MONITORING AND EVALUATION PLAN FOR THE NEZ PERCE TRIBAL HATCHERY

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NOTICE OF ACCEPTANCE

The Nez Perce Tribe hereby submits this Monitoring and Evaluation Plan for the Nez Perce Tribal Hatchery. The Tribe believes the plan is a comprehensive work, encompassing many of the latest assessment techniques useful to determining whether or not hatchery supplementation can be successful in reestablishing and restoring runs of naturally spawning anadromous fish. The plan can be an extremely useful prototype for other supplementation efforts undertaken in the Columbia Basin, in addition to being used to guide efforts of the Nez Perce Tribal Hatchery.

The Nez Perce Tribe reserves the right to treat the plan as a dynamic, evolving effort. Full implementation of the recommendations made in the M&E Plan will be contingent upon funding and changes in information available in the Columbia Basin and the Clearwater Subbasin in particular. Consequently, not every item identified in the implementation strategies may be fulfilled as described in the plan. Specific annual and long-term monitoring and evaluation activities will be determined by the Nez Perce Tribe in coordinated efforts with the funding agencies for the hatchery.

EXECUTIVE SUMMARY

The Nez Perce Tribe has proposed to build and operate the Nez Perce Tribal Hatchery (NPTH) in the Clearwater River subbasin of Idaho for the purpose of restoring self-sustaining populations of spring, summer, and fall chinook salmon to their native habitats. The project comprises a combination of incubation and rearing facilities, satellite rearing facilities, juvenile and adult collection sites, and associated production and harvest management activities. As currently conceived, the NPTH program will produce approximately 768,000 spring chinook parr, 800,000 summer chinook fry, and 2,000,000 fall chinook fry on an annual basis. Hatchery fish would be spawned, reared, and released under conditions that promote wild-type characteristics, minimize genetic changes in both hatchery and wild chinook populations, and minimize undesirable ecological interactions. The primary objective is to enable hatchery-produced fish to return to reproduce naturally in the streams in which they are released.

These and other characteristics of the project are described in further detail in the Nez Perce Tribal Hatchery Master Plan (Larson and Mobrand 1992), the 1995 Supplement to the Master Plan (Johnson et al. 1995), and the Nez Perce Tribal Hatchery Program Environmental Impact Statement (Bonneville Power Administration et al. 1996). The report in hand is referred to in project literature as the NPTH Monitoring and Evaluation (M&E) Plan.

This report describes monitoring and evaluation activities that will help NPTH managers determine. whether they were successful in restoring chinook salmon populations and avoiding adverse ecological impacts. Program success will be gauged primarily by changes in the abundance and distribution of supplemented chinook populations. The evaluation of project-related impacts will focus on the biological effects of constructing and operating NPTH hatchery facilities, introducing hatchery fish into the natural environment, and removing or displacing wild fish, including targeted chinook, non-targeted chinook, and resident species.

The M&E Plan is also meant to support the capability of the Tribe to detect and report on changes in the environment and non-Tribal management activities that might affect the outcome of the hatchery program. Several information-gathering strategies are proposed that will provide meaningful and cost-effective assessment of environmental events and non-project management activities that might affect project status and impacts. NPTH managers can use this information to make informed decisions and resolve potential conflicts.

Monitoring needs, procedures, and products are discussed as they relate to salmon supplementation theory, to NPTH goals and objectives, and to assumptions that are critical to the program's planning and success. The validity of many of these assumptions is uncertain or depends on factors that are beyond the control of program managers. Uncertainty implies an element of risk since making an erroneous assumption may lead to undesirable consequences. Project-related assumptions were carefully evaluated to expose any conceptual inconsistencies or weaknesses in the project, to quantity the risk inherent in project-related assumptions, and to identity ways in which undesirable consequences could be avoided or minimized. Risk was quantified by explicitly considering our level of understanding of the assumption or process in question, the probability that the assumption or predicted outcome is or will be correct, the likely consequences of being incorrect, and whether the risk may be avoided or reduced using available technologies and resources. Three individuals who are familiar with the project and associated resources participated in the risk assessment process.

Information needs identified through the risk assessment process enabled us to identify and prioritize monitoring and evaluation activities, which in turn formed the basis for the conceptual M&E Plan. Monitoring and evaluation will target information that can be used to reduce or eliminate the uncertainty associated with high risk assumptions, so that undesirable ecological or economic impacts can be avoided. If the evidence indicates an assumption is invalid or entails unacceptably high risk, either the assumption or the NPTH program will need to be revised.

Project assumptions were organized hierarchically by category, subcategory, and performance criterion. We were primarily concerned with assumptions relating to "ecological" impacts, which we grouped into three categories: Stock Status, Biological Interactions, and Natural Environment. Stock Status refers to targeted chinook populations; i.e., hatchery and wild components of the supplemented population. This category comprises genetic, life history, and population viability subcategories. Monitoring and evaluation activities associated with these subcategories would be primarily directed at detecting genetic and life history differences between wild and hatchery fish, and changes in population characteristics over time.

Many of the biological processes that can be expected to affect stock status will be investigated under the Ecological Interactions category. However, this category not only includes intraspecific interactions, which involve competition, reproduction, and disease transmission between targeted hatchery and wild chinook populations, but also interspecific interactions, which involve competition, predation, and pathogen interactions between targeted chinook and other species of fish and wildlife.

The third category of interest was the Natural Environment. Some of the assumptions grouped into this category were concerned with the effect of the program on the overall health of the natural system, as indexed by its biological diversity and the status of threatened and endangered species. However, in addition to assumptions that address project impacts, this category comprises several assumptions regarding natural processes and human activities that might affect project success or moderate its impact on the environment. Included in this category are natural factors and human influences that could potentially limit the survival and abundance of wild and hatchery fish. We distinguish between factors affecting the production potential of the system, such as streamflow, water quality, and habitat carrying capacity, and “extrinsic factors”, defined as environmental disturbances or management decisions that could potentially affect chinook stock status and project viability over the long-term. Examples include natural disturbances such as fire, the presence of federally protected species, hydrosystem operations, and other human activities.

In summary, the M&E Plan will not only facilitate assessment of the performance of hatchery fish, it will also enable NPTH managers to determine the effects of the project on wild fish and other aquatic biota, provide information on the capacity of the natural environment to assimilate and support chinook salmon, and give early warning of changes in environmental quality and management policy that may affect the project’s success.

The characteristics of the environment that make good indicators of project status and impact are referred to as performance criteria. Performance criteria include biological characteristics such as population abundance and interspecific competition, as well as non-biological attributes such as streamflow and water quality. For each performance criterion, one or more performance variables were selected to provide readily measurable indices of change. For example, to measure changes in chinook population abundance, we recommended that returning adults be enumerated at stream weirs or, in the case of summer and fall chinook, that redd counts be used as an index of spawning escapement. Chinook parr densities, smolt counts, and harvest were also selected as performance variables for the population abundance criterion (Stock Status category, Population Viability subcategory). Taken together, these variables provide reliable indicators of change in the size and distribution of chinook populations expected under the NPTH program.

The actual parameters to be monitored to measure progress toward meeting program goals, to assess project impacts, and to detect background changes in the environment are called performance variables. They were selected on the basis of their scientific validity, ease and cost of measurement, and relevance to project objectives and critical uncertainties. A total of 83 performance variables were selected. For each variable, we describe why it was selected, how and when it is to be measured, the units (fish, sites, streams, etc.) to be sampled, and the analytical procedures to be applied to the data. We also indicate where opportunities may exist for integrating NPTH monitoring and evaluation activities with ongoing federal and state monitoring programs.

Once performance variables had been identified, tasks and subtasks were defined to describe the activities and flow of information required to measure those variables during pre- and post-implementation sampling periods. Flow diagrams were used to depict the relation between tasks and subtasks and the amount of work required to fully implement the M&E program. The adequacy and prioritization of monitoring and evaluation activities should be periodically reassessed as data and new information becomes available.

Monitoring and evaluation activities may be classified as pre-operational (i.e., baseline) or post-operational depending on whether they occur before or after supplementation begins. An important goal of baseline sampling will be to identify and quantity key characteristics of the streams, habitats, and populations to be supplemented. This information will be used to refine hatchery/natural production goals. Once supplementation begins, M&E will be used to discriminate project from non-project effects and to evaluate alternative management options. Post-operational monitoring will enable managers to determine whether the abundance of naturally produced chinook salmon has increased in response to supplementation, whether ecological impacts are within acceptable limits, and whether the potential exists for additional supplementation and harvest.

A large-scale field experiment will be conducted to determine whet her supplementation has led to significant increases in spring chinook populations. The experimental design requires that five pairs of treatment (supplemented) and control (unsupplemented) streams be repetitively sampled before and after the hatchery begins operation. The response variable of interest is the number of spring chinook spawners counted each year at adult collection weirs located near the mouths of the treatment and control streams. Pre-operation sampling will establish baseline conditions and the relationship between treatment and control streams prior to supplementation. Data collected on populations before project startup will be compared to relationships observed during the post-implementation period. An effect due to supplementation will be considered positive if the proportional abundance of chinook salmon in treatment and control streams increases between pre- and post-implementation periods. A time series of eight to ten years is required to allow unambiguous interpretation of the results.

Inferences regarding the success of fall and summer chinook supplementation will be more tenuous than those or spring chinook due to the lack of opportunity for spatial replication and the difliculty of obtaining accurate estimates of abundance. Rather than count returning fall and summer chinook adults, we propose to evaluate performance on the basis of trends in the peak redd counts obtained annually for these species throughout the Clearwater drainage. A steady increase in summer and fall chinook escapement will be taken as evidence for supplementation success.

Potential effects of supplementation on wild chinook salmon and other aquatic biota will be evaluated through observational and correlational data collected under the M&E Plan. Information of this type does not always give a clear picture of cause-and-effect relationships. However, observational and correlational data can provide greater understanding of the processes and conditions that influence the observed response, and they can suggest testable hypotheses about project effects.

The final chapter of this report provides guidelines by which the Tribe can prioritize implementation of monitoring and evaluation activities. The full suite of tasks and subtasks identified through the risk assessment and performance variable selection procedures constitute the conceptual M&E Plan. By sampling all 83 performance variables, managers would obtain the scientific information and feedback necessary to fully assess the ecological benefits and costs of the NPTH program, and to measure progress toward project goals. However, the resources required to fully implement the M&E Plan will probably exceed those available to the Nez Perce Tribe. Anticipating that the Tribe will need to scale back the M&E program to include fewer performance variables and activities than are identified in the conceptual plan, an effort was made to prioritize performance variables according to their relative importance and cost. Once ranked, the variables were divided into three groups corresponding to minimal, partial, and full levels (Levels I, II, and III, respectively) of implementation.

