pipe ground line was also installed 15 feet below the electrodes following the contour of the river and parallel to the electrode line. The weir was charged by 110 volt, 60 cycle alternating current. Steelhead, Dolly Varden and other trout were passed above the weir when captured in the holding pond. In 1954, due to the effectiveness of the electric weir at higher water flows some spring Chinook were capture and spawned in August. Of the 903,410 Chinook eggs taken in 1954, 35% were derived from spring Chinook. Sockeye eggs were also taken that year and subsequently shipped to Leavenworth NFH for further rearing. In 1954, the state of Washington negotiated an escapement of 50% for Chinook returning to the Entiat. In 1955, an estimated 200 adults reached spawning grounds above the facility. In 1956, escapement was believed to be over 1000 spring and summer Chinook. The goal at that time was to allow all returning spring Chinook to pass while retaining the summer run for artificial propagation.

On March 1st, 1961 the Entiat NFH was no longer a "Salmon Cultural Laboratory" and was returned to a production facility. The hatchery began to rear rainbow trout as well as Chinook salmon. Rainbow trout were distributed to areas on the Yakama Indian Reservation, Nason and Icicle Creeks, juvenile ponds in Cashmere, WA and the Entiat River. Planting areas expanded in 1963 to include areas on the Warm Springs Reservation, Peshastin and Douglas creeks, and Lilly and Clear Lakes. Distributions of Cutthroat trout were also made. Annual reports do not specify whether or not the electric weir was in operation. Reports do state that the State of Washington was trapping Chinook at Rocky Reach Dam for the Chinook program at Turtle Rock. Releases of coho salmon smolts began in 1965 and continued until 1970. It appears from the records that the eggs for the Coho program were shipped from Little White Salmon NFH. Records do not indicate why programs started and/or stopped. There were comments about significant trapping taking place at the newly constructed Rocky Reach Dam in the 60's.

In 1974, Spring Chinook salmon smolt production resumed with eggs from several locations; Cowlitz River (1974), Carson NFH (1975-1982), Little White Salmon NFH (1976, 1978, 1979, 1981), Leavenworth NFH (1979-1981, 1994) and Winthrop NFH (1988). Returning adults have voluntarily entered the fish trap at the facility and have been the primary brood stock for the station in 1980, and from 1982 to 2002 (Cooper et. al. 2002).

Adult spring Chinook salmon return to the hatchery beginning in early to mid-May. The escapement goal for the hatchery is 350 adults for a subsequent release of 400,000 smolts. Extra adults are spawned because of an aggressive program to cull diseased eggs. Bacterial Kidney Disease (BKD) is prevalent at this facility, and highly infected eggs are taken out of production. Spawning begins in mid-August and can continue into mid-September. The ENFH stock of spring Chinook salmon is not listed under the Endangered Species Act (ESA).

All brood stock used for production are volunteers to the facility. Adults swim up the collection ladder and into one of two holding ponds. The holding ponds measure 16 x 120 feet and are supplied with a mixture of surface and ground water for attraction and operation of the ladder.

The ladder operates throughout the entire run spectrum. The goal is to collect all returning hatchery adults so they don't mix and spawn with the listed natural stock found in upriver areas. Excess adults are periodically donated to various tribes for subsistence and ceremonial purposes.

All adult crosses (matings) are randomly made, no selection occurs. Spawning occurs once per week and all females that are ripe on that day are spawned.

Juveniles are released as yearlings annually, in early to mid-April. The yearlings are "force" released directly into the Entiat River when the majority is in a smolt or pre-smolt stage. All juveniles released from ENFH are adipose fin-clipped. With 100% marking of released juveniles, the potential for harvest increases while also strengthening our ability to evaluate ecological affects.

Throughout the years, the spring Chinook release goal at ENFH has varied considerably. The current goal is 400,000 smolts annually. For years 1976 to 2001, the average yearling release was 576,660 fish.

As previously mentioned, the stock of spring Chinook propagated at ENFH is not listed under the ESA. All other stocks found in the Entiat River Basin are listed as "endangered". Therefore, the potential is greater that the program may have a negative influence on the listed stocks present. Potential genetic and ecological affects to the natural population includes; predation, competition, residualism, genetic introgression to natural stocks, and transmission of diseases or parasites. For a description of these effects, please refer to the Hatchery and Genetic Management Plan (HGMP) for this hatchery.

Current evaluation practices include: bio-sampling of returning adults, 100% external marking of all juveniles released, application of PIT tags, assessment of stray rates, travel-time of released juveniles through the Columbia corridor, assessment of potential for hatchery fish to transfer diseases to wild fish, success/failure of hatchery adults spawning naturally, use of NATURE's type rearing,[5] raceway density studies, genetic comparison of hatchery and wild stocks, and feed (fish food) evaluations, among others.

The Leavenworth NFH Complex (Leavenworth, Entiat, and Winthrop NFH's) has a team comprised of staff from the hatcheries, Fish Health, and Mid-Columbia River Fishery Resource Office. This team (Hatchery Evaluation Team) meets twice annually and part of its charge is to evaluate data obtained from on- and off-station studies. If the team decides that the data warrants a change, their request is elevated to supervisors for review or is simply implemented.

IV. Program Success

Entiat NFH was constructed to mitigate for lost habitat due to the construction of Grand Coulee Dam. The primary objective of this facility is to provide fish for harvest. The hatchery stock, although not ESA listed, is a healthy and viable population. Although in some years excess adults were available for harvest, the spring Chinook fishery in the Entiat River has been closed since the mid-1980's. Although few in numbers, some ENFH adults are captured in the lower Columbia River fishery.

Average escapement for years 1980 to 2001 is 677 adults (range = 80 to 2,666). Although no harvest has been allowed in many years, several tribes periodically receive excess adults for subsistence and ceremonial purposes. With 100% marking of released juveniles, the potential for a fishery may increase.

Due to the ESA listing of three species of salmonids in the upper-Columbia region, the USFWS was required to complete a HGMP and numerous Biological Assessments (BA's) describing potential hatchery affects on these populations. The resulting Biological Opinion's (BiOp) are an analysis of the BA's, in which Conservation Recommendations, contained within, direct the USFWS to conduct various assessments. Some of these assessments were mentioned previously in the Monitoring and Evaluation section.

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[5] NATURE's rearing is a "hands off" approach where artificial substrate and woody debris is added to the raceways. Automatic feeders are utilized, negating the need to "hand feed".

Methow Subbasin

I. Introduction

Various processes are underway within the Columbia Basin that direct hatchery program implementation. The listing of certain populations of fish under the ESA has also dictated hatchery program modifications and reform.

Some of the principal processes are:

Federal:

<u>Hatchery and Genetic Management Plans:</u>

The Hatchery and Genetic Management Plan (HGMP) process was initiated to identify offsite mitigation opportunities associated with operation of the Federal Columbia River Power System. The HGMP process is designed to describe existing propagation programs, identify necessary or recommended modifications of those programs, and help achieve consistency of those programs with the Endangered Species Act. The HGMP process only addresses anadromous salmon and steelhead programs.

Hatchery and Genetic Management Plans are described in the final salmon and steelhead 4(d) rule (July 10, 2000; 65 FR 42422) as a mechanism for addressing the take of certain listed species that may occur as a result of artificial propagation activities. NOAA Fisheries will use the information provided by HGMPs in evaluating impacts on anadromous salmon and steelhead listed under the ESA. In certain situations, the HGMPs will apply to the evaluation and issuance of section 10 take permits. Completed HGMPs may also be used for regional fish production and management planning by federal, state, and tribal resource managers.

The primary goal of the HGMP process is to devise biologically-based artificial propagation management strategies that ensure the conservation and recovery of listed Evolutionarily Significant Units (ESUs). The HGMP process also seeks to document and implement hatchery reform in the Columbia Basin. Much of the initial work on the HGMP process was coordinated and combined with efforts to complete the Artificial Production Review and Evaluation (APRE – see below)) analysis, which looked at the same sorts of information.

<u>Artificial Production Review and Evaluation (APRE)</u>

The APRE process seeks to document progress toward hatchery reform in the Columbia Basin. The NPCC used consultants and representatives of the Columbia Basin fishery managers to analyze existing programs and recommend reforms; a draft report that will go to the Council and the region has been prepared. The APRE process includes both anadromous and non-anadromous fish in its analysis.

<u>Pacific Coastal Salmon Recovery Fund</u>

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established in FY2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to Endangered Species Act (ESA) listings of West Coast salmon and steelhead populations. The PCSRF supplements existing state, tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation; promotes efficiencies and effectiveness in recovery efforts through enhanced sharing and pooling of capabilities, expertise and information. The goal of the Pacific Coastal Salmon Recovery Fund is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat.

The PCSRF's enhancement objective is*: To conduct activities that enhance depressed stocks of wild anadromous salmonids through hatchery supplementation, reduction in fishing effort on depressed wild stocks, or enhancement of Pacific salmon fisheries on healthy stocks in Alaska. This includes supplementation and salmon fishery enhancements.*

<u>US v. OR</u>

United States v Oregon, originally a combination of two cases, Sohappy v. Smith and U.S. v. Oregon, legally upheld the Columbia River treaty tribes reserved fishing rights. Specifically the decision acknowledged the treaty tribes reserved rights to fish at "all usual and accustomed" places whether on or off the reservation, and were furthermore entitled to a "fair and equitable share" of the resource. Although the Sohappy case was closed in 1978, U.S. v. Oregon remains under the federal court's continuing jurisdiction serving to protect the tribes treaty reserved fishing rights. This case is tied closely to U.S. v. Washington, which among other things defined "fair and equitable share" as 50 percent of all the harvestable fish destined for the tribes' traditional fishing places, and established the tribes as co-managers of the resource.

In 1988, under the authority of U.S. v. Oregon, the states of Washington, Oregon and Idaho, federal fishery agencies, and the treaty tribes agreed to the Columbia River Fish Management Plan (CRFMP), which was a detailed harvest and fish production process. There are no financial encumbrances tied to the process. Rather, the fish production section reflects current production levels for harvest management and recovery purposes, since up to 90% of the Columbia River harvest occurs on artificially produced fish. This Plan expired in 1998, and has had subsequent annual rollover of portions in which agreement has been reached. However, a newly negotiated CRFMP is forthcoming.

Hatchery production programs in the upper Columbia sub-basins are included in the management plans created by the fishery co-managers identified in the treaty fishing rights case *United States v Oregon*. The parties to *U.S. v Oregon* include the four Columbia River Treaty Tribes – Yakama Nation, Warm Springs, Umatilla, and Nez Perce tribes, NOAA-Fisheries, U.S. Fish and Wildlife Service, and the states of Oregon, Washington, and Idaho. The Shoshone-Bannock Tribe is admitted as a party for purposes of production and harvest in the upper Snake River only. These parties jointly develop harvest sharing and hatchery management plans that are entered as orders of the court that are binding on the parties. The "relevant co-managers" described in the *U.S. v Orego*n management plans are, for the mid-Columbia sub-basins, the federal parties, Yakama Nation, and Washington Department of Fish and Wildlife.

Hatchery programs are viewed by the Yakama Nation as partial compensation for voluntary restrictions to treaty fisheries imposed by the tribe to assist in rebuilding upriver populations of naturally-spawning salmonids. Because treaty and non-treaty fisheries are restricted on the basis of natural stock abundance, the tribal priority is to use hatcheries in a manner that supplements natural spawning and increases average population productivity. Perspectives on the appropriate use of hatchery-origin fish for supplementation vary between federal, state, and tribal fish co-managers. Federal and, to a lesser degree, state co-managers place a higher priority on managing the genetic risks of hatchery supplementation of natural populations, while the tribe sees the demographic threats of habitat loss and degradation as the greater risk to natural populations. In general, however, all parties agree that hatcheries can and should be operated as integral components of natural populations where the survival benefits of the hatchery can result in a significant increase in net population productivity.

ESA

Current ESA Section 10 Permits for listed summer steelhead (Permit #1395); listed spring chinook (Permit #1196) and non-listed anadromous fish (Permit # 1347) also direct artificial production activities associated with the habitat conservation plans. Douglas PUD, Chelan PUD and WDFW are co-permittees, therefore provisions within the permits and associated Biological Opinions are incorporated into the hatchery programs undertaken in the HCP's.

State:
The state, along with the federal government have various forums in which they are active. All have some role in determining or balancing artificial production programs, as well as the ones that follow under "other". Essentially no specific action would occur until the action is determined to be warranted in the already established processes.

Other:

FERC processes:
Under current settlement agreements and stipulations, the three mid-Columbia PUDs pay for the operation of hatchery programs within the Columbia Cascade Province. These programs determine the levels of hatchery production needed to mitigate for the construction and continued operation of the PUD dams.

Habitat Conservation Plans:
In 2002, habitat conservation plans (HCPs) were signed by Douglas and Chelan PUDs, WDFW, USFWS, NOAA Fisheries, and the Colville Confederated Tribes. The overriding goal of the HCPs are to achieve no-net impact[6] on anadromous salmonids as they pass Wells (Douglas PUD), Rocky Reach, and Rock Island (Chelan PUD) dams. One of the main objectives of the

[6] NNI refers to achieving a virtual 100% survival of anadromous salmonids as they pass the mainstem projects. This is achieved through 91% survival of adults and juveniles (or 93% for juveniles) passing the projects, and 7% compensation through hatchery programs and 2% contribution through a tributary fund, which will fund projects to improve salmonid habitat in the tributaries.

hatchery component of NNI is to provide species specific hatchery programs that may include contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest.

Biological Assessment and Management Plan:
The biological assessment and management plan (BAMP) was developed by parties negotiating the HCPs in the late 1990s. The BAMP was developed to document guidelines and recommendations on methods to determine hatchery production levels and evaluation programs. It is used within the HCP as a guiding document for the hatchery programs.

All of these processes affect the hatchery programs within the Methow River Basin in one way or another.

Historic and current programs and facilities

Historic programs

The first hatcheries that released salmonids in the mid-Columbia Basin began operation in 1899 near the confluence of the Twisp River on the Methow River (WDFG 1899). This hatchery was built to replenish the salmon (primarily chinook, and coho) runs, which had virtually been eliminated by the 1890s (Gilbert and Evermann 1895; WDFG 1898).

The biggest problems encountered in the early years of the hatcheries were lack of fish for broodstock, and because of irrigation diversions that entrained large numbers of juveniles (both naturally- and artificially produced; WDFG 1904):

Most of the fish planted from the Methow facility in the first few years of production were probably coho (WDFG 1904-1920; Craig and Suomela 1941). For the first few years, species were not differentiated, with up to 3 million eggs per year collected from the Methow.

Very few chinook were released from the first Methow River hatchery (Craig and Suomela 1941). Egg take between the years 1908 - 1912 ranged from 5,000 - 68,000 (average 24,100). In 1915, the hatchery was moved downstream near the mouth of the river at Pateros. The hatchery was moved for two main reasons: it lacked brood stocks other than coho, and the new location lay downstream from the irrigation intakes (WDFG 1917). From WDFG (1917),

> *Two years of operation of the new hatchery have demonstrated the wisdom of the change. Not only are we now securing more silverside salmon spawn at the new location than we did at the old, but our new location has developed to be the best hatchery in the state for the taking of Steelhead salmon eggs. Also, we have been able here to secure Spring Chinook salmon eggs . . .,*

and from Craig and Suomela,

. . . however, chinooks were never obtained in any quantity. . . some eggs were transferred to Methow from other locations. Even chum salmon eggs were shipped there in 1916 and 1917. . . In many cases there is no indication as to where the transferred chinook eggs were taken, but some were obtained from the U. S. Bureau of Fisheries hatcheries on the lower Columbia and probably some of the Washington hatcheries from that section also contributed late run stock to the Methow River. It is very questionable whether any of these fish were able to return to the Methow River, since the distance they would have to migrate is much greater than that to which the original stock was accustomed. However, these records indicate that the Washington State Fisheries authorities made attempts to introduce strange runs of salmon to the Methow as well as to the Wenatchee.

In 1917, 1.5 million eggs were received at the Methow Hatchery from unknown origin. In the late 1920s, eggs were received from exotic hatcheries, but appear to be mostly late-run chinook (Craig and Suomela 1941).

The release of fry from the early hatcheries on the Wenatchee and Methow rivers probably contributed little to adult returns.

<u>Current program overview:</u>

Current programs

Artificial production of anadromous fish in the Methow Subbasin includes spring Chinook, summer Chinook, summer steelhead and reintroduction of coho salmon (Table 1). Spring Chinook and summer steelhead are currently ESA-listed as endangered through the Endangered Species Act of 1973. Summer Chinook are considered a depressed population. Once extirpated from the Methow Subbasin, small numbers of coho salmon have been reintroduced, and plans are currently in the feasibility stage for larger scale reintroduction. Hatchery intervention in the Methow Subbasin is guided by a two-pronged approach that encourages local adaptation, preservation and enhancement of specific populations while simultaneously spreading the risk through selection of several artificial production alternatives.

Considerable controversy regarding the effects of the GCFMP, non-indigenous introductions, recent fishery management actions (variable broodstock collection and hatchery mating) on population structure, and regarding interpretation of available genetic data has prompted variable interpretations of spring Chinook population structuring in the Methow Basin. In response to uncertainty about population structure, poor adult returns, and a desire to spread the risk of hatchery intervention strategies, a conceptual approach was developed during the creation of the Biological Assessment and Management Plan (BAMP) for mid-Columbia River Hatchery Programs. The approach consisted of enlarging the effective hatchery supplementation spawning population of Methow River and the Chewuch River populations during periods of low adult returns, by managing them as a single gene pool. During years of sufficient adult returns, tributary trapping locations would be utilized to obtain the broodstock components of each tributary population and within population mating would be a priority in an attempt to preserve and enhance discrete population attributes that exist in the Methow Basin.

Management decisions regarding the Twisp River population varied from those developed for the Methow and Chewuch populations. The Twisp River population was deemed the most divergent of the indigenous populations in the Subbasin and the least tolerant of genetic introgression (Wells Project Coordinating Committee 1995). The Twisp River population is managed more as a distinct population, using adult supplementation and captive broodstock programs. The Joint Fisheries Party (JFP, composed of federal and state agencies and tribes) opted to phase out the Twisp Captive brood program beginning in 2000, leaving 1999 as the last brood year remaining in the program.

Table 1. Artificial anadromous fish production in the Methow Subbasin

Fish Species	Facility	Funding Source	Production level goals
Spring Chinook	Methow Fish Hatchery Acclimation sites at the Methow, Biddle, Twisp and Chewuch Acclimation ponds (Operated by WDFW)	Douglas County PUD	(349,000)[7]
	Winthrop NFH (Operated by USFWS)	Bureau of Reclamation	600,000
Steelhead	Wells Dam Hatchery Complex (Operated by WDFW)	Douglas County PUD	349,000 (post HCP)
	Winthrop NFH (Operated by USFWS)	Bureau of Reclamation	100,000
Summer Chinook	Wells Dam Hatchery Complex (Carlton acclimation pond) (Operated by WDFW)	Chelan County PUD	400,0008
Coho	Winthrop NFH (Operated by USFWS)	BPA (Fish & Wildlife Program)	250,000
Coho	Acclimation sites at Eight Mile Creek and Biddle Pond on Wolf Creek (Operated	BPA (Fish & Wildlife Program)	

[7] Under the Wells Settlement Agreement, Douglas PUD is required to raise 225,000 spring chinook for Wells mitigation. Once the HCP is approved, Douglas PUD only needs to raise 61,000 fish to meet its NNI obligation for spring chinook. However, under a separate agreement, Douglas will raise an additional 288,000 (which will be reduced to 90,000 after 2013) spring chinook for Chelan PUD for mitigation under the HCP, bringing the total to 349,000 fish

[8] Under a “species trade agreement” between Chelan and Douglas PUDs, all 400,000 of these fish are currently for Douglas PUD mitigation. Once the HCP is approved then 200,000 of these fish are raised for Douglas PUD mitigation in exchange for fish at the MFH and the remaining 200,000 fish are for the Chelan PUD mitigation.

by YN)

Federal programs

Grand Coulee Fish Maintenance Project (GCFMP)
The USFWS operates the Leavenworth NFH Complex in the UCR region constructed by the U.S. Bureau of Reclamation (BOR) to replace fish losses that resulted from construction of Grand Coulee Dam. These programs were authorized as part of the Grand Coulee Fish Maintenance Project (GCFMP) on April 3, 1937, and re-authorized by the Mitchell Act (52 Stat. 345) on May 11, 1938. The complex consists of three hatchery facilities, Leavenworth, Entiat, and Winthrop NFHs, with the following mission:

"To produce high quality spring Chinook salmon and summer steelhead smolts commensurate with the production goals established by the Columbia River Fisheries Management Plan" (USFWS 2002a)

Historically, these facilities have reared and released spring Chinook salmon eggs transferred from the Carson NFH on the lower Columbia River. Carson-stock spring Chinook salmon are not included in the ESA-listed UCR spring Chinook salmon ESU. The USFWS has discontinued transferring eggs from Carson NFH in favor of utilizing hatchery-origin adult spring Chinook salmon returning to each facility as the primary egg source.

The hatcheries built as part of the GCFMP began operation in the early 1940s at Leavenworth (Icicle Creek, a tributary of the Wenatchee River), Entiat, and Winthrop (Methow River). The Leavenworth facility was built as the main hatchery site, and the Entiat and Winthrop hatcheries as substations. These hatcheries were built as part of the program to relocate populations of salmon and steelhead that formerly ascended the Columbia River upstream from the Grand Coulee Dam site.

Winthrop National Fish Hatchery (NFH)
Located on the Methow River, this substation of the Leavenworth NFH complex began operation in 1941. The Winthrop Hatchery released stream-type Chinook every year from 1941 through 1962. Releases of spring Chinook ceased until 1976, when the current program began, and have since been ongoing. Releases of sockeye have taken place at Winthrop from 1943 to 1957. Spring chinook, steelhead and coho are all currently cultured at the facility.

Broodstock origin for fish released from Winthrop NFH has varied over the years. The first four years of releases were from broodstock collected at Rock Island Dam as part of the GCFMP (see above). Eggs from the Cowlitz, Little White, Carson, Klickitat, and Leavenworth (all Carson stock) hatcheries have been raised and released from Winthrop since the current program began in 1976, although since 1992, all brood used for the program has come from adults returning to the Methow River.

Since brood year 1999, which is the same year spring Chinook were listed under the ESA, no releases of the "pure" unlisted Carson stock has occurred. The listed Methow Composite stock has been utilized in an effort to aid in the recovery of that population.

Facility description: Located on the Methow River, at river mile 50.4, this facility has two 40 by 80 ft adult holding ponds (construction was never completed), sixteen 17 x 76 ft. Foster-Lucas ponds, sixteen 12 x 102 ft, and 30 8 x 80 ft raceways. Inside the hatchery building there are 42 (8 tray) incubators, thirty-five 3 x 16 ft fiberglass tanks, and four 16.5 x 16 concrete starting troughs (USFWS 1986c).

The primary water source for the hatchery is the Methow River. The water right allows for withdrawals up to 50 cfs. Spring Branch Springs provides up to 10 cfs, and two groundwater infiltration galleries and wells provide 1,500 gpm each, with a maximum of 2,400 ac. ft. per year each. The springs and infiltration galleries provide warmer water during the winter months. A third infiltration gallery, capable of pumping 4,500 gpm, is currently under construction.

Evaluation: The Mid-Columbia River Fishery Resource Office (MCRFRO) provides monitoring, evaluation, and coordination services concerning Winthrop NFH production. MCRFRO staff monitors hatchery returns, biological characteristics of the hatchery stock, fish marking, tag recovery, and other aspects of the hatchery program, and they maintain the database that stores this information. MCRFRO also cooperates with the hatchery, fish health and technology centers, and co-managers to evaluate fish culture practices, assess impacts to native species, and coordinate hatchery programs both locally and regionally.