Level I implementation would include monitoring of 27 performance variables considered essential to evaluating project effectiveness and impacts. We assigned highest priority to performance variables associated with the Population Abundance and Survival performance criteria. Also targeted are indicators that facilitate evaluation of stream carrying capacities, the status of genetic resources, impacts on resident fishes, and the potential effects of non-project management activities.

Level II implementation would include monitoring of 60 performance variables, including those identified for Level I. Monitoring at this level will provide a much stronger scientific and empirical basis for evaluating NPTH success and impacts than would Level I implementation. Level II implementation would substantially reduce the cost and effort (relative to full implementation)of monitoring and evaluation without sacrificing significant amounts of information.

Level III implementation would include the entire 83 performance variables identified in the conceptual M&E Plan. Measurement of these variables would provide the greatest assurance that high-risk critical uncertainties will be addressed within an ecosystem management framework.

The prioritization schemes and cost-reducing strategies recommended in the final chapter of this report are meant to assist NPTH managers in developing annual and multi-year M&E implementation plans. If funding levels or available information do not justify full implementation of the conceptual M&E Plan, we recommend sampling the broadest spectrum of performance variables possible to diminish the chance of overlooking or misinterpreting project effects. The challenge will be to strike a balance between intensively monitoring a few key variables so that specific objectives can be evaluated, and monitoring many variables to be able to detect unanticipated impacts.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

1. INTRODUCTION

"Perfection of means and confusion of goals seem,
in my opinion, to characterize our age."
Albert Einstein[1]

1.1 Purpose and Scope of this Report

This report describes monitoring and evaluation (M&E) activities that will help Nez Perce Tribal Hatchery (NPTH) managers decide how supplementation should be used to restore chinook salmon to the Clearwater River subbasin in Idaho. Several information-gathering strategies are proposed that, if implemented, will provide meaningful and cost-effective assessment of project status and impacts. Monitoring needs, procedures, and products are discussed as they relate to supplementation theory, to NPTH goals and objectives, and to assumptions (uncertainties) that have been judged critical to project planning and success. We suggest ways that project uncertainties and associated risks can be minimized through experimentation, monitoring, and evaluation.

In the present context, monitoring and evaluation is the process whereby key environmental variables, processes, outcomes, etc. are measured and assessed, and the results conveyed to managers so that proper and informed decisions are possible. The process is a dynamic one in which new information resulting from monitoring and evaluation is continually fed into the evolving knowledge base. To be effective, M&E activities should have clearly defined and relevant objectives. They should be designed and implemented in such a way as to yield unambiguous information, preferably using accepted sampling methods and performance (monitoring) variables. The M&E guidelines provided in this report satisfy these criteria.

Managers must be willing to use the information gained through monitoring and evaluation to evaluate the consequences of their actions and to change, if necessary, earlier decisions that were made without benefit of complete knowledge. Monitoring and evaluation is integral to the process of managing the risk associated with such

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[1] Quote attributed to Einstein by Savory (1988), as related by Bormann et al. (1993)

decisions. The activities identified in this report were developed within a formal risk assessment/adaptive management framework. Because of the complexity and cost of the NPTH program, it is very important that this Framework allow managers to make decisions in a logical and consistent manner.

A clear distinction is made between M&E activities designed to address specific questions related to supplementation benefits and those of a more general nature. Supplementation benefits to be evaluated under the proposed M&E program include increases in the number and distribution of chinook populations in the Clearwater subbasin.[2] To measure these benefits, changes in the abundance of chinook salmon in the mainstem Clearwater and its tributaries will be monitored over the next decade.

In addition to measuring project-related benefits, the M&E program is designed to provide information on the capacity of the natural environment to support chinook production, give early warning of adverse impacts caused by the project on resident biota, and track trends in environmental quality and management policy that may affect the project's success.

M&E activities associated with the NPTH project may be classified as either pre-operational (i.e., baseline) or post-operational depending on whether they occur before or after supplementation begins. An important goal of baseline sampling will be to identify and quantify key characteristics of the streams, habitats. and populations to be supplemented. This information will be useful in identifying information gaps and refining hatchery/natural production goals. Once supplementation begins, M&E will be used to test alternative experimental hypotheses and, by measuring key biological and environmental variables over space and through time, to discriminate project from non-project effects. Post-operational monitoring will enable managers to determine whether the abundance of naturally produced chinook salmon has increased in response to supplementation, whether ecological impacts are within acceptable limits, and whether the potential exists for additional supplementation and harvest.

The actual parameters to be monitored to assess project effects and detect changes in the environment are called performance variables. They were selected on the basis their scientific validity, ease. and cost of measurement, and relevance to project objectives and critical uncertainties. For each variable, we describe why it was selected, how and when it is to be measured, the units (fish, streams, etc.) to be

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[2] **The M&E activities recommended in this report are not intended to measure the socioeconomic benefits which might accrue from the NPTH program. such as increased job opportunities and tribal harvest: monitoring activiities designed to measure these particular benefits will need to be developed separately.**

sampled, and the analytical procedures to be applied to the data. We indicate where opportunities may exist for integrating NPTH monitoring and evaluation activities with ongoing federal and state monitoring programs.

Once performance variables had been selected, tasks and subtasks were defined to describe the activities and effort required to measure those variables during pre- and post-operation sampling periods. Flow diagrams were used to concisely depict the relation between tasks and subtasks and the amount of work required to fully implement the M&E program.

The full complement of tasks and subtasks identified through the risk assessment and variable selection procedures constitute the conceptual M&E Plan. Implementation of the M&E Plan would provide the scientific information and feedback necessary to fully assess the ecological benefits and costs of the NPTH program. However, the resources required to fully implement the M&E Plan will probably exceed those available to the Nez Perce Tribe. Anticipating that the Tribe will need to scale back the M&E program to include fewer performance variables and activities than are identified in the conceptual plan, an effort was made to prioritize performance variables according to their relative importance and cost. Once ranked, the variables were divided into three categories, corresponding to minimal, partial, and full levels (Levels I, II, and III, respectively) of implementation. Level 1 implementation would include M&E activities directed at monitoring the most important and cost-effective performance variables. Level II implementation would approximately double the number of variables sampled, including those identified for Level I. Level III would include all performance variables identified in the conceptual M&E Plan. We recommend that the greatest number of variables be monitored as funding allows.

The prioritization schemes and cost-reducing strategies recommended in the final chapter of this report are meant to assist NPTH managers in developing annual and multi-year M&E implementation plans.

1.2 Overview of NPTH Program

The Nez Perce Tribe has proposed to build and operate a hatchery complex in the Clearwater River and lower Salmon River subbasins of Idaho for the purpose of restoring and augmenting populations of spring, summer, and fall chinook salmon in streams that historically supported these species. The Clearwater River and the Salmon River are major tributaries to the lower Snake River which, in turn, is the principal tributary to the Columbia River in the Pacific Northwest. The Nez Perce Ceded Territory (Treaty lands) and Reservation, and the subbasins to be supplemented are located in west-central Idaho (Figure I).

The Nez Perce Tribal Hatchery will comprise facilities for adult chinook collection and holding, egg incubation, and juvenile rearing, acclimation, and release. With the exception of a single, fairly complex, central incubation and early rearing facility located near Cherrylane on the lower Clearwater River, plans call for decentralized, low-cost facilities that are sited to take advantage of local opportunities for supplementation. This low-capital, small-scale approach is consistent with the original directives of Program Measure 703 (g)(2) of the Fish and Wildlife Program of the Northwest Power Planning Council (NPPC 1987).

The Fish and Wildlife Program called for a "facility plan" to guide NPTH program development (NPPC 1987). The resulting document, referred to as the Master Plan, was completed in 1992. Upon reviewing the Master Plan, the Council called attention to several uncertainties associated with the NPTH project and directed the Bonneville Power Administration and the Nez Perce Tribe to undertake additional planning, coordination and monitoring activities to resolve those uncertainties. This report represents one of the products of this effort.

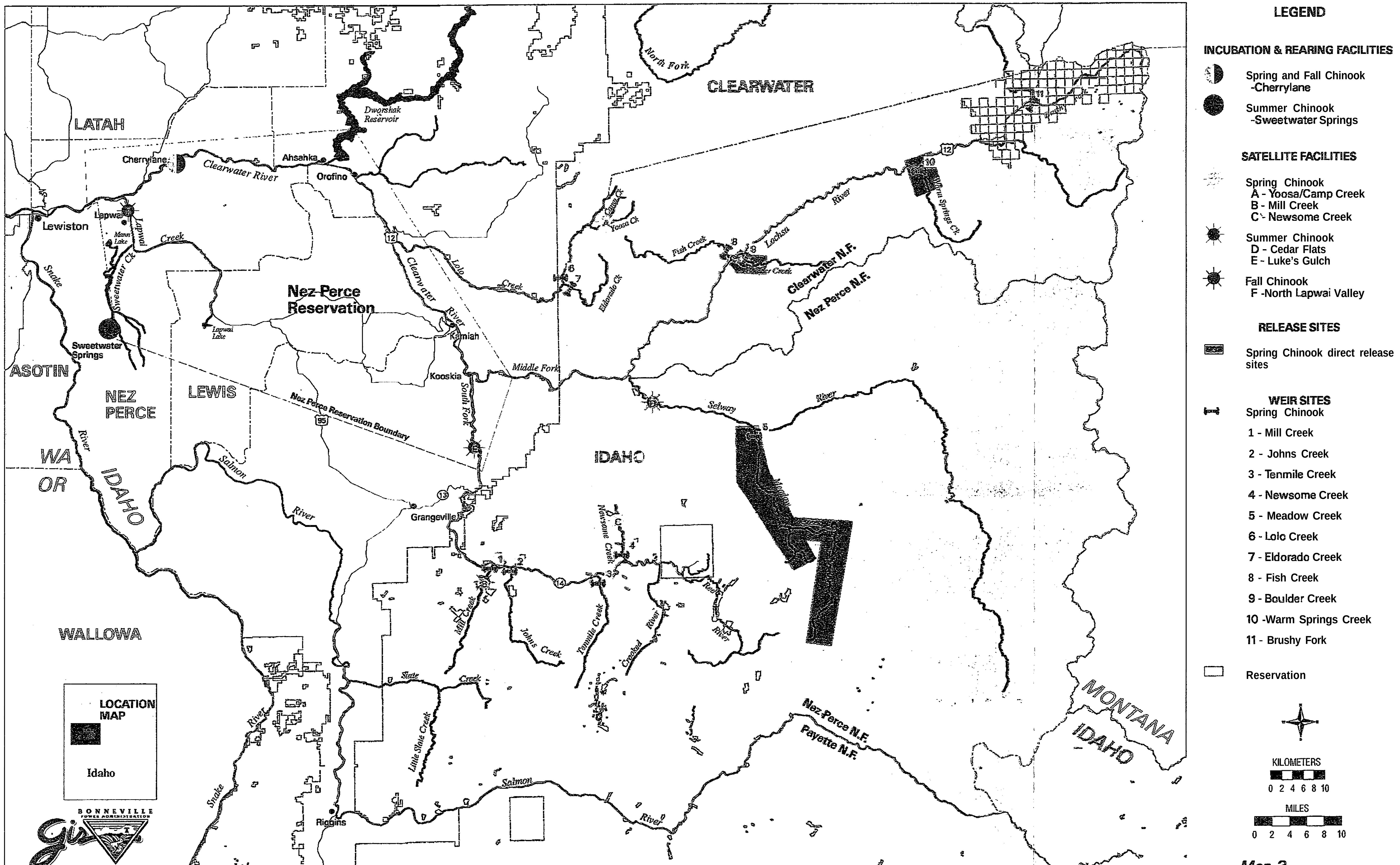
The Master Plan identified project goals. outlined various production objectives along with the strategies and schedules by which they could be attained, and provided specific guidance for the development of monitoring and evaluation plans, harvest plans, and coordination between the Tribe, resource management agencies, and the public (Larson and Mobrand 1992).

A number of significant changes have occurred in NPTH program since the Master Plan was written. Most of these changes are chronicled in the following project documents:

- Supplement to the Nez Perce Tribal Hatchery Master Plan (Johnson et al. 1995)
- Genetic Risk Assessment of the Nez Perce Tribal Hatchery Master Plan (Cramer and Neeley 1992)
- Selway River Genetic Resource Assessment (Cramer 1995)
- Nez Perce Tribal Hatchery Predesign Study (Montgomery Watson 1994)
- Nez Perce Tribal Hatchery Program Environmental Impact Statement (EIS)

The most current source of information on the Nez Perce Tribal Hatchery program may be found in the EIS, available from the Bonneville Power Administration office in Portland. A brief summary of the changes and current specifications of the NPTH is provided below.

NEZ PERCE TRIBAL HATCHERY



Map 3

Facilities and Release Sites

1.2.1 *Program Goals*

The primary goal of the NPTH supplementation project is to re-establish and supplement natural populations of chinook salmon in the Clearwater subbasin until natural production has stabilized at sustainable levels. By sustainable we mean long-term persistence under conditions of environmental variability and moderate exploitation by humans. Supplementation is necessary because, without it, chinook populations are unlikely to become re-established and self-sustaining.

The Nez Perce Tribal Hatchery program has the following goals (Larson and Mobrand 1992, NPTH Program EIS):

- Protect, mitigate impacts to, and enhance Columbia River Basin anadromous fish resources;
- Develop, increase, and reintroduce natural spawning populations of salmon within the Clearwater River subbasin;
- Provide long-term harvest opportunities for Tribal and non-Tribal anglers within Nez Perce Treaty lands within four salmon generations (20 years) following project completion;
- Rebuild or re-establish spring, summer and fall chinook populations in mainstem areas and tributaries within the and Salmon River subbasins;
- Sustain long-term fitness and genetic integrity of target fish populations;
- Keep ecological and genetic impacts to non-target fish populations within acceptable limits; and
- Promote Nez Perce Tribal management of Nez Perce Tribal Hatchery facilities and production areas within Nez Perce Treaty lands.

The NPTH project will span 20 years, divided into three sequential time periods. Phase I (Years 1 - 5) will be devoted to re-establishing natural production in selected tributaries and mainstem reaches by outplanting the progeny of selected hatchery donor stocks. Phase II (Years 6 - IO) will increase and stabilize production using returning adults as broodstock. If populations have reached sustainable levels, Phase III (Years 1 1-20) will attempt to create harvestable surpluses through continued supplementation. Harvest rates will be regulated to sustain hatchery and wild production over the long-term.

1.2.2 Terminology

To facilitate communication, several terms need to be defined <u>Target chinook</u> populations include hatchery chinook produced by the NPTH and the wild populations from which they are drawn or introduced. <u>Non-target chinook</u>

populations include all other chinook (both hatchery or wild) regardless of place of origin. By hatchet-v chinook we mean fish that have been confined in a hatchery or manmade structure for a significant portion of their life. When we use the term wild chinook, it is in reference to the progeny of naturally spawning salmon, regardless of parentage.

Larson and Mobrand (1992) considered spring and summer chinook salmon as separate races in the NPTH Master Plan. Evidence for separate racial identities is equivocal (Cramer and Neeley 1992, Chapman and Witty 1993). The National Marine Fisheries Service ruled that spring and summer chinook should be considered a single Evolutionarily Significant Unit for Endangered Species management purposes because available data are not sufficient to demonstrate separate lineages (Matthews and Waples 1991). In this report, we reserve the term spring chinook for fish that rear for one or more years in freshwater before migrating to the ocean. Adult spring chinook typically spawn early in the fall in smaller tributaries of the mainstem Clearwater River. They are currently distributed throughout the system but their numbers are well below historical run sizes.

The term fall chinook refers to fish that spawn later in the fall in mainstem reaches and in the lower ends of larger tributaries. Their progeny migrate seaward during their first year of life. Fall chinook have been recognized as being genetically distinct from chinook in the Snake River (Waples et al. 1991). A small population of fall chinook currently exists in the lower Clearwater River.

Summer chinook exhibit the same basic life history characteristics as fall chinook except that they spawn somewhat earlier and higher up in the drainage. The distinction between summer and fall chinook is somewhat arbitrary since there is no conclusive evidence that they differ genetically. Although summer chinook have not been reported in the Clear-water River, historical records indicate that summer chinook once spawned in the nearby Grande Ronde subbasin (S. Cramer, personal communication). At present, NPTH managers believe that the Cleat-water subbasin will support viable populations of summer chinook. One of the goals of the M&E Plan is to determine if this assumption is tenable.

1.2.3 Production Facilities

The NPTH will comprise two central incubation and rearing facilities, seven satellite ponds for rearing juveniles and holding adults, and 10 to 15 temporary weirs for trapping returning adult salmon. The location of the various facilities is shown in Figure 1. The Cherrylane Incubation and Rearing Facility (CIRF) and the Sweetwater Springs CIRF will be used for spawning, egg fertilization, incubation, and early rearing. After a brief period of rearing, most of the fish will be transferred to acclimation ponds located near the rivers and streams targeted for supplementation

The ponds will provide a safe yet semi-natural environment where fish can grow and adjust to local conditions. Hatchery-produced fish are expected to return as adults to spawn in the streams in which they are released.

Approximately 768,000 spring chinook and 2,000,000 fall chinook juveniles will be produced at Cherrylane CIRF to accommodate the revised production goals. A portion of the spring chinook will be moved in late spring to acclimation ponds on Yoosa, Mill, and Newsome Creeks, where they will be reared and released in the autumn. The remaining spring chinook will be outplanted as fingerlings in early summer into Meadow Creek (Selway River), Warm Springs Creek, and Boulder Creek.' Spring chinook are expected to overwinter in the receiving streams before migrating downstream as smolts in the spring of the following year.

Most (1.5 million) of the fall chinook reared at the Cherrylane facility will be released as subyearling smolts directly into the lower mainstem Clearwater River. The remaining fall chinook will be diverted to the Lapwai Creek satellite facility where they will imprint on the local water supply. After a brief period of rearing. these fish will be released into Lapwai Creek.

Summer chinook egg incubation and early rearing will take place at the Sweetwater Springs facility, which is located off-river at the former Idaho Department of Fish and Game hatchery site (Figure 1). When the fish reach fry stage, they will be moved into acclimation ponds located on the lower South Fork Clearwater River (Luke's Gulch) and the lower Selway River (Cedar Flats). After a few months of rearing, the summer chinook will be released into the adjacent river to begin their seaward migration. Approximately 800,000 summer chinook are targeted for release.

Temporary weirs and adult traps will be operated on study streams and at hatcheries to monitor returning adults and collect broodstock.

1.2.4 *Integration of Hatchery and Natural Production*

NPTH managers plan to use innovative techniques for mating, incubating, rearing, and releasing hatchery-produced fish into the wild. Egg fertilization procedures, water temperatures, water velocities, substrates, lighting, feeding, and the size and method of release will be regulated in an attempt to mimic natural conditions, instill wild-type behaviors in hatchery fish, and increase post-release survival. Hatchery fish are to be released as juveniles into vacant or underutilized natural habitats where they

[3] Section 3.0 of this report provides further information on the number and type of streams selected for supplementation.

are expected to return to spawn as adults. Most of the fish will be acclimated to local conditions in semi-natural ponds dispersed throughout the basin prior to release.

The number of hatchery chinook released, when added to the number of wild chinook already present, will be calibrated so as not to exceed the carrying capacity of the receiving stream. Plans have been developed to scale back hatchery production and/or divert hatchery fish into other streams if the carrying capacity of the experimental streams is reached (Johnson et al. 1995).

At this time, we do not know whether the proposed release locations, times of release, and life stage at release will accomplish project objectives. Determining the relative performance of chinook salmon stocked at different places, times, and life stages is essential to evaluating the project's success and fine-tuning management in the future. Studies are already underway in Meadow Creek on the Selway to determine whether chinook fry outplants result in acceptable levels of smolt production and adult return (Steward and Johnson, in preparation).

1.2.5 Rivers and Streams to be Supplemented

The Master Plan (Larson and Mobrand 1992) recommended supplementing mainstem reaches of the Clearwater River with fall chinook and several smaller tributaries in the basin with spring chinook. Summer chinook (as defined in this report) were not considered until later. Several streams have since been added, while others have been dropped from the list identified in the Master Plan. The location of the streams and river reaches to be supplemented is displayed in Figure 1 The reasons for changing supplementation plans are explained in Section 3.0 of this report and in the Supplement to the NPTH Master Plan (Johnson et al. 1995). To summarize:

<u>Spring Chinook</u>

- Slate Creek -- a tributary to the lower Salmon River -- was dropped because its spring chinook population is part of the larger ESA-protected Snake River population.
- Meadow Creek, a tributary to the South Fork of the Clearwater River, has also been eliminated from consideration due to hatchery production constraints.
- Lolo, Mill, and Newsome Creeks have been retained, and Boulder and Warm Springs Creeks have been added to the list of "treatment" streams to be stocked with juvenile spring chinook as part of a large-scale field test[4] of supplementation.

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[4] The selection of paired treatment and control streams was guided by the experimental design described in Section 3.0.