The Leavenworth NFH Complex (which includes Winthrop NFH) has a team comprised of staff from the hatcheries, Fish Health, and the MCRFRO (Hatchery Evaluation Team). Current evaluation practices/studies include: bio-sampling of returning adults, 100% marking of released juveniles, application of PIT tags, assessment of stray rates, travel-time of released juveniles through the Columbia River corridor, assessment of potential of hatchery fish to transfer diseases to wild stocks, success/failure of hatchery produced adults to reproduce naturally, use of NATURE's type rearing[9], raceway density studies, genetic comparisons of hatchery and wild stocks, and feed (fish food) evaluations, among others.

State programs

Methow Fish Hatchery Complex

The Methow Fish Hatchery Complex (MFHC) was built to compensate for losses of smolts caused by the operation of Wells Dam (Erho and Bugert 1995). The facility was constructed by, and operates, under funding from Douglas PUD. Eggs are collected at weirs on the Methow, Twisp, and Chewuch rivers and incubated discretely at the central facility near the town of Winthrop. Smolts (246,000 for each facility) are released from acclimation ponds on the Twisp, Chewuch, and Methow (central facility) rivers (Peck 1993; Bartlett and Bugert 1994).

[9] NATURE's rearing is a "hands off" approach where artificial substrate and woody debris is added to the raceways. Automatic feeders are also utilized, negating the need to "hand feed".

One of the guiding principles of the Methow Basin Spring Chinook Salmon Supplementation Plan (MBSCSP) is to increase natural production of the three principal stocks from the main stem Methow, Chewuch, and Twisp rivers. With the supplementation concept in mind, the general supplementation plan has established separate strategies for two of the three streams with the fish managers agreeing to maintain one composite brood stock for the Methow and Chewuch rivers and a separate brood stock for the Twisp River. Each stock will have specific escapement goals, designed to provide a basis for evaluating the progress of achieving the original intent of the program.

Facility description: The MFHC consists of a central facility on the Methow River, near the town of Winthrop, and two satellite facilities on the Chewuch and Twisp rivers. The main facility is located on the Methow River, approximately 45 miles upstream of the confluence with the Columbia River. This facility has three canopy-covered 8 x 78 x 4 ft adult holding ponds, 12 canopy-covered juvenile raceways of the same dimensions as the adult ponds, and 24 indoor 3 x 59 x 4.5 ft start tanks. In addition, there are three separate incubation rooms with 15 single stack (eight trays per stack) vertical incubators and one 107 x 59 x 4.5 ft acclimation pond, which releases into the mainstem Methow River (Bartlett and Bugert 1994).

The main water source for the Methow facility is from four wells that provide almost 10 cfs. An additional water right of 18 cfs of Methow River water is provided, with 11 cfs guaranteed (the additional 7 cfs is shared with Winthrop NFH in the spring; Bartlett and Bugert 1994).

Almost eight miles upstream of the confluence of the Methow River is the Chewuch River acclimation site. The site has one large acclimation pond, which measures 107 x 70 x 4.5 ft. The water source of the acclimation pond is the Chewuch River, which is supplied by gravity feed from the Chewuch Canal Company's irrigation ditch. The maximum flow to the pond is 6 cfs (Bartlett and Bugert 1994). Adult trapping for the Chewuch fish occurs at Fulton Dam, approximately 4.5 miles downstream of the acclimation pond (1.5 miles upstream of the confluence with the Methow River).

The Twisp River acclimation site is approximately 5 miles upstream of the confluence with the Methow River. The facility has one acclimation pond which measures 107 x 59 x 4.5 ft. The water source of the pond is the Twisp River from the Valley Power irrigation canal, with a maximum flow of 6 cfs. The adult collection weir and trap is located adjacent to the acclimation pond (Bartlett and Bugert 1994).

II. Program Goals and Objectives

Federal programs

Grand Coulee Fish Maintenance Project (GCFMP)

The USFWS's mission for the Leavenworth complex is:

"To produce high quality spring Chinook salmon and summer steelhead smolts commensurate with the production goals established by the Columbia River

*Fisheries Management Pla*n" (USFWS 2002a)

Winthrop National Fish Hatchery (NFH)**:**
Objectives originally established for the Leavenworth Hatchery Complex, as part of the GCFMP were (from Calkins et al. 1939):

1) *. . . to bring, by stream rehabilitation and supplemental planting, the fish populations in the 677 miles of tributary streams between Grand Coulee Dam and Rock Island Dam, up to figures commensurate with the earlier undisturbed conditions and with the natural food supply in the streams.*

2) *. . . to produce in addition, by the combination of artificial spawning, feeding, rearing and planting in these streams, a supplemental downstream migration equivalent to that normally produced by the 1,245 miles of streams and tributaries above Grand Coulee Dam.*

Current objectives of the USFWS hatcheries are outlined in USFWS (1986a, b). In the USFWS Statement of Roles and Responsibilities, the broad role of the hatcheries are,

. . . to seek and provide for mitigation of fishery resource impairment due to Federal water-related developments . . . the Fishery Resource Program goal, in fulfilling its mitigative responsibilities, is to ensure that established and future fishery resource mitigation requirements are fully and effectively discharged. Implicit in this goal is the replacement of fishery resource losses caused by specific Federal projects . . . and another responsibility of the Leavenworth Hatchery . . . is to restore depleted Pacific salmon and steelhead stocks of national significance in accord with statutory mandates such as the Pacific Northwest Electric Power Planning and Conservation Act, Mitchell Act, Salmon and Steelhead Conservation Act, Pacific Salmon Treaty Act of 1985 and Indian Treaties and related Court decisions.

Shelldrake (1993) updated the objectives of the mid-Columbia NFHs:

- *Hatchery production* [specific to each facility].
- *Minimize interaction with other fish populations through proper rearing and release strategies.*
- *Maintain stock integrity and genetic diversity of each unique stock through proper management of genetic resources.*
- *Maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens.*
- *Conduct environmental monitoring to ensure that hatchery operations comply with water quality standards and to assist in managing fish health.*
- *Communicate effectively with other salmon producers and managers in the Columbia River Basin.*

State programs

Methow Fish Hatchery Complex

One of the guiding principles of the Methow Basin Spring Chinook Salmon Supplementation Plan (MBSCSP) is to increase natural production of the three principal stocks from the main stem Methow, Chewuch, and Twisp Rivers. With this in mind, the general supplementation plan has established separate strategies for each of the three streams. Each stock will have specific escapement goals, designed to provide a basis for evaluating the progress of achieving the original intent of the program. From Erho and Bugert (1995),

> ***Methow River****: Collaboration between Winthrop FH and Methow FH is of paramount importance for the MBSCSP. Gene flow between the two hatcheries will inevitably occur. To be consistent with this situation, all spring chinook salmon that spawn in the mainstem Methow River upstream of the Chewuch River confluence will be managed as one genome. To be successful, this management strategy requires three conditions: 1) no spring chinook salmon from outside this reach will be imported to either hatchery for propagation and released into the Methow River (exogenous salmon may be reared at the hatcheries if they are acclimated and released into their natal stream), 2) all salmon released from either hatchery into the Methow Basin will be externally marked, and 3) salmon that spawn in the Lost River will be included in this population.*
>
> ***Chewuch River****: The Fishery Parties recognize the opportunity to implement innovative fish cultural practices at Methow FH, yet also are acutely aware of the need to ensure high survival of the supplemented populations. The Chewuch River population will therefore be the designated stock used for innovative hatchery management. In general terms, the Chewuch stock may be considered an experimental "treatment" stream, compared to the Twisp River population, which will serve as the "reference". Alternative fish culture may include such practices as life skills training (Olla and Davis 1989, Suboski and Templeton 1989), side channel rearing (Budhabhatti and Maughan 1994), and autumn pre-smolt releases (Bjornn 1978, Bilby and Bisson 1987), or other prototypical hatchery strategies.*
>
> ***Twisp River****: The Twisp River stock will be managed in a manner that ensures the highest survival of both natural and hatchery salmon in that river. Low risk production strategies will be implemented in all stages of the program. The Evaluation Plan will place an emphasis on long-term genetic and demographic monitoring of the Twisp population, to evaluate the stability of a small semelparous population. An estimate of minimum viable population (MVP; Shaffer 1981, 1990, Lacava and Hughes 1984) size will be derived, either through empirical or heuristic analysis (Kapuscinski and Lannan 1986). The escapement goal for the Twisp River will then be based upon the estimated MVP.*

The overall goal of the state hatcheries is to use artificial production to replace adult production lost due to smolt mortality at mainstem hydroelectric projects, while not reducing the natural production or long-term fitness of salmonid stocks in the area (WDF 1993). Specific goals of the WDFW hatcheries (WDF 1993) are:

- *Hatchery production* [in terms of number of fish released from each site],

- *minimize interactions with other fish populations through rearing and release strategies, maintain stock integrity and genetic diversity of each population or unique stock through proper management of genetic resources.*
- *maximize survival at all life stages using disease control and disease prevention techniques. Prevent introduction, spread or amplification of fish pathogens,*
- *conduct environmental monitoring to ensure that the hatchery operations comply with water quality standards and to assist in managing fish health,*
- *communicate effectively with other salmon producers and managers in the Columbia River basin, and with implementers of local and regional flow and spill programs, and*
- *develop a Conservation Plan and conduct a comprehensive monitoring/evaluation program to determine that the program meets mitigation obligations, estimate survival to adult, evaluate effects of the program on local naturally producing populations, and evaluate downstream migration rates in regards to size and timing of fish released.*

Yakama Nation Program

The long-term goal of the YN/BPA Mid-Columbia Coho Reintroduction Feasibility Project is to reestablish naturally reproduction coho salmon populations in mid-Columbia river basins (Wenatchee, Entiat, and Methow), with numbers at or near carrying capacity that provide opportunities for harvest (YN et.al. 2002). This long-term goal is closely tied to the vision of reintroduction of coho to the Yakima basin and to other areas from which the species has been eliminated. Mid-Columbia coho reintroduction is identified as a priority in the *Wy-Kan-Ush-Mi-Wa-Kish-Wit* document (Tribal Restoration Plan) and by the four Columbia River Treaty Tribes and has been affirmed as a priority by the Northwest Power Planning Council.

The short term goals of the feasibility phase, expected to last through 2004, is to determine whether a broodstock can be developed from Lower Columbia River coho stocks, whose progeny can survive in increasing numbers to return as adults to the mid-Columbia Region, and to initiate natural reproduction in areas of low risk to sensitive species and in other select areas to study the risks and interactions with sensitive species (YN et al. 2002). Studies done in this phase will inform future decisions about whether the long-term vision can be achieved. Many of the studies regarding species interactions, competition, and predation, which have been conducted in the Yakima, Wenatchee and Methow rivers are transferable and will be used to implement a long term program in the Methow sub-basin. Currently, coho smolt releases are only from the federal hatchery with the sole purpose of broodstock development and to collect initial survival data. The YN is proposing to expand the program to releases in the natural production areas of the basin to allow implementation of the tribal goal of natural reproduction. Releases to date have indicated that some returning adults have sought out small tributaries in the basin for successful spawning.

III. Program Operations

Federal program

Winthrop NFH

USFWS operates the Winthrop National Fish Hatchery (WNFH) located only a few miles downstream from the Methow FH. Broodstock are typically collected from the volunteer trap located in the hatchery outfall. Approximately 600,000 smolts are released annually directly into the Methow River from the WNFH.

Adult spring Chinook salmon return to the hatchery beginning in early to mid-May. The escapement goal for this hatchery is 350 adults for a subsequent release of 600,000 smolts annually. Spawning begins in mid-August and can continue to mid-September. The stock of spring Chinook propagated at WNFH is listed as "endangered" under the Endangered Species Act (ESA). Brood year 1999 was the first year propagating this stock. Prior to the switch in stocks, a Carson NFH (lower Columbia River) stock was utilized (not ESA listed).

In most years, all brood stock used for production are volunteers to the hatchery. Adults swim up the collection ladder and into a holding area. The capacity of this pond can only support about 400 adults. The current program calls for adults in excess of brood needs to spawn naturally. Therefore, hatchery staff must limit the number of adults entering the ladder. A weir is placed in the channel leading to the ladder and is selectively opened and closed.

During years of extremely low adult returns, as in 1996 and 98, all spring Chinook ascending Wells Dam are captured and transferred to WNFH and the Methow Fish Hatchery. Adult brood for the Winthrop program has, in some years, been captured at the MFH and transferred to WNFH.

For years 1984 to 2001, an average of 685 adults of WNFH origin have returned to the Methow River Basin. Although the original objective of this mitigation program was to provide fish for harvest, it is also trying to aid in the recovery of ESA listed populations.

All juveniles released from WNFH have a coded-wire tag (CWT) inserted in their snout. During the spawning of adults, CWT's from all adults are removed and de-coded prior to the mixing of gametes. This way FWS has the ability to manage particular crosses (matings), as some are more desirable than others.

Juveniles are released as yearlings annually, in mid-April. The smolts are forced from the raceways into the _ mile long spring fed channel (where the ladder is located), which flows to the Methow River. Currently, all juveniles carry a CWT and a portion may also have an adipose-fin clip (depending on lineage).

Throughout the years, the spring Chinook release goal at WNFH has varied. The current goal is 600,000 smolts at 15 to18 fish/pound. For years 1980 to 2001, an average of 642,682 have been released annually.

Winthrop NFH also has a small summer steelhead program. This stock is listed as "endangered" under the ESA. The annual release goal is currently 100,000 smolts. Brood for this program is secured at Wells Dam by WDFW; none of the steelhead are collected as volunteers to WNFH.

Eyed eggs are transferred to WNFH from Wells Hatchery in January or February each year. Approximately 14 months later, the smolts are volitionally released over a 2 – 4 week period starting in early April. Juveniles are 100% fin-clipped and returning adults may be harvested in the sport fishery above Rocky Reach Dam.

State program

Spring Chinook

The Methow Fish Hatchery operates as an adult-based supplementation program using multiple adult broodstock collection locations including the Chewuch, Twisp, and upper Methow rivers. Additional supplementation includes volunteer returns to Methow Fish Hatchery and Winthrop NFH. The long-term production objective for the Methow Fish Hatchery was set at 738,000 yearling spring Chinook smolts in the Wells Dam Settlement Agreement (1990). However, the maximum capacity of the facility was modified during the development of the Mid-Columbia Habitat Conservation Plan (MCHCP) to 550,000 yearlings at 15 fish/lb. (BAMP 1998).

Poor returns of wild fish and limited broodstock collection capabilities coupled with historically poor spring Chinook replacement rates of 0.7 recruits per spawner (1985-1990; L. LaVoy, WDFW, unpublished data) prompted the development of a 3-tiered broodstock collection protocol for the spring Chinook supplementation program in the Methow Subbasin. Under a revised approach adopted in 1996, the location and extent of broodstock collections is based on projected escapement at Wells Dam (Table 2). Broodstock collection protocols are now developed annually and are determined by adult escapement above Wells Dam, expected escapement to tributary and hatchery locations, estimated wild/hatchery proportion, and production objectives and stock origin (endemic/non-endemic).

Table 2. Broodstock collection guidelines of the Methow Basin spring Chinook supplementation plan (ESA Section 7 Draft Biological Opinion, Section 10 Permit 1196)

Wells Escapement Projection	Broodstock Collection Objective
< 668	100% collection of Wells Dam escapement; place all fish into the adult-based supplementation program.
>668 <964	Pass a minimum of 296 adults upstream of Wells Dam for natural spawning.
> 964	Collection at levels to meet interim production level of 550,000 and 600,000 smolts at Methow Fish Hatchery and Winthrop NFH, respectively.

The hatchery and acclimation ponds are operated in a manner that is consistent with accepted aquaculture standards and those identified in the Wells Dam Settlement Agreement. Broodstock handling, spawning, fertilization, incubation, rearing, fish transport, and release activities are detailed in annual summary reports of specific brood years for the Methow Basin Spring Chinook Salmon Hatchery Program (Bartlett et al. 1994; Bartlett 1996; Bartlett 1997; Bartlett 1998; Bartlett 1999; and Jateff 2001).

Production at the Methow Fish Hatchery has varied considerably since the program began with brood year 1992. The variability in production is entirely a function of poor adult returns and different broodstock collection strategies stemming from adaptive management strategies for this population. Smolt production from the Methow Fish Hatchery has averaged 388,471 smolts over the past five years, representing 71% of the interim production level of 550,000 fish identified in the BAMP (1998).

Since adult returns were so low in the beginning years of the program, WDFW used some Carson stock fish in their program. WDFW is now actively avoiding fish of Carson ancestry in their broodstock, and the WNFH is also moving away from using these fish too.

WDFW spawns both listed hatchery x natural and natural x natural crosses to the extent possible and evaluate the success of the two types of crosses. When possible, naturally produced fish retained for broodstock shall represent the natural-origin population in terms of age composition, sex ratio, and run timing. To the greatest extent possible, WDFW shall maintain known Twisp River spring Chinook salmon as a separate broodstock within the hatchery. The progeny of known Twisp River spring Chinook salmon shall be distinctly marked for identification purposes.

To reduce and control fish disease incidences, WDFW will use the disease control procedures identified in the operations plans and adhere to the Washington Co-Manager, Pacific Northwest Fish Health Protection Committee and IHOT [Integrated Hatcheries Operation Team] fish disease control policies.

<u>Summer Chinook</u>
Artificial production of summer Chinook for the Methow Subbasin is provided through the Rock Island Project Settlement Agreement (and will be superseded by the HCP), via the Eastbank Hatchery. The hatchery was constructed in 1989 and is located adjacent to Rocky Reach Dam on the Columbia River. The program is funded by Chelan County PUD and operated by WDFW. Summer Chinook production at Eastbank Hatchery is intended to mitigate for summer Chinook losses at Rock Island Dam. The production objective for the Methow River is a total of 400,000 yearling summer Chinook at 10 fish/lb (BAMP 1998).

Broodstock (556 adults) are collected at the Wells Dam east ladder trapping facility and transported to the Eastbank Hatchery. These fish originate from Okanogan/Methow (Wells Dam traps) summer Chinook populations of natural or hatchery-origin, and are indigenous to the Methow/Okanogan system. Returning salmon from the Carlton (Methow River) program also volunteer into Wells Fish Hatchery, yet they are identified by Code Wire Tags (CWT) and can be placed into their program of origin if desired (Eltrich et al. 1995; BAMP 1998). Incubation, spawning, and initial rearing of Methow summer Chinook take place at the Eastbank facility. The fish are then transferred to the Carlton Acclimation Pond towards the end of their second winter, where they are volitionally released at smolt size (10fish/lb.) into the Methow River in April-May (these fish are currently raised for Wells mitigation under a "species trade" between Chelan and Douglas PUD. Once the HCPs are finalized, the 400,000 fish will be spilt 50:50 between the two PUDs (until 2013, when Chelan's obligation may go down)).

Broodstock collection protocols are developed annually and determined by annual escapement at Rocky Reach Dam, subject to in-season adjustments. Specific broodstock collection criteria are listed below (adapted from Petersen et al. 1999b and BAMP 1998). Facility operation description, biological attributes and aquaculture practices and standards are detailed in the HGMP for summer Chinook as developed for the Section 7 Draft Biological Opinion for ESA-section 10 Permit #901/902 (Incidental Take of Listed Salmon and Steelhead from Federal and Non-federal Hatchery Programs that Collect, Rear and Release Unlisted Fish Species; WDFW 2000) and as developed for the Rocky Reach and Rock Island Anadromous Fish Agreement and Habitat Conservation Plan.

- Trap no more than 20% of the adult run, based on counts at Rocky Reach Dam;
- If cumulative adult counts at Rocky Reach Dam are less than 40% of the ten-year average, cease trapping until the 40% escapement level has been reached;
- Begin trapping after June 28 and end trapping on or before August 28;
- Conduct trapping on no more than 3 days per week for a maximum of 16-hours per day;
- Do not use the west ladder on Wells Dam for broodstock collections unless difficulties are encountered with broodstock collections in the east ladder;
- Mark all summer Chinook trapped in the Wells Dam ladders to differentiate them from fish volunteering to the Wells Hatchery trap; and
- Collect the run-at-large including the age-3 component.

<u>Summer Steelhead</u>

Steelhead are collected from the run-at-large at the west ladder trap at Wells Dam. Beginning in 2003, wild origin fish were also collected from the east ladder trap to incorporate a greater number of wild fish into the broodstock (33%). Adult steelhead are spawned and reared at Wells FH.

Approximately 125,000 eyed-eggs are shipped to Winthrop National Fish Hatchery to support a 100,000 smolt program that are released directly from the hatchery into the Methow River. Wells FH annually transports and releases an additional 350,000 smolts into the Twisp, Chewuch, and Methow Rivers and an additional 130,000 steelhead smolts for release into the Okanogan and Similkameen rivers.

Non-anadromous fish releases

Non anadromous fish have been planted within the Methow Basin since the early 1900s. Rainbow trout, cutthroat trout, brook trout, and a few brown trout have all been planted at various times through multiple hatchery programs.

Following micro-habitat work in the 1980s that showed negative effects on pre-smolt steelhead from "catchable" releases of rainbow trout, all releases of rainbow were shifted from streams to various lakes within the basin which did not have connectivity to anadromous areas.

Yakama Nation Program

Coho

Coho salmon are collected as volunteers into the Winthrop National Fish hatchery and from the run-at-large at Wells Dam west bank and/or east bank fish traps to support a 250,000 smolt program (YN et al. 2002) .   Methow basin coho broodstock may be supplement with eyed-eggs transferred from Wenatchee Basin incubation facilities or from hatcheries on the lower Columbia River (Cascade FH, Eagle Creek NFH, or Willard NFH) in years where broodstock collection falls short of production goals. Coho reared at Winthrop NFH are volitionally released into the Methow River or transferred to the Wenatchee River for acclimation and release. Under the current feasibility program, coho releases from the Winthrop National Fish Hatchery are design to contribute to the broodstock development process. Details on mating protocols, rearing and acclimation strategies, size at release and monitoring and evaluation can be found in the Yakama Nation's Mid-Columbia Coho HGMP (YN et al.2002).

Conservation of the Species: The capture of endangered UCR spring Chinook salmon and summer steelhead by WDFW for artificial propagation efforts are designed to benefit the species. The primary objectives of these efforts are to preserve extant spring Chinook and steelhead populations in the region, and to boost the abundance of remaining stocks. There are risks of ecological and genetic impacts to the ESA-listed juvenile and adult spring Chinook salmon and steelhead resulting from the proposed programs. However, the risk of extinction to natural populations is high enough that aggressive intervention is required.

Genetic and Ecological Effects on Natural Populations: The genetic risks to naturally produced populations from artificial propagation include reduction in the genetic variability (diversity) among and within populations, genetic drift, selection, and domestication which can contribute to a loss of fitness for the natural populations (Hard *et al.*1992; Cuenco *et al.* 1993; NRC 1996; and Waples 1996).

Disease interactions between hatchery fish and listed fish in the natural environment may be a source of pathogen transmission. Because the pathogens responsible for diseases are present in both hatchery and natural-origin populations, there is some uncertainty associated with determining the extent of disease transmission from hatchery fish (Williams and Amend 1976; Håstein and Lindstad 1991).

It is acknowledged that among-population diversity for a portion of the ESU (Methow River Basin populations) may be negatively affected by the WDFW and USFWS programs if escapements remain low. Specifically, this effect may result from the consolidation of Methow Basin populations into a single Methow population through collection and mating of upriver-origin spawners arriving at Wells Dam. However, this strategy will provide unique information on how best to increase the abundance of fish, and the populations' recovery.

USFWS and the fisheries co-managers have implemented the phasing out of the non-endemic Carson-stock spring Chinook hatchery program to address the potential for genetic introgression and out-breeding depression. Efforts are being made to minimize the effects of these fish on the natural spawning population. By phasing out the Carson-stock spring Chinook and changing to Methow Composite stock, the potential adverse genetic effects from natural spawning hatchery fish will be greatly reduced.