- Five streams have been designated controls for the supplemented streams. Control streams include Eldorado, Johns, Ten Mile, Fish, and Brushy Fork (see Section 3.0).
- Meadow Creek in the Selway River drainage will also be outplanted with juvenile spring chinook, but will not be included in the paired treatment-control stream experiment design. Plans call for conducting short term experiments to evaluate different outplanting techniques (see Section 3.3).

Summer Chinook

- Summer chinook will be released from acclimation sites located at Cedar Flats on the lower Selway River and Luke's Gulch on the lower South Fork Clearwater.

Fall Chinook

- Releases of fall chinook will be restricted to the lower mainstem Clearwater River (i.e., below the mouth of the North Fork Cleat-water River) and Lapwai Creek.

The specific stream and river reaches into which fish are to be released contain ample chinook habitat and lie within traditional fishing areas of the Nez Perce Tribe.

Because extant wild populations of spring and fall chinook in the Clearwater River are too small to tap for broodstock, and a summer chinook population does not exist, the Tribe plans to obtain donor stock from established hatcheries until enough fish return to support a broodstock program. Genetic evidence, ecological requirements, environmental constraints, stocking histories, and availability argue for using Rapid River Hatchery spring chinook, Wenatchee River summer chinook, and Lyons Ferry Hatchery fall chinook as initial sources of N'PTH broodstock (Cramer and Neeley 1992, Cramer 1995).

1.3 Monitoring and Evaluation Priorities

1.3.1 Stock Abundance

The Master Plan identified stream-specific natural production and harvest goals along with phased hatchery production and release strategies for attaining them. Natural production goals were based on estimated stream carrying capacities. A chinook salmon life cycle model was used to estimate how many juveniles would need to be produced annually by the NPTH to seed target streams to capacity, maintain hatchery and naturally-spawning populations, and provide for tribal harvest. Estimates of adult returns, broodstock requirements, and potential harvest were refined before being published in the NPTH Program EIS (Table I).

Although natural production goals and strategies were clearly stated in these two documents, they do not lend themselves to tests of hypotheses regarding supplementation effects. To determine whether supplementation has worked, it seems appropriate to ask whether natural production has significantly increased in supplemented streams - not to some predetermined level, but in comparison to pre-supplementation levels and to non-supplemented streams (i.e., controls). If such comparisons were possible, then one could determine whether natural production objectives have been met (they may not be in the short-term) or need to be adjusted to better reflect system constraints.

In Section 3.0, we identify several experimental designs, response variables, and associated statistical tests that, if implemented, will enable managers to answer the question "Has supplementation worked?" Our assessment of alternative experimental designs for spring, summer, and fall chinook focuses on their statistical validity, interpretability, and feasibility given NPTH funding and other constraints. A preferred experimental design is identified for each species that will provide greater insights into the data and more precise tests of supplementation effects than will other designs. A key requirement of the spring chinook experiment is that chinook populations be monitored in the same number of supplemented and control streams during pre-operational and post-operational periods. Counts of marked adults returning to weirs located downstream of spawning areas will provide the best measure of population status and trend (Figure 1). The experimental design will provide the statistical resolution necessary to evaluate project success, and the data will give important information on spatial and temporal variability in natural production.

The abundance of summer and fall chinook will be indexed by the number of redds counted in surveys of the Clearwater River and its principle tributaries. Because estimates of abundance for these species are more difficult to obtain, and opportunities for spatial replication are lacking, the effects of supplementation will not be as easily discerned as they will be for spring chinook

1.3.2 *Harvest*

Hatchery production and harvest goals were linked to natural production goals in the Master Plan and thus are subject to the same uncertainties. Harvest goals were indexed to projected escapement levels, with surplus hatchery fish being targeted. Harvest management strategies include phased implementation, selective harvest of hatchery and natural fish. imposition of area, time, and gear-type restrictions, and provision for "exceptional" harvest opportunities. The effectiveness of these

Table 1. Projected number of adult chinook salmon returning to NPTH facilities and streams (Source: Table 2-2 in NPTH Program EIS, 1996)

Stream	Total Adult Returns	Adults Available for Broodstock	Adults Available for Natural Reproduction	Adults Available for Harvest
Spring Chinook				
Lolo Creek (1)	373	136	162	75
Mill Creek (1)	95	36	46	13
Newsome Creek (1)	173	68	51	54
Boulder Creek (2)	147	67	60	20
Warm Springs (2)	34	16	14	4
Meadow (Selway) (2)	684	322	244	118
Number at 20 years	1,506	645	577	284
Summer Chinook				
Luke's Gulch (3)	743	276	298	169
Cedar Flats (3)	743	276	298	169
Number at 20 years	1,486	552	596	338
Fall Chinook				
Cherrylane (3)	2,359	788	960	611
North Lapwai Valley (3)	780	258	320	202
Number at 20 years	3,139	1,046	1,280	813

(1) Assumes postrelease survival is 65% and molt-to-adult survival is double the current rate.
(2) Assumes postrelease survival is 65% and smolt-to-adult survival is double the current rate (because fish have acquired a fitness advantage due to extended rearing in the wild).
(3) Assumes postrelease survival is 50% and smolt-to-adult survival is double the current rate.

strategies and their impact on targeted chinook populations will need to be assessed at the time they are implemented. However, because opportunities for harvest are still years away, harvest monitoring and evaluation needs and priorities are not addressed in this report.

1.3.3 Genetic Risks

As Cramer and Neeley (1992) point out, the process of identifying appropriate genetic management strategies begins with identification of the different types of genetic risks which subtend supplementation. The Master Plan summarizes these risks as follows:

1. Population extinction

2. Loss of diversity or genetic variation within the population

3. Loss of, or change in, population identity including loss of diversity among populations, characteristics of adaptation within populations, or of other evolved features of genetic organization

4 Changes in genetic composition as an adaptation to survival in a hatchery environment

The first of these - extinction - is a genetic risk only in the sense that the molecular structure that codes for heredity is irretrievably lost when the organism no longer exists. The other three risks have been discussed in considerable detail elsewhere (Cramer and Neeley 1992, Cramer 1995, RASP 1993, Lichatowich and Watson 1993) and do not warrant further discussion here, except in reference to monitoring and evaluation activities. Genetic monitoring needs are addressed in Section 5.1.1.

Several general strategies for minimizing undesirable genetic changes in NPTH chinook populations were recommended by Larson and Mobrand (1992), Cramer and Neeley (1992), Cramer (1995). Strategies include delineation of population structure based on genetic and phenotypic criteria, preservation of population structure through isolation and separate culture, use of naturally-produced fish as broodstock, restrictions on the ratio of hatchery to natural fish in the natural spawning population, and application of external marks to distinguish hatchery from naturally-produced fish. Management procedures designed to implement these strategies and minimize genetic risks have been developed in general (RASP 1993, Kapuscinski et al. 1993), but need to be defined more explicitly with regard to NPTH opportunities and constraints. While this report refers to the need to develop monitoring and evaluation capabilities to determine whether hatchery practices are meeting genetic standards, the specific operating procedures and performance audits to be applied to NPTH facilities will be developed in a separate document.

1.3.4 *Ecological Interactions*

The Master Plan enjoins us to keep “ecological impacts within acceptable limits.” Exactly how to accomplish this goal is not clear since strategies appear to be directed primarily at maximizing the post-release survival of hatchery fish, and secondarily at minimizing negative interactions between hatchery and natural fish. No mention is made of interactions involving non-target species. Better defined goals and clearly-specified performance criteria (what type and degree of impact is “acceptable”?) are needed to develop an effective monitoring and evaluation program. By well-specified we mean meaningful, measurable, and unambiguous.

The Master Plan calls for minimizing the potential for negative ecological interactions by tailoring the time, age, size, and number of hatchery fish released to take advantage of available resources without disrupting the distribution and ecology of resident species. Intraspecific interactions, in particular, are likely to penalize both hatchery and natural fish through increased expenditures of energy, decreased feeding and growth, increased risk of predation, and ultimately, lower survival. Several strategies are therefore proposed that aim to minimize contact between hatchery and naturally-rearing juvenile fish: (1) scattered releases of comparatively small numbers of chinook salmon fry into underseeded habitats, (2) volitional emigration of pre-smolts from acclimation ponds at the end of the summer growing season, and (3) releases of smolts under conditions that favor their immediate downstream migration in the spring.

Monitoring and evaluation activities that are designed to assess different release strategies are discussed in Section 3.3. An experiment is already underway in Meadow Creek to determine whether high and low density releases are equally effective in seeding rearing habitats, maximizing survival, and minimizing undesirable ecological interactions. Inferences regarding the timing and rate of emigration of chinook pre-smolts and smolts from NPTH streams will be drawn from observational data collected at smolt traps and other detection sites downstream.

Aside from the examples discussed above, the potential for adverse ecological impacts was poorly delineated within the Master Plan. Because of the risks involved, it is important that project impacts be monitored at several levels of biological organization, from genetic to species to community. Recognizing this need, we organized information needs into hierarchical categories so that supplementation effects could be evaluated across several levels of ecosystem structure and function. This approach is consistent with the Nez Perce Tribe’s goal of fully integrating the NPTH into the natural system.

2. FRAMEWORK

2.1 Overview

Risk analysis was used to identify monitoring and evaluation priorities. In the present context, "risk" is defined as the probability of occurrence of an adverse effect on the environment or the project. "Risk assessment" refers to the procedure we used to evaluate the risks associated with project assumptions and proposed actions, decide what to do about those risks, implement the decision, and evaluate the results. In general, a risk may be eliminated, avoided, or reduced by eliminating, controlling, or isolating the factors which cause or facilitate adverse effects. A prerequisite to taking appropriate action is an understanding of the problem. The process of developing an effective M&E program is one of identifying gaps in our knowledge and prioritizing our information gathering activities based on the relative opportunity for risk reduction. This process is a continuous one that includes assessing project assumptions and attendant risks, developing strategies to minimize adverse effects, implementing those strategies, monitoring effects, and revising, if necessary, project goals and objectives (Figure 2, Table 2).