Direct competition for food and space between hatchery and listed fish may occur in spawning and/or rearing areas, the migration corridor, and ocean habitat. These impacts are assumed to be greatest in the spawning and nursery areas and at points of highest fish density (release areas) and to diminish as hatchery smolts disperse (USFWS 1994).

Competition for space and cover in the Methow River probably occurs between hatchery and natural fish shortly after release and during downstream migration, but based on the smolt travel times the duration of interaction is minimal in the river (WDFW 1998a). Rearing and release strategies at all WDFW salmon and steelhead hatcheries are designed to limit adverse ecological interactions through minimizing the duration of interaction between newly liberated hatchery salmon and steelhead and naturally produced fish.

Hatchery fish may prey upon listed fish. Due to their location, size, and time of emergence, newly emerged Chinook salmon fry are likely to be most vulnerable to predation by hatchery released fish. Their vulnerability is believed to be greatest as they emerge and decreases somewhat as they move into shallow, shoreline areas (USFWS 1994). Emigration out of hatchery release areas and foraging inefficiency of newly released hatchery smolts may minimize the degree of predation on Chinook salmon fry (USFWS 1994).

Hatchery salmonids that do not emigrate after release are said to have residualized. These fish that residualize can adversely affect naturally produced fish through competition and predation. Chinook salmon do not tend to residualize (Groot and Margolis 1991), thus no effects are expected on natural UCR spring Chinook salmon or steelhead in the Wenatchee River.

Harvest Management: Fish harvest in the Columbia River basin affects the listed species by incidentally taking them in fisheries that target non-listed species. The largest potential impacts on UCR spring Chinook and steelhead come from treaty Indian and non-tribal fisheries in the Columbia River mainstem and potentially tributaries (Myers *et al.* 1998).

A sport fishery for steelhead in the UCR has been authorized under Section 10 Permit 1395. In years when the escapement of hatchery origin steelhead is greater than expected (i.e., over-escapement) the fishery was specifically designed to remove excess hatchery fish from the spawning grounds with minimal impacts to the natural origin steelhead.

Domestication of Hatchery Fish: Another concern of the artificial propagation of salmon is domestication, which is the change in quantity, variety, and combination of alleles within a captive population or between a captive population and its source population in the wild that are the result of selection in an artificial environment (Busack and Currens 1995). Domestication occurs because putting fish into an artificial environment for all or part of their lives imposes different selection pressures on them than does the natural environment. The concern is that domestication effects will decrease the performance of hatchery fish and their descendants in the wild. The concern is that hatchery fish selected to perform well in a hatchery environment tend to not perform well when released into the wild due to the difference between the hatchery and the wild environments. Potential impacts to the natural population occur when the hatchery fish spawns in the wild and the resulting performance of the natural population is reduced due to outbreeding depression (Busack and Currens 1995). The selection of broodstock is a common source of biased sampling. In general, broodstock selection should be random but bias occurs when selection is based on particular traits. Genetic changes due to unintentional selection can be caused by the hatchery environment, which allows more fish to survive compared to the natural environment. The elimination of all risks due to genetic diversity loss and domestication is not possible, but NOAA Fisheries believes that these risks can be minimized through the following measures proposed for the adult supplementation program:

- Address genetic concerns regarding selectivity, the collection of adult broodstock at traps for the supplementation program shall be representative of the run-at-large with respect to natural and hatchery parentage, migration timing, age class, morphology, and sex ratio;
- Provide that a proportion of each population that will not be subjected to artificial propagation and the associated potential risk of negative genetic effects, upstream escapement goal of approximately 80 adults per population will be maintained as a minimum level for natural spawning when escapement to Wells Dam is greater than 668 adults;
- An effective population size (N_e) of 500 fish per population per generation should be the *long-term* program production objective to maintain an adequate genetic base, even thought an N_e of at least 50 adults per generation is required to reduce the risk of inbreeding depression and genetic drift in the short term (fewer than 5 salmon generations) (BAMP 1998). If fewer adults are available, production can be scaled to ensure that hatchery-origin progeny do not overwhelm the population as a whole;
- Rear fish at minimum pond loading densities to reduce the risk of domestication effects and;
- Eliminate of Carson-stock spring Chinook (a highly domesticated stock) that will further reduce potential genetic effects.

Monitoring and Evaluation*:* The Wells Settlement Agreement (by which MFHC was authorized, and which will be superseded by the HCP) includes provision for evaluation of the MFHC, both in terms of meeting its production requirements under Phase I of the HCP, and its effects on natural production. This evaluation plan includes genetic monitoring of hatchery and naturally produced fish, migration timing and survival studies of hatchery releases, and studies to evaluate interaction between hatchery- and naturally produced fish. Monitoring and evaluation of the hatchery programs in the Methow River is on-going. The plan for the adult-based supplementation program addresses three critical uncertainties associated with the program:

- whether the hatchery facilities can safely meet their production objectives;
- the effect of the programs on the long-term reproductive success of the population in the natural environment;
- the identification of ways to operate the facilities to reduce the short-term ecological impacts to the naturally produced fish (WDFW 1998a).

Adaptive Management

The monitoring and evaluation program will also provide data that can be used to change the program if the results suggest doing so. The monitoring and evaluation programs will also provide invaluable data on the use of supplementation to conserve and recover ESA-listed salmon species.

Tribal Harvest Allocations

All hatchery programs in the Methow Basin are currently included in the Columbia River Fish Management Plan (i.e., US *v.* Oregon).

IV. Program Success

Federal program

Winthrop NFH was constructed to mitigate for lost habitat due to the construction of Grand Coulee Dam. The original objective of this facility was to provide adults for harvest. This role has changed in recent years. While in some years a sport fishery is open for adult steelhead returning to WNFH, it is desired that adult spring Chinook salmon (in excess of brood needs) are allowed to spawn naturally in the Methow River. This program change was driven by the ESA, and now focuses primarily on recovery.

State program

Viable Populations:

Spring Chinook

In recent years the number of hatchery fish on the spawning grounds have greatly exceeded the number of wild fish (>90%). The number of spring chinook (hatchery and wild) returning to the Methow Basin has also greatly exceeded escapement levels. While an increase in wild fish abundance has been observed, future adult returns should provide more information to the efficacy of the hatchery program in increasing the abundance of naturally produced populations.

Summer Chinook

Record escapements of summer Chinook in the Methow Basin in recent years have been positively influenced in part by the hatchery program at Carlton Pond. A goal of a supplementation program is to increase the number of spawners by allowing hatchery fish to spawn naturally. Subsequent increases in the number of naturally produced fish on the spawning grounds would support the hypothesis that hatchery fish contributed to future adult returns.

Steelhead
An increase in the number of wild fish incorporated into the broodstock would reduce any potential genetic impacts to the wild fish. In the Methow Basin, a high abundance of hatchery fish due to above average SAR's has lead to escapement levels far above the carrying capacity of the basin. In response, the WDFW developed a methodology using a sport fishery to reduce the number of hatchery fish on the spawning grounds, reducing not only density dependent effects but also genetic impacts.

Hatchery fish have been a dominant part of the spawning population for many years. However, the objective of the hatchery program has only recently changed to a recovery role versus a harvest augmentation role. Wild or naturally produced fish comprise approximately 10% of the run over Wells Dam. If the hatchery program is successful the proportion of wild fish should increase in subsequent years.

<u>Contribution of adults to recovery or harvest:</u>
Returning adults from these programs are intended to increase to naturally spawning populations. The hatchery programs have successfully contributed adults to the naturally spawning populations. However, harvest does occur in years of high abundance on summer chinook. Harvest of steelhead has recently been authorized under Section 10 Permit 1395 as a method to reduce hatchery fish on the spawning grounds.

Summer/fall Chinook smolts released from the Carlton acclimation pond have averaged 0.19 return rate to adults, ranging from 0.02 to 0.81 for brood years 1989 through 1997.

<u>Effects on Wild and Native Populations and Environment:</u> Effects on the wild populations (target and non-target) will be assessed at the juvenile stage using smolt traps and when fish return as adults. The relative productivity of the spawning population will be monitored over time using smolt traps located within the Basin. Relationships between smolt production and spawner abundance (% hatchery fish on the spawning grounds) will provide information related to reproductive potential of the stocks and habitat. Relationships in productivity between stocks would also provide some information regarding competition in the freshwater environment. Smolt traps also provide information regarding trends in other species not directly associated with hatchery programs (i.e., non-target taxa of concern).

Spawning ground surveys will not only be used to develop smolt-to-adult return rates (SARs) for hatchery and wild fish, but provide information on spawn timing and distribution. Biological data collected from carcasses will also provide data concerning age and size at maturity.

Comparisons of any these parameters (juvenile or adult) between hatchery and wild fish would provide insight on the effects hatchery fish may have on wild populations. Any effects that are detected (greater than acceptable levels) would be addressed in subsequent changes in the respective hatchery program.

Yakama Nation

Coho Salmon

Adult coho returns to Winthrop NFH in 1999 marked the first generation of the developing mid-Columbia coho broodstock. This first generation of mid-Columbia brood coho was spawned and reared at Winthrop NFH and acclimated and released in the Wenatchee Basin. Since then releases in the Methow River have continued to focus on the broodstock development process. Smolt-to-Adult rates for coho returning to the Methow River have ranged between 0.02% and 0.27%. Natural coho spawning has been document in the mainstem Methow River, Beaver Creek, Gold Creek, and Spring Creek.

Studies to evaluate species interactions have primarily been conducted in the Yakima and Wenatchee sub-basins, however many of the results may be transferable to coho reintroduction efforts in the Methow sub-basin. The YN has observed only low levels of predation by hatchery coho smolts on spring chinook fry as demonstrated through several predation evaluations in the Wenatchee and Yakima Rivers. Studies to evaluate predation by naturally produced coho on spring chinook fry are in the early stages, while two microhabitat and competition evaluations indicated that naturally reared coho parr selected different habitats than spring chinook parr or steelhead.

Okanogan Subbasin

I. Introduction

Various processes are underway within the Columbia Basin that direct hatchery program implementation. The listing of certain populations of fish under the ESA has also dictated hatchery program modifications and reform.

Some of the principal processes are:

Federal:

Hatchery and Genetic Management Plans:

The Hatchery and Genetic Management Plan (HGMP) process was initiated to identify offsite mitigation opportunities associated with operation of the Federal Columbia River Power System. The HGMP process is designed to describe existing propagation programs, identify necessary or recommended modifications of those programs, and help achieve consistency of those programs with the Endangered Species Act. The HGMP process only addresses anadromous salmon and steelhead programs.

Hatchery and Genetic Management Plans are described in the final salmon and steelhead 4(d) rule (July 10, 2000; 65 FR 42422) as a mechanism for addressing the take of certain listed species that may occur as a result of artificial propagation activities. NOAA Fisheries will use the information provided by HGMPs in evaluating impacts on anadromous salmon and steelhead listed under the ESA. In certain situations, the HGMPs will apply to the evaluation and issuance of section 10 take permits. Completed HGMPs may also be used for regional fish production and management planning by federal, state, and tribal resource managers.

The primary goal of the HGMP process is to devise biologically-based artificial propagation management strategies that ensure the conservation and recovery of listed Evolutionarily Significant Units (ESUs). The HGMP process also seeks to document and implement hatchery reform in the Columbia Basin. Much of the initial work on the HGMP process was coordinated and combined with efforts to complete the Artificial Production Review and Evaluation (APRE – see below)) analysis, which looked at the same sorts of information.

Artificial Production Review and Evaluation (APRE)

The APRE process seeks to document progress toward hatchery reform in the Columbia Basin. The NPCC used consultants and representatives of the Columbia Basin fishery managers to analyze existing programs and recommend reforms; a draft report that will go to the Council and the region has been prepared. The APRE process includes both anadromous and non-anadromous fish in its analysis.

Pacific Coastal Salmon Recovery Fund

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established in FY2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to Endangered Species Act (ESA) listings of West Coast salmon and steelhead populations. The PCSRF supplements existing state, tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation; promotes efficiencies and effectiveness in recovery efforts through enhanced sharing and pooling of capabilities, expertise and information. The goal of the Pacific Coastal Salmon Recovery Fund is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat.

The PCSRF's enhancement objective is*: To conduct activities that enhance depressed stocks of wild anadromous salmonids through hatchery supplementation, reduction in fishing effort on depressed wild stocks, or enhancement of Pacific salmon fisheries on healthy stocks in Alaska. This includes supplementation and salmon fishery enhancements.*

<u>US v. OR</u>

United States v Oregon, originally a combination of two cases, Sohappy v. Smith and U.S. v. Oregon, legally upheld the Columbia River treaty tribes reserved fishing rights. Specifically the decision acknowledged the treaty tribes reserved rights to fish at "all usual and accustomed" places whether on or off the reservation, and were furthermore entitled to a "fair and equitable share" of the resource. Although the Sohappy case was closed in 1978, U.S. v. Oregon remains under the federal court's continuing jurisdiction serving to protect the tribes treaty reserved fishing rights. This case is tied closely to U.S. v. Washington, which among other things defined "fair and equitable share" as 50 percent of all the harvestable fish destined for the tribes' traditional fishing places, and established the tribes as co-managers of the resource.

In 1988, under the authority of U.S. v. Oregon, the states of Washington, Oregon and Idaho, federal fishery agencies, and the treaty tribes agreed to the Columbia River Fish Management Plan (CRFMP), which was a detailed harvest and fish production process. There are no financial encumbrances tied to the process. Rather, the fish production section reflects current production levels for harvest management and recovery purposes, since up to 90% of the Columbia River harvest occurs on artificially produced fish. This Plan expired in 1998, and has had subsequent annual rollover of portions in which agreement has been reached. However, a newly negotiated CRFMP is forthcoming.

Hatchery production programs in the upper Columbia sub-basins are included in the management plans created by the fishery co-managers identified in the treaty fishing rights case *United States v Oregon*. The parties to *U.S. v Oregon* include the four Columbia River Treaty Tribes – Yakama Nation, Warm Springs, Umatilla, and Nez Perce tribes, NOAA-Fisheries, U.S. Fish and Wildlife Service, and the states of Oregon, Washington, and Idaho. The Shoshone-Bannock Tribe is admitted as a party for purposes of production and harvest in the upper Snake River only. These parties jointly develop harvest sharing and hatchery management plans that are entered as orders of the court that are binding on the parties. The "relevant co-managers" described in the *U.S. v Orego*n management plans are, for the mid-Columbia sub-basins, the federal parties, Yakama Nation, and Washington Department of Fish and Wildlife.

Hatchery programs are viewed by the Yakama Nation as partial compensation for voluntary restrictions to treaty fisheries imposed by the tribe to assist in rebuilding upriver populations of naturally-spawning salmonids. Because treaty and non-treaty fisheries are restricted on the basis of natural stock abundance, the tribal priority is to use hatcheries in a manner that supplements natural spawning and increases average population productivity. Perspectives on the appropriate use of hatchery-origin fish for supplementation vary between federal, state, and tribal fish co-managers. Federal and, to a lesser degree, state co-managers place a higher priority on managing the genetic risks of hatchery supplementation of natural populations, while the tribe sees the demographic threats of habitat loss and degradation as the greater risk to natural populations. In general, however, all parties agree that hatcheries can and should be operated as integral components of natural populations where the survival benefits of the hatchery can result in a significant increase in net population productivity.

ESA

Current ESA Section 10 Permits for listed summer steelhead (Permit #1395); listed spring chinook (Permit #1196) and non-listed anadromous fish (Permit # 1347) also direct artificial production activities associated with the habitat conservation plans. Douglas PUD, Chelan PUD and WDFW are co-permittees, therefore provisions within the permits and associated Biological Opinions are incorporated into the hatchery programs undertaken in the HCP's.

State:

The state, along with the federal government have various forums in which they are active. All have some role in determining or balancing artificial production programs, as well as the ones that follow under "other". Essentially no specific action would occur until the action is determined to be warranted in the already established processes.

Other:

<u>FERC processes:</u>
Under current settlement agreements and stipulations, the three mid-Columbia PUDs pay for the operation of hatchery programs within the Columbia Cascade Province. These programs determine the levels of hatchery production needed to mitigate for the construction and continued operation of the PUD dams.

<u>Habitat Conservation Plans:</u>
In 2002, habitat conservation plans (HCPs) were signed by Douglas and Chelan PUDs, WDFW, USFWS, NOAA Fisheries, and the Colville Confederated Tribes. The overriding goal of the HCPs are to achieve no-net impact[10] on anadromous salmonids as they pass Wells (Douglas

[10] NNI refers to achieving a virtual 100% survival of anadromous salmonids as they pass the mainstem projects. This is achieved through 91% survival of adults and juveniles (or 93% for juveniles) passing the projects, and 7% compensation through hatchery programs and 2% contribution through a tributary fund, which will fund projects to improve salmonid habitat in the tributaries.

PUD), Rocky Reach, and Rock Island (Chelan PUD) dams. One of the main objectives of the hatchery component of NNI is to provide species specific hatchery programs that may include contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest.

Biological Assessment and Management Plan:
The biological assessment and management plan (BAMP) was developed by parties negotiating the HCPs in the late 1990s. The BAMP was developed to document guidelines and recommendations on methods to determine hatchery production levels and evaluation programs. It is used within the HCP as a guiding document for the hatchery programs.

All of these processes affect the hatchery programs within the Upper Columbia Basin in one way or another.

Historic and current programs and facilities

Historic programs

Other than two releases of sockeye as part of the Grand Coulee Fish Maintenance Project, anadromous fish releases began in the Okanogan Basin in the early 1960s, when steelhead were released into the Similkameen River as part of a state program (Chapman et al. 1994). Periodic releases of steelhead have been made since the 1960s (and regularly since the early 1990s) into Omak Creek, and regularly since 1966 into the mainstem Okanogan River as mitigation for the operation of Wells Dam, which is funded by Douglas PUD. A small number of "catchable" trout were also released into the Okanogan; once in the 1940s, and then three more times in the 1970s. Since the early 1990s, summer/fall Chinook have been released in the Similkameen River.

Current program overview:

Currently, there are releases of summer/fall Chinook, steelhead, and experimental programs for spring Chinook and sockeye (in Canada).

Table 1. Current artificial anadromous fish production in the Okanogan Subbasin.

Fish Species	Facility	Funding Source	Production level goals
Spring Chinook	Omak Creek, Ellisford Pond	BPA, CCT	30,000-150,000 (current production is dependent on availability of Carson-stock eggs)
Steelhead	Wells hatchery, Omak Cr.	DPUD	100,000
Summer Chinook	CPUD	Similkameen rearing pond	576,000
Sockeye	none	Douglas PUD	To compensate for __ smolts, DPUD has funded a cooperative water flow effort in the Okanogan River upstream from Lake Osoyoos, which has increased survival of incubating sockeye.

Coho	n/a	n/a	n/a

State and other programs

Summer/Fall Chinook: Artificial propagation of summer Chinook was initiated in 1989 through a mitigation agreement with Chelan and Douglas PUDs. The program is intended to mitigate for the loss of summer Chinook from the operations of Wells, Rocky Reach, and Rock Island dams (WDFW 1999). This program also provides surplus fish for recreational and tribal ceremonial and subsistence fisheries.

Spring Chinook: Spring Chinook were extirpated from the Okanogan River before the 1930s due to excessive harvest in the lower Columbia River, and habitat destruction in Canadian waters and tributaries of the Okanogan River in the U.S. (Craig and Suomela 1931; Fish and Hanavan 1948). There has never been a formal mitigation program for spring Chinook in the Okanogan River.

Currently, spring Chinook are artificially propagated and released in the Okanogan subbasin through a cooperative agreement between NOAA Fisheries, USFWS, CCT, and WDFW, as an interim, segregated harvest program to support tribal ceremonial and subsistence fishing and provide information for a proposed, long-term integrated recovery program.

Steelhead: Wells Hatchery is funded by Douglas PUD and operated by WDFW as mitigation for passage mortalities at Wells Dam. Steelhead are artificially propagated and released in the Okanogan subbasin as an integrated harvest program. The Colville Tribes have also initiated a local broodstock program and will be starting a kelt reconditioning program to create a comprehensive integrated recovery program through funding by BPA.

Release numbers and locations of Wells Hatchery stock steelhead have varied considerably over the past 12 years. In the lower Similkameen River, releases have varied from 37,500 to 82,415 since 1992 (APRE 2003b). Releases elsewhere in the Okanogan subbasin, primarily Omak and Salmon Creeks, has varied from 30,000 to 160,756 since 1992 (APRE 2003a). Current releases of Wells Hatchery stock steelhead are planned at 50,000 into the lower Similkameen River and 50,000 at other locations in the Okanogan subbasin.

Coho: There never has been an artificial propagation program for coho salmon in the Okanogan subbasin, and none are proposed at this time, but may be in the future.

Sockeye: Sockeye salmon were to be propagated in the subbasin as part of the authorized mitigation program for Grand Coulee Dam. However, while there were two releases of sockeye into Lake Osoyoos during the GCFMP, the sockeye hatchery was not constructed. A short-term sockeye propagation program was initiated in the 1990s at Cassimer Bar Hatchery, but suspended after only a few years as success was questionable and the direction of mitigation was shifted to habitat improvement in Canadian waters.

Currently, a program funded by Douglas PUD for compensation of sockeye passage losses at Wells Dam, coordinates water releases in the upper Okanogan River, which has increased egg and fry survival of sockeye.

Facilities Description:

Summer/fall Chinook
This propagation program is operated as an integrated harvest program to mitigate for the effects of the three PUD dams. Adult summer Chinook are collected at the Wells Dam trap, held at Eastbank Hatchery located on the Columbia River at Rocky Reach Dam, north of Wenatchee. All spawning, incubation and early rearing occur at Eastbank Hatchery. In October, the fingerling Chinook are transported to Similkameen Pond, located at river mile 3.1 on the Similkameen River. Here the fish are acclimated through the winter until their release in April of the following year. In 2004, 100,000 of the program's 576,000 smolt release were reared at the Bonaparte Pond, located at river mile 56 on the Okanogan River, with the intent of dispersing subsequent spawning of returning adults in historical habitats. This program may continue in the future if facility modifications are made to reduce over-winter mortality.

Spring Chinook
Two spring Chinook programs have been initiated in the Okanogan subbasin on an interim, informal basis. In Omak Creek, an integrated recovery program is underway to reintroduce spring Chinook in this historical habitat. The program was initiated in 2001 with scatter planting of 40,000 yearling spring Chinook in Omak Creek, below Mission Falls. These fish were of Carson stock origin reared at Winthrop NFH. These releases continued in 2002 with a scatter planting of 48,000 Carson stock Chinook from Leavenworth NFH. In 2003, 35,000 spring Chinook from Leavenworth NFH were again released in Omak Creek, but were first acclimated at the newly constructed St. Mary's Mission Acclimation Pond. All 45,000 Chinook scheduled for release in 2004 were lost when the new acclimation pond's pump failed. These releases are intended to test the capability of Omak Creek and the Okanogan River to again support spring Chinook.

In the Okanogan River, a segregated harvest program was initiated in 2001 with the acclimation of 254,000 Carson stock spring Chinook in Ellisforde Pond for release in April 2002. These fish were from Winthrop NFH and were surplus to management needs in the Methow subbasin. Releases of 100,000 spring Chinook from Leavenworth NFH were made in 2003 (from Bonaparte Pond) and 2004 (again from Ellisforde Pond). The first returns from these fish are expected in 2005 as four-year-olds. The objective of these fish is to test the capability of the Okanogan River to support spring Chinook migration and to provide a tribal ceremonial and subsistence fishery. No spawning of these fish in the Okanogan River is desired.