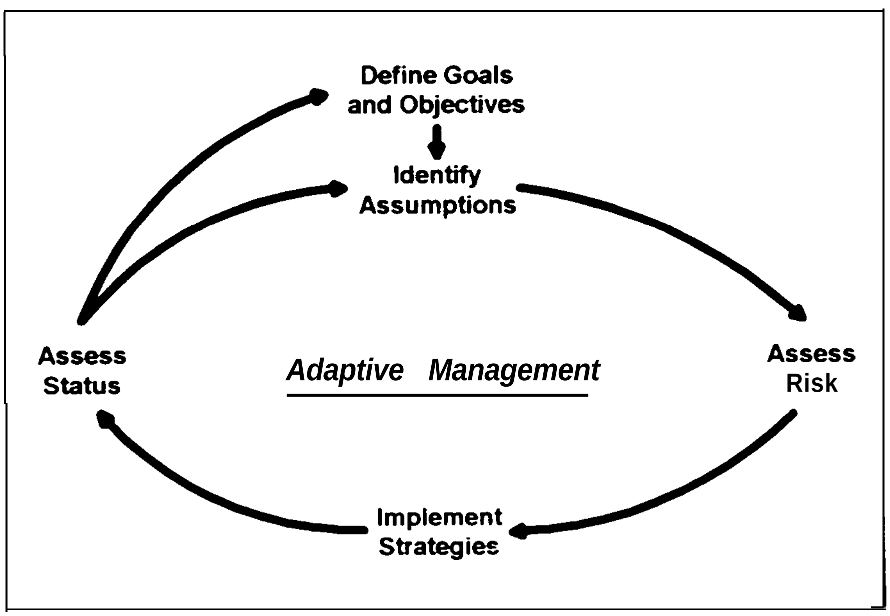

Figure 2. Adaptive management in the context of NPTH monitoring and evaluation.

In the remaining sections of this report, we discuss monitoring and evaluation needs, procedures, and products as they relate to salmon supplementation theory, to NPTH goals and objectives, and to assumptions that are critical to the program's planning and success.

Table 2 Steps for scoping and managing critical uncertainties (after RASP 1993).

Steps	Description
1. Identify key assumptions	Describe key assumptions, including sources of information, and their relationship to project goals and activities;
2 Assess uncertainties and develop risk reduction strategies	Determine the probability and consequences of being wrong; identify approaches and schedules for addressing uncertainties
3 Implement strategies	Undertake project activities
4 Assess status	Determine whether uncertainties have been or can be resolved by acquiring more knowledge
5. Revise project goals, tasks and objectives	Revise project activities based on status of uncertainties and reassessment of risk
6. Repeat steps 1 - 5	Apply adaptive management

2.2 Project Assumptions, Critical Uncertainties, and Risk

Like other supplementation projects, the NPTH program is based on numerous assumptions about how and when to proceed so that the desired results can be achieved (RASP 1993). An important first step in setting M&E objectives was to explicitly consider project assumptions and to formally assess the relative risk they pose to the project and environment.

Assumptions by definition are uncertain Uncertainty is a function not only of unpredictability but also of our state of knowledge and our confidence in that knowledge Most of the uncertainties we face can be attributed to either the inherent randomness of the ecosystem or a lack of scientific understanding of the principles that govern their occurrence (RASP 1993). Other uncertainties stem from our inability to objectively measure or fully comprehend the processes and conditions that make up our surroundings Thus, the effects of our actions may not be readily observed or may be confounded with other environmental impacts

It is important to address uncertainty because it often serves as a pretext for inaction or, worse yet, may lead to inappropriate management actions. The importance of resolving critical uncertainties is evident when one considers the consequences; for example, driving other species to extinction or spending considerable amounts of money with little or no benefits to show for it. We can reduce uncertainty by careful planning, improving our state of knowledge, reducing sources of bias, and using appropriate methodologies (e g., sampling, statistical, and modeling techniques).

Over 200 project-related assumptions were considered in the development of NPTH M&E Plan. The assumptions were compiled from project-related literature and other published material. We grouped assumptions into different ecological categories and classified those thought most critical to project success into a taxonomy of uncertainties (Figure 3). Assumptions are considered "safe" when the associated action or anticipated effect are likely to be inconsequential, even if the assumptions prove to be incorrect. If this is the case, it is usually possible to recover quickly and take corrective action. The risk or penalty associated with safe assumptions is either low or can be reduced to acceptable levels.

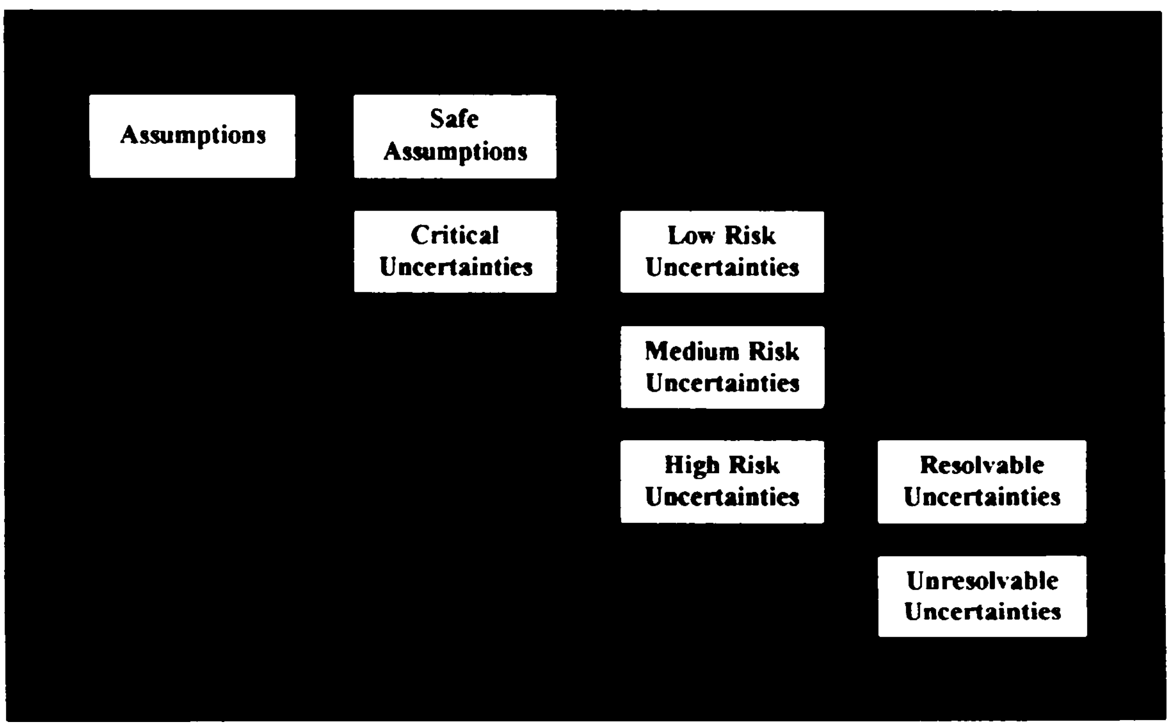

Figure 3. Assumption levels used to categorize and manage risk.

Assumptions are "critical" if they entail an element of risk, i e . if the assumption is false. the project may not achieve its stated goals or may have an adverse impact It is important that critical uncertainties be identified and their relative risk assessed during the project planning stage High-risk critical uncertainties can be addressed through a combination of planning, research, and monitoring and evaluation Planning involves careful consideration of the likely effects of proposed activities and the development of strategies to minimize risk Research can take a variety of forms. including consultation among experts, literature review. modeling. and carefully controlled studies designed to yield insight into the phenomenon of interest

Monitoring and evaluation is meant to detect and provide early warning of changes in the environment and non-Tribal management activities that that might affect project status and impacts If properly designed and implemented, M&E activities will improve our understanding of cause and effect relationships between project objectives, management actions, and environmental impact. Although monitoring implies post-operational effects, data should be collected during the pre-operational period to establish benchmarks for assessing project-related impacts.

Some critical uncertainties are not amenable to resolution, usually because their effects cannot be readily observed, measured, or anticipated These would include uncertainties associated with events or effects that are difficult to predict due to their natural randomness. Examples include natural disturbances such as floods, fires, and El Nino events; and human-related disturbances such as dewatering of hatchery raceways, disease outbreaks, and juvenile transportation failures. “Risk containment” monitoring refers to the collection and processing of environmental data -- not necessarily to discern a cause and effect relationship between the project and characteristics of the environment -- but to facilitate a rapid response to potentially catastrophic events.

A total of 134 assumptions were evaluated by the risk assessment process.[5] Once identified, assumptions were assigned to safe, low-risk, medium-risk, and high-risk categories according to our perception of the hazard posed to the project or the environment if the underlying assumption proved false. We used four criteria to specify the type of risk involved:

A. Status of knowledge

B Probability of being incorrect,

C Consequences of being incorrect, and

D Whether the risk can be reduced or not

[5] Project assumptions are tabulated in Section 5 0 of this report

Four levels of risk, ranging from low (1) to high (4) for each criteria, were used to quantify the risk associated with each assumption (Table 3)

Table 3 Information used to determine the risk associated with project assumptions

Level	Risk Criteria	Score
Level of knowledge		
1	Excellent empirical data and/or prior knowledge	1
2	Good empirical data and/or prior knowledge	2
3	Fair empirical data and/or prior knowledge	4
4	Poor empirical data or prior knowledge	8
Probability of assumption being incorrect		
1	Less than 1%	1
2	Between 1 and 10 %	2
3	Between 10 and 25%	4
4	Between 25 and 50%	8
Consequences of incorrect assumption		
1	No economic or environmental impacts	1
2	Low economic and/or environmental impacts	2
3	Intermediate economic and/or environmental impacts	4
4	High economic and/or environmental impacts	8
Can uncertainty be reduced?		
1	Yes. Risk can be reduced before project startup	1
2	No Risk can be contained through monitoring	2
3	Yes Risk can be reduced after project startup	4
4	No Risk cannot be contained through monitoring	8

For each project assumption, project biologists were asked to use their best judgment to determine the level of risk (1, 2. 3. or 4). considering each criteria separately The weighting value (1, 2, 4, or 8) corresponding to that level of risk was recorded -- one value per risk criteria. four values per assumption The four values were multiplied together to obtain a weighted cumulative score for each assumption. Cumulative scores could potentially range from 1 to 4096, indicating uniformly low and high risk levels. respectively Each assumption was assigned to one of four Risk Categories, depending on its cumulative score

Risk Category	Cumulative Score
Safe Assumption	≤ 8
Low Risk Uncertainty	≤ 16
Medium Risk Uncertainty	≤ 64
High Risk Uncertainty	≥ 128

The risk assessment procedure described above was performed independently by three individuals who possess above-average knowledge on fish hatcheries and supplementation, and who are familiar with the biological, physical, economic, and political constraints of the NPTH program. Those individuals included the author of this report and Dave Johnson and Grant Walker of the Nez Perce Tribal Fisheries Department

A comparison of individual scores obtained for 134 critical uncertainties revealed generally close agreement among assessors There was unanimous agreement on 59 percent of the assumptions, one individual disagreed with the other two on 32 percent of the assumptions, and none of the individuals agreed on 9 percent of the assumptions. Major disparities in risk scores were reduced through group discussion. In attempting to reconcile differences of opinion, we were able to share information and better understand our biases and the relative importance of various assumptions.