Steelhead
Wells Hatchery is located adjacent to Wells Dam at river mile 535 of the Columbia River. The hatchery production destined for the Okanogan is currently operated as an integrated recovery program, contributing to the conservation of the population, but also providing some harvest opportunity. Broodstock is collected from the west bank fish ladder at Wells Dam and from

volunteer returns to the Hatchery, held to maturity and spawned at the Hatchery. Two mating categories are used, wild x hatchery crosses and hatchery x hatchery crosses (APRE 2003a). The latter crosses have been released in the Okanogan subbasin, however, plans are now to release H x W crosses in the Okanogan whenever possible. Juvenile steelhead are reared to yearlings, then transported to the Okanogan subbasin where they are scatter planted in the Similkameen River (50,000), Omak Creek, Salmon Creek, and the Okanogan River (50,000) in late April to mid May.

In 2003, the Colville Tribes initiated a local broodstock program, collecting steelhead returning to Omak Creek. Eggs are incubated and subsequent fingerlings and pre-smolts reared at Colville Trout Hatchery, river mile 542 of the Columbia River. The integrated recovery program is planned to release 20,000 smolts in April or May of each year (NMFS 2003).

Genetic Integrity of Populations

Summer/fall Chinook

The Okanogan subbasin population of summer/fall Chinook is a fully integrated between the natural and hatchery origin fish. “There are no known genotypic, phenotypic, or behavior differences between the hatchery stocks and natural stocks in the target area” (WDFW 1999). The Okanogan and Methow populations have been managed as a single entity with a common hatchery broodstock.

The later-arriving component of the Okanogan summer/fall Chinook population has been severely depressed due to mortalities imposed by passage through nine mainstem dams, higher harvest rates on these fish in lower river fall Chinook fisheries, and the lack of artificial propagation. This component of the run is proposed by intensive propagation to restore its abundance (CCT 2004a).

Spring Chinook

There currently is no natural spring Chinook population in the Okanogan subbasin.

Steelhead

Current steelhead populations originated from a mix of indigenous upper Columbia Basin stocks intercepted during the GCFMP of the 1930s and 1940s, and potential resident fish. The Wells Hatchery stock was initiated in the 1960s from naturally spawning populations migrating past Priest Rapids Dam. The genetic background of the stock is therefore from a mix of populations. The stock is considered highly domesticated from years of broodstock collection at the hatchery and the low level of natural-origin fish available for inclusion in the broodstock. With about 81% of the natural spawning escapement consisting of hatchery-origin fish and the Okanogan subbasin receiving progeny of H x H crosses, the natural populations have been substantially affected by the Wells Hatchery program.

The new conservation programs initiated by the Colville Tribes and further efforts of WDFW at the hatchery to incorporate different matings (HxW, etc.) are intended to improve the viability and adaptability of steelhead in the Okanogan (and other) subbasin.

II. Program Goals and Objectives

Summer/fall Chinook

The goal of the Similkameen Pond program is "…to mitigate for the loss of summer Chinook salmon adults that would have been produced in the region in the absence of Wells, Rocky Reach, and Rock Island hydroelectric projects" (WDFW 1999). To this end, the mitigation agreement requires the production and release of 576,000 yearling summer Chinook in the Okanogan subbasin. Performance objectives and performance indicators have been established for the program (WDFW 1999) that addresses program benefits and risks.

Spring Chinook

The goal of the integrated recovery program in Omak Creek is to restore a natural spawning population of spring Chinook in historical habitats that contributed to the fisheries of the Confederated Tribes of the Colville Reservation. This program would also assist, longer-term in the recovery of endangered Upper Columbia River Spring Chinook when Carson stock is replaced with Methow Composite stock. Phase I of this program is intended to return 200- 700 adults to the subbasin to allow assessment of survival parameters and suitability of habitat.

The goal of the segregated harvest program is to mitigate for the loss of spring Chinook due to the construction of Grand Coulee, Chief Joseph, Wells, Rocky Reach, Rock Island, Wanapum, Priest Rapids, McNary, John Day, The Dalles, and Bonneville Dams. The fish will be managed for tribal ceremonial and subsistence fisheries and recreational angling. The Phase I of this program is intended to return 400 – 1,400 adults to the Okanogan River for tribal and recreational harvest. These fish will also be used to test the feasibility of live-capture, selective fishing gears the Colville Tribes intend to deploy for subsistence fishing.

Steelhead

The goal of the Wells Hatchery program in the Okanogan subbasin is to contribute to the conservation and recovery of steelhead while providing for recreational and tribal harvest when compatible with recovery.

From brood year 1981 through brood year 1996, smolt-to-adult survival for Wells Hatchery stock has ranged from 0.29% to 7.54 %, with a median survival of 0.92% and a mean survival of 1.63 % (WDFW 2002).

<u>Proposed programs</u>

Summer/fall Chinook

The Colville Tribes are proposing the construction of Chief Joseph Dam Hatchery and the use of 2 new acclimation ponds on the Okanogan River to increase the abundance, distribution and diversity of the propagation program for summer/fall Chinook in the Okanogan subbasin.
The Colville Tribes (CCT 2004a) have proposed to increase production levels of summer/fall Chinook to increase the abundance, diversity, and distribution of the naturally spawning

population and provide a more stable base for tribal ceremonial and subsistence fishing and recreational angling. The proposed program would initially release an additional 400,000 yearling summer/fall Chinook from a new acclimation site proposed near river mile 49, and 700,000 yearling and sub-yearling Chinook from a new acclimation pond at the mouth of Omak Creek (river mile 32). The broodstock for these releases would constitute the later-arriving Chinook that are not included in the current propagation program.

The current escapement goal for summer/fall Chinook in the Okanogan and Methow rivers is 3,500 fish past Wells Dam. The Colville Tribes have proposed to expand this escapement initially by 1,200 later-arriving summer/fall Chinook in the Okanogan subbasin. The Colville Tribes, in their draft Okanogan River Summer/Fall Chinook HGMP, are proposing an expanded management program to increase the escapement of summer/fall Chinook throughout their historical range in the Okanogan River by employing habitat enhancement and an expanded and diversified propagation program. The ultimate management goal will need to be derived from monitoring and evaluating the significant new program. The goal will need to include both increased escapement and stable harvestable surpluses for tribal and recreational fisheries.

Spring Chinook

The Colville Tribes are seeking an extension of the interim programs described above until a larger and more formal program can be initiated. The Colville Tribes are seeking a program that would initially release 200,000 Carson stock spring Chinook from Ellisforde Pond and 50,000 from St. Mary's Mission Pond. Eggs for this program would be collected at Leavenworth NFH then incubated and reared at Willard NFH prior to transfer to the two acclimation ponds in October (CCT, 2004b).

The Colville Tribes have proposed in their Okanogan River Spring Chinook HGMP to initiate a significant reintroduction effort. This would begin using Carson stock in an integrated recovery program followed by a transition to endangered Upper Columbia River Spring Chinook from the Methow subbasin upon its availability. The Colville Tribes are also proposing an initial isolated harvest program using Carson stock Chinook to be converted later to an integrated harvest program upon the availability of Methow subbasin fish. The HGMP's recovery goal is to restore spring Chinook in their historical tributary habitats, including eventually in Canadian waters. Enumerating a recovery goal at this time is premature until the Colville proposals are approved.

Steelhead

The Colville Tribes have initiated preparation of an Okanogan River Steelhead HGMP. The goal of the program will be to restore endangered steelhead in their historical habitats and create harvestable surpluses for tribal ceremonial and subsistence fisheries and for recreational harvest. Recovery of steelhead will require a mix of habitat restoration actions in tributary streams and artificial propagation. The later will include initiating a local Okanogan River broodstock to replace the homogenized, domesticated stock at Wells Hatchery and a kelt reconditioning program. Enumerating a recovery goal at this time is premature until the Colville Tribes' HGMP has been completed and implementation approved.

The objective of the new local broodstock project is to release 20,000 yearlings in Omak Creek starting in 2004. At that time, Wells Hatchery steelhead will no longer be released in Omak Creek.

The Colville Tribes will also soon be initiating a kelt recondition project in Omak Creek as part of a research experiment to compare the relative reproductive success of natural-origin, hatchery-origin, and reconditioned kelts in producing offspring.

The Colville Tribes are initiating development of a comprehensive HGMP for future management of steelhead in the Okanogan subbasin, working directly with WDFW and other fishery co-managers. Objectives for future management will include recovery of the population and provisions for tribal ceremonial and subsistence harvest and recreational angling that is consistent with recovery

Sockeye & Coho
There have never been or are no longer artificial propagation programs for sockeye or coho salmon in the Okanogan subbasin. Rehabilitation of the sockeye population in the Okanogan subbasin is currently being pursued through habitat rehabilitation efforts largely in Canada. First Nations in Canada have also initiated an artificial propagation program to increase fry production in lake waters. The Colville Tribes may soon propose a coho salmon reintroduction program for the Okanogan River. At that time, an HGMP will be prepared.

Relationship Between Artificial and Natural Populations

Summer/fall Chinook
The current propagation program uses broodstock collected at Wells Dam from mid July through August 28th, a combination of Chinook destined for the Okanogan and Methow rivers (and perhaps Columbia River). The Similkameen Pond program has successfully increased the abundance of the naturally spawning Chinook as evidenced by the high proportion of hatchery fish in the spawning population. The resulting population of hatchery-origin and natural-origin fish is fully integrated.

It appears that the Similkameen program has been essential in maintaining at least the short-term health of the summer/fall Chinook population in the Okanogan subbasin. [note – this is speculative, and if it is just dam based – then why has the Wenatchee late-run population been increasing over the last 40 years?] As with almost all supplemented populations of salmon, however, what is not known is the relative reproductive success of these hatchery-origin fish compared to the natural-origin Chinook in producing offspring.

Historically, natural Okanogan summer/fall Chinook have displayed a dominate sub-yearling or ocean-type life history strategy with juvenile fish entering the ocean in their first year. More recently, biologists have been documenting that many natural-origin adults are the result of a yearling or reservoir reared life history, apparently over-wintering in the Columbia River reservoirs prior to entering the ocean (J. Sneva, WDFW, pers. Comm.). However, the presence of the reservoir reared pattern became apparent well before demographic changes could have taken place through the summer Chinook supplementation yearling programs. And in fact, the reservoir rearing could be an environmental adaptation for summer Chinook in the impounded Columbia River system. The Similkameen Pond propagation program releases yearling smolts that have been shown in other summer/fall Chinook programs to survive at much higher rates than sub-yearling releases. The effect of yearling releases on the long-term health of the population is not known.

A second variation of the artificial propagation program relative to the natural population is the timing of broodstock collection. All broodstock collected for the hatchery program is done from mid-July through August 28th, although summer/fall Chinook continue to migrate past Wells Dam into November. This truncated collection period was initiated to avoid including stray fall Chinook from lower river programs in the broodstock. This straying problem has since been eliminated, because Turtle Rock no longer uses Priest Rapids Hatchery fall Chinook, but rather uses summer Chinook collected at Wells Hatchery.

The expanded propagation program proposed by the Colville Tribes (CCT 2004) has been designed to enhance the qualities of the current Similkameen Pond program. Adult Chinook would be collected in or near the Okanogan River to create a fully localized broodstock of fish adapted to the Okanogan River. Broodstock would include the later-arriving population component (September to early November) that are believed to spawn in the lower river reaches, later in the fall. The added numbers of juvenile fish would be acclimated at two new sites in the mid and lower Okanogan River (Riverside and Omak) to seed these underutilized, historical habitats. And also, about 40% of the juvenile releases at Omak would be sub-yearling fish, the natural life history, to monitor their success relative to the yearling hatchery releases and the natural-origin migrants.

Spring Chinook

Spring Chinook salmon were extirpated from the Okanogan subbasin so there is no natural population. Carson stock spring Chinook have been used as eggs and are readily available from the Wenatchee subbasin and the stock has performed relatively successfully in the Columbia Cascade Province when artificially propagated. The Colville Tribes have proposed to use Carson stock until a surplus of ESA-listed Methow Composite stock is available from Winthrop NFH and Methow State Hatchery that can be introduced into the Okanogan subbasin as an experimental population under the terms of the ESA (CCT 2004b).

Steelhead

Steelhead populations are currently listed as endangered in the Columbia Cascade Province with natural cohort replacement rates prior to 1995 thought to be 0.3 or less for the various populations. The Okanogan subbasin has been a low priority for steelhead recovery efforts. At one time, NOAA Fisheries concluded that, “Current habitat conditions are not conducive to steelhead in the Okanogan River subbasin.” Further, the Wells Hatchery releases destined for the Okanogan subbasin are from hatchery x hatchery crosses which would be expected to have the least success in natural reproduction. WDFW’s spawning ground objective for the listed ESU has been 6,000. However, the Okanogan subbasin was not included in this objective.

With recent habitat improvements in Omak and Salmon creeks, natural reproduction of steelhead in the Okanogan subbasin has been increasing. In 2002, 39 steelhead redds were observed in two miles of reference reaches and natural-origin steelhead fry were abundant (Fisher 2003a). In 2003, 21 steelhead redds were observed in the same reaches. Fry were again abundant in some reaches, but not others due to a kill resulting from an accidental dumping of fire retardant (Fisher 2003b). Also in 2003, six steelhead redds were observed in Salmon Creek following an experimental release of water by the Okanogan Irrigation District. Subsequently, fry production was observed (Fisher 2003c). Further demonstrating the improved status of natural-origin steelhead in the Okanogan subbasin, with issuance of Section 10 (a)(1)(A) Permit 1395 to WDFW in October of 2003, NOAA Fisheries designated mortality limitations to natural-origin steelhead in the Okanogan River with runs up to 600 natural-origin fish.

Internal and External Consistency of Program to Purpose

Summer/fall Chinook
The Similkameen Pond program has been operated consistently with the planned objective of managing the Okanogan and Methow summer/fall Chinook as a single population. Actions that need to be undertaken in the Okanogan subbasin to improve the consistency of the existing program include:

1. Develop a local Okanogan broodstock, separate from the Methow population.
2. Propagate the entire summer/fall Chinook run, including fish arriving in September, October, and November.
3. Propagate and evaluate the benefits and costs of releasing the natural sub-yearling type juvenile in addition to the yearling smolts.
4. Continue to disperse acclimated hatchery releases throughout the full range of historical habitat.
5. Develop harvest strategies that manage for the proportion of hatchery-origin fish in the spawning population to optimize the population's viability.

Spring Chinook
The programs are too new to evaluate internal or external consistency. A key external risk that must be evaluated is the extent, if any, to which the Carson-stock spring Chinook stray to the Methow subbasin and spawn with ESA-listed Chinook of the Upper Columbia River Spring Chinook ESU or survive through the summer in the Okanogan River and spawn with summer/fall Chinook. Management actions will be taken to minimize these risks.

Steelhead
The current steelhead program in the Okanogan subbasin is going through a substantial change. Additional planning and execution via a new HGMP will be required to direct a holistic and consistent program. Actions that need to be undertaken in the Okanogan subbasin to improve the consistency of the existing program include:

1. Implement new acclimation sites for Wells Hatchery stock steelhead in the Okanogan subbasin that will provide ongoing conservation and fishery benefits, but not conflict with the new local broodstock and kelt reconditioning programs being developed in Omak Creek.

2. Transition from the aggregate, domesticated Wells Hatchery stock to an entire Okanogan subbasin program supported by local broodstock.
3. Implement a steelhead marking program that will support, yet differentiate the Wells Hatchery stock and Omak Creek programs.
4. Expand the local broodstock and kelt reconditioning programs from a base of Omak Creek to programs appropriate for the entire Okanogan subbasin.
5. Adjust proposed programs based on results of planned research in Omak Creek to evaluate the relative reproductive success of hatchery-origin, natural-origin, and reconditioned kelt steelhead.

III. Program Operations

Summer/fall Chinook

To implement the current Similkameen Pond program, broodstock are collected at the Wells Dam east ladder trap from mid-July through August 28th then immediately transported to Eastbank Hatchery for holding and maturing. For both the Okanogan and Methow programs, 556 Chinook are taken with equal numbers of males and females. In taking broodstock, there in no protocol for selecting for or against any particular trait. The program has specific protocols that ensure broodstock collection does not adversely affect natural spawning goals (WDFW 1999).

Adults are primarily spawned from late September through late October. A 1:1 mating scheme is employed. Eggs are placed in Heath stack incubators. Ponding of swim-up fry occurs after accumulation of about 1,700 temperature units from early May through June. About 85% of fertilized eggs survive to fry ponding. Rearing of juveniles is performed in raceways following loading densities of 6 lbs./gpm and 0.75 lbs./cu. ft. (WDFW 1999).

Fish health and disease are continuously monitored (10-15 times) by professionals in compliance with standard fish health policy standards. BKD is the primary disease of concern.

In October, fingerlings are transferred from Eastbank Hatchery to Similkameen Pond where they are reared for 6 months through the winter until release in early April. The objective for smolts is 576,000 at 10 fpp. All smolts are adipose fin clipped and coded wire tagged for identification.

Okanogan summer/fall Chinook contribute in various amounts to fisheries along the West Coast from S.E. Alaska to the Columbia River. Prior to recent harvest restrictions implemented due to widespread listings of salmon species pursuant to the Endangered Species Act, summer Chinook were harvested at high rates in ocean fisheries of Alaska and British Columbia. With the increased runs of the past three years, recreational fishing and tribal treaty fisheries in the Columbia River have enjoyed increased harvests. In the past two years, recreational fishing in the Okanogan River has resumed. The Okanogan summer/fall Chinook provide the Colville Tribes' with their last remaining ceremonial and subsistence fishery of any magnitude. Average Tribal harvests have been consistently below 1,000 fish until the past few years when harvest has exceeded 3,000 Chinook.

Spring Chinook
Broodstock collection, mating, egg incubation, and early rearing of the spring Chinook released in the Okanogan subbasin is performed at Leavenworth NFH, the operations of which can be viewed in the appended Okanogan River Spring Chinook HGMP (CCT 2004b) or sought in that facility's HGMP or the Wenatchee Subbasin Plan.

In October of each year the fingerling spring Chinook are transported to St. Mary's Mission Pond on Omak Creek and Ellisforde Pond on the Okanogan River. Ellisforde Pond is an open-air pond, is 225' x 90' x 6' deep, and has 121,500 cubic feet of useable rearing volume. The Pond's water is supplied by six pumps, each delivering 5 cfs from the Okanogan River. The pond is located on the left bank of the Okanogan River at river mile 62, near the community of Ellisforde. St Mary's Mission Pond is 72' x 12'x 4' and served with gravity flow from Omak Creek and from a well. Either water source can provide the necessary 550 gpm water supply. The Chinook are fed a restricted diet through the winter months followed by increased feeding and accelerated growth prior to their April release. The size objective for these Chinook is 15 fpp.

Steelhead
Steelhead broodstock for the Wells Hatchery stock program are collected in the west ladder of Wells Dam and from volunteer returns to the Hatchery. Fish are collected from throughout the run starting in August and into the following spring. To supply sufficient steelhead for all subbasins in the upper Columbia, 420 steelhead are collected for broodstock. Wild-origin fish have made up 5-12% of the broodstock. Fish are spawned in the spring as they ripen. Steelhead matings for the program are W x W, H x W, and H x H, with the latter destined for the Okanogan subbasin.

For the new local broodstock program, the 10 - 16 adult fish required for broodstock are collected at a weir and trap located at approximately river mile 0.5 in Omak Creek near its confluence with the Okanogan River. The trap is operated from March until early May. Collected steelhead are transported to Cassimer Bar Hatchery for holding. Hatchery-origin broodstock may be returned to Omak Creek if natural-origin steelhead are later trapped in order to meet broodstock protocols. Broodstock are examined weekly for ripeness and accordingly spawned. The mating preference is W x W crosses and secondarily H x W crosses.

At Cassimer Bar Hatchery, eggs are incubated in vertical Heath trays. Green egg to eyed egg survival is expected to be about 80%. Upon hatching and button-up, fry are transferred to modified Capillano troughs (63 cu. ft). Steelhead are reared in the troughs until July or when they reach 400/lb, when they are transferred to outside raceways (Golder 2002). Fingerlings are marked using elastomer-type tags. Due to water and space limitations at Cassimer Bar Hatchery, final rearing of the steelhead occurs at Colville Trout Hatchery.

Steelhead are reared to a size of 10 to 15 fish per pound and then scatter-planted in Omak Creek prior to mid-April. Any production above the 20,000 smolt objective, will be planted into other Okanogan River tributaries (e.g. Tunk or Bonaparte creeks).

Program Success

Summer/fall Chinook
The Similkameen Pond program has been operated consistently with the planned objective of managing the Okanogan and Methow summer/fall Chinook as a single population. The program has been successful in maintaining at least minimum numbers of spawning fish through years of poor freshwater and marine survival. In more recent years, the program has supported revitalized recreational and tribal fisheries throughout the Columbia River. Recent dispersal of production to Bonaparte Pond should improve the program contribution to population diversity in the Okanogan Basin.

The propagation of summer Chinook in the Okanogan subbasin was initiated with the 1989 brood year and a subsequent release of 352,600 yearling smolts in 1991. Since that time, releases have varied about the 576,000 program objective (WDFW 1999). Through 2003, all releases were made from Similkameen Pond. However, this has resulted in excessive use of the spawning habitat in the Similkameen and upper Okanogan rivers while other historical habitats are under utilized. In 2004, 100,000 of the Chinook historically released from Similkameen Pond may be released from Bonaparte Pond. If successful, this release may be increased to 200,000 yearlings (depending on modifications to the pond – see above).

The summer/fall Chinook destined for the Okanogan River has recently experienced a substantial increase. From runs of under 5,000 fish passing Wells Dam, returns since 2001 have ranged from about 40,000 to 69,000 adults. The proportion of hatchery-origin fish in the naturally spawning population is substantial ranging from just under 50% in the lower runs of recent years to over 70% in the last few larger runs.

The smolt-to-adult return rate for the Similkameen rearing pond has averaged 0.74 for brood years 1989 through 1997, ranging from 0.001-2.11.

Spring Chinook
Adults are not expected to start returning until May or June of 2005. Therefore no measurements of program success are available. Performance standards and indictors have been developed for the program and will be the basis for a monitoring and evaluation program.

Rearing in the new acclimation ponds has not been without mishap, however. At St Mary's Mission Pond, 10,000 fish were lost just prior to release. In 2004, all 45,000 fish were lost when the gravity water supply iced up and the auxiliary pump failed.

Steelhead
From brood year 1981 through brood year 1996, smolt-to-adult survival for Wells Hatchery stock has ranged from 0.29% to 7.54 %, with a median survival of 0.92% and a mean survival of 1.63 % (WDFW 2002).

REFERENCES

APRE. 2003a. APRE-HGMP Phase II Report, Okanogan Subbasin Summer Steelhead.

APRE. 2003b. APRE-HGMP Phase II Report, Lower Similkameen (Okanogan) Summer Steelhead.

NMFS. 2003. Section 10(a)(1)(A) Permit 1412 for Take of Endangered/Threatened Species.

Fisher, C., Arterburn J. 2003a. Steelhead Surveys in Omak Creek, 2002 Annual Report.

Fisher, C., Arterburn J. 2003b. Steelhead Surveys in Omak Creek, 2003 Annual Report.

Fisher, C. 2003c. Snorkel Survey for Salmon Creek – 2003.

WDFW. 2002. Section 10 direct Take Permit Application to Enhance the Propagation or Survival of Endangered or Threatened Species Under the Endangered Species Act of 1973.

Golder and Associates. 2002. Draft Okanogan Basin Summer Steelhead Integrated Recovery Program.

CCT. 2004a. Okanogan River Summer/Fall Chinook Hatchery and Genetic Management Plan.

CCT. 2004b. Okanogan River Spring Chinook Hatchery and Genetic Management Plan.

WDFW. 1999. Hatchery and Genetic Management Plan, Upper Columbia Summer Chinook Salmon Mitigation and Supplementation Program, Eastbank Fish Hatchery and Wells Fish Hatchery Complexes

Yakama Nation, Washington Department of Fish and Wildlife, Bonneville Power Administration. 2002. Hatchery and Genetic Management Plan, Mid-Columbia Coho Reintroduction Feasibility Project.