Under the scoring system used, most (42%) of the 227 possible combinations of scores fall in the high risk category (Figure 4) Of the 130 Stock Status. Ecological Interactions, and Natural Environment assumptions actually scored, 37% were judged to be of high risk. 35% of medium risk, 2 1% of low risk, and 8% were considered "safe"

Assumptions classified as high risk uncertainties were reconsidered in light of the fourth risk criteria ("Can uncertainty be reduced"") Under this criteria. assumptions assigned values of 1 or 3 represent critical uncertainties that will be explicitly addressed through research For assumptions assigned a risk level of 2. uncertainty

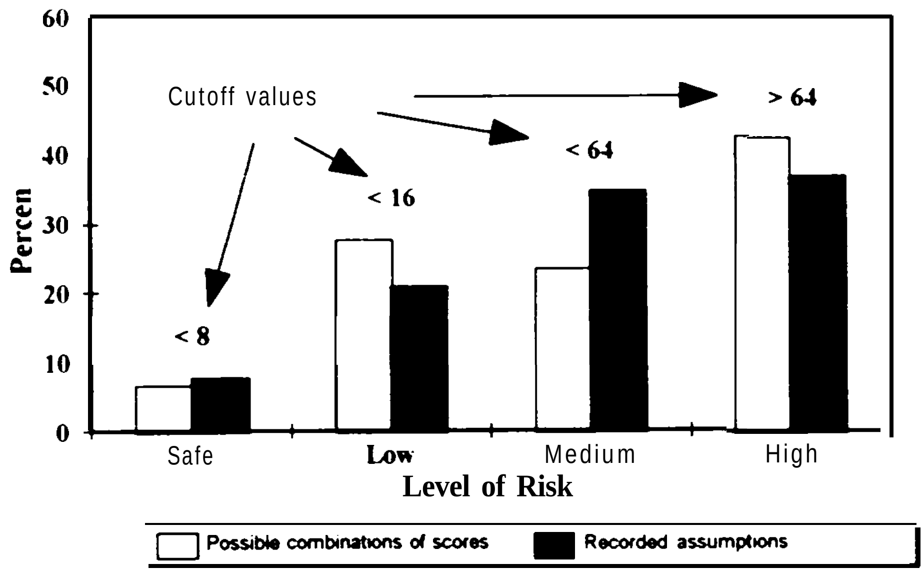

Figure 4 Possible and observed frequencies of risk scores, ranging from safe to high risk

will be addressed through risk containment monitoring. A value of 4 ("Risk cannot be contained through monitoring") would require re-evaluation of project goals; no assumptions fell into this category

It is our experience that risk assessment helps lower the potential for misunderstanding and adverse impacts, and that it greatly enhances information exchange and decision-making among scientists, managers, and other interested parties. Some people may disagree with the information or procedures that we used to quantify risk Others may have different risk propensities. they may see risk where we see none, and vice-versa We encourage further discussion of these issues Differences of opinion should be reconciled as objectively as possible, striving to keep personal values separate from assessments based on science and technological factors

A final comment is in order regarding risks inherent to the NPTH It is the intention of NPTH managers to continually upgrade hatchery operations by applying the best available knowledge, drawing upon past experience and data obtained from similar systems elsewhere (Larson and Mobrand 1992) This is a laudable goal but if haphazardly applied, it may result in programmatic changes being made without sufficient cause The iterative risk assessment process described here is designed to prevent this from happening

2.3 Categories, Subcategories, and Performance Criteria

Risk assessment was used to establish a hierarchy of critical uncertainties that linked NPTH Program goals with monitoring and evaluation tasks and implementation strategies Information needs identified through the risk assessment process were organized hierarchically by

Category,

Subcategory, and

Performance Criterion

The type of information sought at each level of organization is listed in **Table** 4 and described in detail in Section 5.0

Three categories of potential impacts were inferred from NPTH Program goal statements (see Section 1.2 1):

1. Changes in Stock Status
2. Effects on Ecological Interactions
3. Effects on the Natural Environment

Each category was subdivided into two or three subcategories that focused more narrowly on particular attributes of the category (Table 4). Stock Status, for example, was partitioned into Genetic Resources. Life History Types. and Population Viability subcategories.

Associated with each subcategory are one or more performance criteria. A performance criterion is a feature, attribute, or process that is both measurable and has assessment value When measured, the criteria give useful evidence of the status, trend, or response to supplementation. Examples include genetic variability. population size, predation, and species diversity Performance criteria should not be considered in isolation even though they are grouped under separate subcategories Instead, they should be viewed as more-or-less interdependent parts of a whole

Note that not all performance criteria relate to impacts that are necessarily attributable to supplementation; some were chosen to quantify natural processes. environmental disturbances, and management actions whose effects on the NPTH may be significant. yet are outside the project's scope

Table 4 M&E information needs organized by category, subcategory, and performance criterion

Category	Subcategory	Performance Criterion
Stock Status	Genetic Resources	Adaptedness Variability Relatedness
	Life History Types	Composition Distribution Key attributes
	Population Viability	Abundance Survival Reproductive success Long-term fitness
Ecological Interactions	Intraspecific	Competition Reproduction Disease transmission
	Interspecific	Competition Trophic dynamics Pathogen interactions
Natural Environment	Production Potential (Limiting Factors)	Hydrology Water quality Riparian areas Macrohabitat Mesohabitat Microhabitat
	Biological Community	Sensitive species Species composition and diversity
	Extrinsic Factors	Logging Agriculture Other land uses Natural stressors Dams and diversions Management impacts

2.4 Performance Variables

Performance variables are the parameters measured to quantify performance criteria These variables or their surrogates provide a measure of the status or response of the associated performance criteria To monitor population abundance. for example, we may choose from an assortment of measures number of returning adults. redd density, smolt yield. etc. We recommend that multiple variables be identified and measured for each criterion to better reflect its status and to minimize the risk of overlooking important effects.

We desire measures that give some direct indication of both short-term and long-term impacts of supplementation We also want to monitor ecosystem health (e.g., habitat quality) and external factors that might cause the project to fail (e g., anthropogenic sources of stress). There is substantial uncertainty about the best variables to use for these purposes. In some cases the variables of interest are difficult to measure. For example, variables such as recruits-per-spawner, while conceptually important, may be impossible to estimate with enough precision to detect changes of the magnitude expected (Lichatowich and Cramer 1979). Egg-to-fry survival is an important parameter, but the practical difficulties of measuring it may force us to consider alternative measures.

Depending on the scale and level of observation. the question of which performance variables to use is a crucial one, since considerable effort and expense will be wasted if inappropriate metrics are selected. Clearly, variable selection should be based on perceived risks and hypotheses of interest, and should meet basic scientific standards A method for selecting performance variables for monitoring and evaluating supplementation effects was unavailable, so we developed our own. Our approach and the set of variables we derived are consistent with other monitoring and evaluation techniques currently in use in the Columbia River Basin

One difficulty encountered in selecting performance variables is that most variables relate to more than one performance criteria and most criteria can be indexed by multiple variables. The challenge was to winnow a few key variables from a much longer list of candidate variables for each criterion As a first step in this process. we compiled a list of potential performance variables along with a brief description of their intended use This list was circulated among managers and scientists who are familiar with the project in general and the performance criteria in particular These individuals were asked to add other variables to the list that they considered promising, and to evaluate each candidate variable with reference to the following (desirable) criteria [6]

1 Relevant Addresses one or more critical uncertainties having high risk

2 Responsive Sensitive indicator of supplementation or environmental effects.

3 Integrative Integrates effects over space, time (life stages), or several levels of biological organization

4 Anticipatory Useful predictor or provides early, reliable warning of change

5 Standardized Is easy to quantify using standardized and tested techniques

6 Bias Can be measured with high accuracy and precision.

7 Variability Is inherently non-random or can be readily decomposed into component sources of error

8 Precedence. Is already part of ongoing monitoring program, or historical data either exists or can be compiled from accessible sources.

9 Compatible. Is compatible with monitoring programs or has widespread applicability Provides unique information while complementing other performance variables

10 Cost-effective Provides maximum amount of information per unit effort; is inexpensive to measure Can be combined with other variables to optimize sampling effort

The criteria presented above were provided to facilitate the identification and selection of performance variables Our intention was to select a few key performance variables for each performance criteria within the category/subcategory spectrum After eliminating redundant or flawed variables, a final list was assembled for all performance criteria in Stock Status, Ecological Interactions. and Natural Environment categories

The performance variables considered and eventually selected for measurement under the NPTH monitoring and evaluation program are discussed in Section 5 0 below The list of performance variables will be refined as the project unfolds. experience is gained through monitoring and evaluation activities, and new methods are developed based on advances in our understanding of ecological processes and supplementation effects

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[6] Several research groups have proposed similar sets of selection criteria Hunsaker and Carpenter (1990). for example, identified criteria to guide the selection of ecosystem indicators for use in the Environmental Monitoring and Assessment Program of the U S Environmental Protection Agency

2.5 Purpose and Need for Information

2.5.1 *Stock Status*

The evaluation of ***Stock Status*** is concerned primarily with the characteristics and performance of hatchery and natural chinook salmon populations. Stock status is both a descriptive and operational term that encompasses the following subcategories. Genetic Resources, Life History Types, and Population Viability (Table 4).

As long as evidence suggests that hatchery and natural populations possess different ecological characteristics, their status will be monitored separately. Judging from past experience, the potential for poor post-release survival and reproductive success among hatchery fish is significant (Steward and Bjomn 1990). Individual and population fitness may be reduced by exposure to hatchery environments and practices (Table 5).

Table 5 Fitness-related traits of salmonids potentially affected by the hatchery environment and practices (Sources: RASP 1993. Steward and Bjomn 1990).

Trait	Description
Health	Overall health related to diet. exercise. and exposure and resistance to, and treatment for. pathogens and stress
Body size	Length and condition factor at time or age
Body composition	Nutritional status. body fat. muscle composition
Swimming ability	Burst speed. maneuverability. and stamina associated with swimming
Agonistic behavior	Various behaviors associated with securing or defending food. space. or reproductive opportunities
Feeding behavior	Use of foraging areas. ability to recognize and secure prey. and other energetic considerations.
Predator recognition and avoidance	Ability to detect. assess, and escape predation hazards
Reproductive behavior	Mate selection. redd construction. redd defense. and spawning
Dispersal	Estent and rate of dispersal within the natural environment
Habitat utilization	Use of habitat and associated physical resources at different times
Migratory characteristics	Timing. rate. and routes of migration within and manne habitats
Smoltification status	Physiological and behavioral readiness to migrate seaward
Reproductive status	Age and size at return. rate of sexual maturation. fecundity

2 5 1 1 Genetic Resources

Supplementation has been defined as the restoration or augmentation of natural production via hatchery production while *conserving genetic resources* (Kapuscinski et al 1993) For NPTH to succeed, the hatchery population must be sufficiently adapted to the natural environment to survive, it should be genetically compatible with the targeted wild population, and it should be managed to conserve or enhance genetic variability It follows, then, that project monitoring and evaluation of genetics resources should focus on at least three performance criteria - Genetic Adaptedness. Genetic Relatedness, and Genetic Variability.

NPTH managers have carefully adhered to genetic conservation principles and guidelines in the development of production strategies and hatchery practices (Larson and Mobrand 1992) NPTH genetic conservation strategies are summarized by performance criteria in Table 6.

The loss or alteration of wild-type genes and genotypes through selection in the hatchery probably poses the greatest threat to the long-term persistence and productivity of the population. The potential for genetic contamination of non-targeted wild stocks due to straying should also be carefully considered due to the proximity of populations of chinook salmon that have been listed as threatened and endangered species under the ESA. The protection of listed wild stocks has been given the highest priority. Their separate status will be maintained by restricting gene flow (straying) into neighboring populations (see Intraspecific Interactions. Section 5.2.1 below)

Intense selection by environmental factors operating outside of the NPTH may have unwanted effects. Habitat alteration, shifts in community structure, pollution. fishing. and other environmental stressors have generated an assortment of selective pressures not present historically. NPTH managers will be able to influence some of these factors, for example, by establishing escapement and harvest policies that are commensurate with genetic conservation objectives However, the primary hedge against “unnatural” selection will be the maintenance of genetic diversity at levels that allow for normal evolutionary responses.

Table 6 NPTH genetic conservation management strategies, organized by performance criteria

Performance Criteria: Adaptedness

Rationale: Salmonid populations are uniquely adapted to the environments in which they are found, different environments impose different selection pressures.

In situ	*Ex situ*
Use as many naturally-produced fish as broodstock as possible	Delineate natural populations
Return hatchery adults to the stream, up to 50% of the naturally-spawning population	Maintain reproductive isolation
Identify, monitor, and maintain unique heritable characteristics	Maintain habitat quality and diversity; allow natural selection to maintain genetic diversity
Exclude strays from broodstock	
Purge population of deleterious alleles	

Performance Criteria: Variability

Rationale: Genetic diversity is essential to the long-term viability of a population; loss of genetic diversity has been associated with reduced fitness and lowered adaptability.

In situ	*Ex situ*
Maintain genetic compatibility and distinctiveness	Attain viable population sizes as soon as possible
Maintain qualitative and quantitative genetic variability	Replicate populations, maintain between-population variability
Maximize large effective population sizes	Maintain diversity of high quality natural habitats
Avoid selective breeding	
Reduce inbreeding	
Facilitate natural behaviors	

Table 6 (continued) NPTH genetic conservation management strategies, organized by performance criteria

Performance Criteria: Relatedness

Rationale: Population fitness is reduced by outbreeding depression and other genetic processes relating to genetic incompatibility

In situ	*Ex situ*
Use surplus naturally-produced fish for hatchery broodstock Select a random and representative sample of the natural population for hatchery broodstock Maintain natural genetic. phenotypic and life history characteristics Minimize artificial selection Avoid outbreeding depression and hybridization	Allow no more than 50% of the natural spawners to be hatchery-produced fish Allow enouyh fish to spawn to meet minimum effective population size requirements (determined from genetic and MVP considerations);[a], use surplus fish for hatchery broodstock until production quotas are reached

[a] Cramer and Neeley (1992) suggested a minimum of 25 spawners during the first generation of supplementation (5 years).

2.5 1.2 Life History Types

Maximum supplementation benefits will be obtained when the composition, distribution, and life history characteristics of the hatchery and target populations are such that the carrying capacity of the natural environment is fully exploited We define a *life history type* or form as a succession of life stages that collectively exhibit a unique pattern of adaptive strategies, as reflected by their movement and distribution within the environment (RASP 1993). Life history types therefore represent a level of biological organization and function that is intermediate to genetic and population levels. Performance under the Life History Type subcategory will be evaluated by three criteria Composition, Distribution. and Key Attributes of different life history types (Table 4)

When we speak of life history types in reference to salmon, we are referring primarily to variability in dispersal and migratory behaviors. These behaviors are controlled by both genetic and environmental factors. It is through life history and individual variability that salmon are able to efficiently exploit different habitats and take advantage of seasonal and spatial variations in resource availability, thereby reducing intraspecific competition and increasing overall fitness (Gross 1985) A diversity of life history types also serves to buffer the population against environmental unpredictability. If critical habitats are destroyed or altered, the affected life histories are not likely to persist within the population matrix.

If the physiological or behavioral traits that distinguish one life history from another have a genetic basis, and if they enhance the fitness of individuals possessing those traits, then natural selection will favor that life history type. Although certain life history characteristics may be inherited and reflect adaptation to local conditions. it would be premature and probably incorrect to assert that the entire array of behaviors observed in salmon is genetically controlled Life history asymmetries may result, in part, from spatial and temporal variation in growth and survival among geographic areas Age-at-smolting among Atlantic salmon. for example. depends on fish attaining a genetically determined size threshold, environmental conditions determine when that threshold is reached (Thorpe et al 1992) Density-dependent mechanisms influence not only growth and survival but, to varying degrees, the behavior of fish. Behavioral changes may alter population selection pressures or the probability of extinction (Taylor 1991) Until our understanding of the interaction between genes, the environment, and life history variation improves. it would be prudent to measure. preserve. and enhance both genetic and life history diversity

The number and type of life histories that can reasonably be restored and maintained through supplementation is a major NPTH uncertainty The desirability of restoring a diversity of life history types needs to be evaluated in relation to the balance of the benefits obtained and the costs incurred Once successful life history types have been propagated, their natural life history patterns will be used as a performance standard against which hatchery fish will be compared

2 5.1.3 Population Viability

This subcategory is intended to assess the current status of chinook populations and the prognosis for long-term persistence based on demographic trends and vital statistics Four performance criteria will be evaluated. Abundance, Survival, Reproductive Success, and Long-term Fitness (Table 4)

RASP (1 993) proposed three performance criteria[1] that are germane to the Population Viability subcategory post-release survival, reproductive success, and long-term performance or fitness (the fourth RASP criterion, ecological interactions, is discussed under Ecological Interactions and Natural Environment categories). *Post-release survival* refers specifically to the rate of loss of hatchery fish between the time of their release to the time that they are harvested or return to the subbasin. As a performance criterion, post-release survival has special significance because considerable potential exists to reduce the mortality of hatchery fish by improving their overall quality and by lessening the impacts of environmental factors. Evidence suggests that current mortality rates of hatchery smolts are nearly twice those of natural smolts. Far more adult salmon will return if survival can be improved

Reproductive success is a measure of the relative fitness of hatchery and natural adult chinook, expressed as the average number of progeny that survive to adulthood. An individual's reproductive success is influenced by a number of factors. the availability of suitable mates and spawning habitat, its gametic output, and trans-generational survival probabilities. At the population level, reproductive success is sensitive to population size in ways other than the obvious one According to Nelson and Soule (1987), reproductive performance is disproportionately and negatively influenced by inbreeding; a 5% - 10% decrease in fitness for a particular reproductive trait may lead to a total decrease in reproductive performance of 25% or more To guard against declines in reproductive success in hatchery and natural populations, we propose to monitor several reproduction fitness characters and performance variables

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[1] What we refer to as performance attributes. Lichatowich and Watson (1993) term "dimensions of the management objectives." by which they mean post-release survival. reproductive success. long-term performance. and ecological interactions

RASP (1 993) defines *long-term performance* as "the capacity of a population to persist in the face of environmental variability while undergoing natural genetic change " This performance criterion, which we refer to as long-term fitness, can be indirectly measured by a variety of genetic and productivity indices Long-term fitness implies that the population is able to evolutionarily track changes in the local environment There exist no direct measures of fitness for natural populations, since fitness can be defined only with respect to the properties of the (constantly changing) environment in which it is expressed. To gain some idea of a population's adaptedness to an existing environment, its ability to adapt to new environments, and its evolutionary uniqueness relative to other populations, we measure and describe genetic and phenotypic traits thought to have fitness-related value. We assume that changes in long-term fitness will be reflected by changes over time in genotype, phenotype, life history characteristics, and stock productivity.

The Population Viability subcategory fully embraces the RASP concepts of post-release survival, reproductive success, and long-term performance. We treat them as population characteristics that are influenced by genetic, life history, and environmental factors.

2.5.2 Ecological Interactions

By Ecological Interactions we mean interactions involving targeted and non-targeted chinook populations (including hatchery and wild chinook), and interactions between targeted chinook and other biological species (excluding humans). Two subcategories were identified: Intraspecific Interactions and Interspecific Interactions.

2.5.2.1 Intraspecific Interactions

At the intraspecific level, hatchery and natural fish can interact in several ways, with potentially harmful consequences. Of the intraspecific interactions reviewed by Steward and Bjomn (1990), all but cannibalism apply to chinook salmon.

- Exploitative and interference competition (sensu McFadden 1969)
- Altered territorial, predator avoidance, and migratory behaviors
- Inappropriate courtship and mating behaviors
- Disease and parasite transmission

We have grouped the foregoing types of intraspecific interactions into three performance criteria- competition. reproduction, and disease (Table 4)

Significant intraspecific interactions between hatchery and natural fish are not anticipated in the near-term since natural production is clearly depressed However, the potential for such interactions will increase as natural populations rebuild, and it may become necessary to monitor short-term disruptions in wild juvenile chinook behavior caused by hatchery releases The potential for negative interactions involving NPTH fish and chinook salmon from populations outside the basin is unknown, but is important due to the sensitive status of many of those populations.

If wild juvenile chinook are present in significant numbers, introduced hatchery juveniles may be at greatest risk due to food limitations and disruptions in normal patterns of movement. The type and degree of intraspecific interactions involving juveniles will depend on environmental conditions and the quality (behavior, health, etc) of hatchery fish as affected by rearing and release practices.

2 5.2.2 Interspecific Interactions

Targeted populations of chinook salmon are expected to interact significantly with steelhead trout and other fish species in the Clearwater River system and elsewhere. The potential for disrupting competitor, predator, and prey populations is greatest in the Clearwater -- in the short run in response to outplanting of hatchery fish, and over the long run as naturally reproducing chinook populations rebuild. The potential for interspecific interactions involving chinook salmon will depend on resource demand and availability. and the degree of overlap of competitors, predators, and prey in space and time.

The performance criteria to be evaluated under this subcategory are interspecific competition, trophic dynamics (predator-prey interactions), and pathogens (viral, bacterial, and parasites). The risk of interspecific hybridization was not considered great enough to warrant its inclusion as a fourth criterion.

Interactions between abiotic and biotic (including chinook salmon) components of the ecosystem are not addressed under the Ecological Interactions category Biophysical processes affecting habitat carrying capacity and other factors regulating chinook salmon abundance are discussed under the Natural Environment category

Human-fish interactions constitute another type of ecological interaction Most interactions involving humans and fish are of two types those related to natural resource management, and those related to fishing The potential effects of external management activities on NPTH program goals are assessed as extrinsic factors under the Natural Environment category Interactions based on fishing are not explicitly considered in this report, but should be addressed separately in a Harvest Management Plan (see Section 6 3)

2.5.3 *Natural Environment*

Stock status and performance can be evaluated only with respect to the properties of the natural environment in which the population is found or will occur in the future. For this reason, information on the Natural Environment was identified as a priority need to be addressed through monitoring and evaluation. The Natural Environment category was defined by three subcategories: Production Potential, Biological Community, and Extrinsic Factors.

2.5.3.1 Production Potential

An assessment of supplementation opportunities must consider the amount and quality of habitat available within the environment, at scales ranging from the individual stream channel unit to the watershed to the ocean. For practical reasons, we focus primarily on factors that regulate population abundance and determine carrying capacities of freshwater habitats. Several performance criteria relating to the physical structure and function of NPTH streams as they affect salmonid habitat and production are identified (Table 4). Riparian areas are included because they represent important linkages between terrestrial and aquatic environments.

Baseline sampling, process modeling, and trend analysis are proposed as monitoring and evaluation activities which will enable NPTH managers to refine natural and hatchery production objectives prior to project implementation. If possible, the production potential of NPTH streams should be defined as it existed under pristine conditions, as it currently exists, and as it might exist at some point in the future. The process of identifying and quantifying production potential and limiting factors should also suggest opportunities for habitat protection and enhancement.

2.5.3.2 Biological Community

Salmon populations and the biological community of which they are part mutually influence each other. This is because salmon are both sources and processors of energy, and by their numbers and ecology, either directly or indirectly influence the distribution and abundance of other species. It is also true that the presence of other species affects the abundance and ecological role of salmon. Most of the direct forms of interaction expected under the NPTH will be monitored under Ecological Interactions performance criteria Under the Biological Community subcategory we are more concerned with the possibility of a decline in the variety and abundance of native aquatic species, either as a consequence of supplementation or due to other causes Our basic premise is that chinook populations can be re-established only in biological and physical environments that are within the adaptive range of the species A diverse, stable, and productive biological community is indicative of a normally functioning ecosystem and is essential to supplementation success For this reason, we propose to monitor the variety and abundance of key freshwater species using a number of indices of ecological well-being (Table 4)

2 5 3 3 Extrinsic Factors

Extrinsic Factors are broadly defined to include intentional and unanticipated environmental disturbances or management decisions that may affect chinook stock status and project viability over the long-term Implicit to this subcategory is the recognition that non-project factors and forces will have direct, immediate and paramount impacts on project management and success

Performance criteria under the Extrinsic Factors subcategory represent broad categories of impact expressed within and outside of the Clearwater River system (Table 4). Examples include logging, natural stressors (e g., tire, floods). and a multitude of "downriver" impacts, especially those stemming from management actions. While the NPT may not be able to eliminate unwanted effects stemming from external causes, they should monitor and, if possible. take steps to ameliorate those policies affecting chinook salmon from Clearwater River basin It would be imprudent to undertake supplementation without explicitly considering the potential for change in ecological condition and other impacts due to Extrinsic Factors.

It is particularly important that NPTH managers coordinate supplementation, monitoring, and management activities with other resource agencies and affected parties within the area of project impact. For this reason, we have proposed several monitoring and evaluation tasks whose purpose is to gather information and to improve communication and coordination among interested parties.

A Word of Caution

The foregoing categories, subcategories, and performance criteria are consistent with information needs identified in the NPTH Master Plan and the published literature on supplementation The types of information sought are sufficiently broad to enable monitoring and evaluation of project-related impacts and external factors that might influence the outcome of supplementation As with most categorization schemes, however, there is unavoidable overlap in information needs within and across levels of organization due to interdependencies among the variables and processes involved. Many of the redundancies inherent to this scheme will be eliminated before implementation of the M&E Plan occurs (see Section 6 0)

3. EXPERIMENTAL DESIGN

3.1 General Approach

The NPTH project may be viewed as a large-scale manipulative experiment to determine whether natural populations can be augmented by repeated introductions of hatchery fish We would like to know whether supplementation has been successful and what factors or underlying processes are responsible for the observed response. For example, if natural populations increase in size, was it the result of reproductive success, improved passage, increased marine survival, or some other factor? We also want to know whether impacts are within acceptable limits

We propose to answer the general question "Was supplementation successful?" by applying inferential statistics to analysis of variance (ANOVA) designs, using both spatial and temporal controls. Due to the need for replication, the ANOVA design will be applicable only to spring chinook streams/populations. Alternative models and inferential statistics will be employed to evaluate the success of fall chinook supplementation under the NPTH.[8] For the sake of simplicity we present an experimental design that considers the effects of supplementation on the proportional abundance of spring chinook salmon in supplemented and control streams. The recommended approach is one that maximizes our ability to detect and explain supplementation effects with the smallest expenditure of time and effort.

The NPTH "experiment" is designed to evaluate whether supplementation works or not, primarily by testing for changes in the proportional abundance of spring chinook salmon. The statistical test will not necessarily identify the reasons for success or failure. Possible causal factors will be investigated through comparative studies and correlation analysis For starters, it would be useful to know whether hatchery and naturally-produced chinook differ in genetic, life history, and ecological characteristics We propose to collect data on genetic and life history performance variables that will be useful in describing differences or similarities between the two groups of fish.

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[8] The response of fall chinook to supplementation will be monitored by fitting exponential growth/decay and spawner-recruit models to a time series of redd count data Positive trends in the number of fall chinook redds counted within the entire Clearwater basin will be taken as evidence for supplementation benefits

The Master Plan indicated that several release strategies will be employed to minimize ecological risks and maximize supplementation benefits. Unfortunately, research hypotheses relating to release strategies will be difficult to evaluate under a classical experimental design because opportunities for replication and randomization are scarce. We propose to conduct studies in Meadow Creek (Selway), however, that are specifically designed to answer the question "How should chinook fry be released?" These studies, which are outlined below in Section 3.3, will determine whether point (high density) releases and scattered (low density) releases are equally effective in seeding fry rearing habitats, maximizing survival, and minimizing undesirable ecological interactions

Although emphasis is on large-scale, manipulative experiments, there will also be opportunities to collect observational and correlational data to help resolve specific supplementation uncertainties. For example, we propose to monitor the status and trends of ecologically important species and processes to determine whether changes have occurred, and if so, whether they appear to have been brought on by supplementation. Questions concerning specific ecological differences among hatchery and wild chinook, as well as general information on the behavior and ecological requirements of the species, may be effectively answered through field and laboratory studies. The usefulness of these studies will be enhanced by careful observations obtained under controlled conditions, preferably over a protracted period of time.

The design of large- and small-scale studies to investigate the questions posed above involves a number of interrelated activities:

1. Derivation of scientific hypotheses from critical uncertainties,
2. Identification of appropriate performance criteria and variables,
3. Formulation of statistical hypotheses,
4. Determination of treatments or independent variables to be employed, along with extraneous conditions that are to be experimentally or statistically controlled,
5. Specification of the number and type of experimental or observational units (e.g., streams, populations, individual fish), and
6. Specification of the performance (dependent) variables of interest and the methods and statistical tests to be applied

We provide further detail by way of example on each of these steps below The approach we have taken begins with a general statement of scientific hypotheses We recommend that alternative statistical hypotheses be identified from a consideration of critical uncertainties Depending on project objectives and logistical constraints (i e , sample sizes, environmental variability, etc) one or more experimental approaches can be specified to test the hypotheses.

3.2 Was Supplementation Successful?

NPTH planners have been asked to apply state-of-the-art supplementation theory and technique to the task of devising appropriate operational and monitoring strategies within acceptable (i.e., socially responsible, scientific, and cost-effective) limits The problems they faced may be summarized as follows :

1. The "best" supplementation strategies are unknown;
2. Natural populations and the environmental factors that regulate them are highly variable, making it doubtful that any but major changes will be detected;
3. Only a limited number of streams and hatchery facilities are available for experimental purposes.
4. The type and number of observations that are feasible may limit statistical evaluation of project effects; and
5. It may take years and large expenditures of effort and money before project effects can be measured and described.

These uncertainties and constraints are challenging but not insurmountable. Our job will be an easy one if supplementation results in dramatic and measurable benefits. However, because supplementation is an unproven technique, and because current environmental and management regimes do not favor a resurgence in natural chinook populations, the process of rebuilding upriver stocks is likely to be a slow one. The preferred experimental design is one that will detect changes in the status of supplemented and non-supplemented chinook populations under these conditions.

Experimental designs that might be used to evaluate project effects will necessarily be "repeated measure designs," because they will involve the collection of data from the same streams for the same response variables under pre-operational and post-operational regimes They have the advantage of increasing the precision of the treatment analysis by accounting for variability between experimental units (e g., streams, populations, individuals) One disadvantage of repeated measure designs is that treatments cannot be randomly assigned to experimental units over time. Another is that measurements of dependent variables from the same experimental unit may be temporally correlated

There are two general types of repeated measures designs that can be used to determine whether supplementation has benefited natural populations Both require baseline and post-supplementation monitoring of population abundances (either absolute or index) The first approach, termed a "Before-After Experimental Design." involves repeated sampling of supplemented streams over time The second experimental approach also requires repeated measures over time, but includes spatial controls to account for temporal effects It is referred to as a Before-After. Treatment-Control Experimental Design

3.2.1 *Before-After Experimental Design*

This is the study design generally alluded to in the Master Plan. Several streams are selected for supplementation, and repeated measurements of response variables are obtained Before and After supplementation begins Sampling times are considered replicates. The H_0 of interest is "no change in supplemented streams." Sampling would look like this:

	Before		After
Stream 1	0 0 0 0	X	0 0 0 0
Stream 2	0 0 0 0	X	0 0 0 0
Stream *n*	0 0 0 0	X	0 0 0 0

where 0 represents one or more observations over time and X indicates the start of supplementation on *n* streams.

A randomized block design (streams are blocks) can be used to evaluate supplementation effects since temporal variability within pre- and post-treatment periods is expected to be less than the variability between streams (Table 7). Although temporal controls (pre-treatment measurements) are included, it may be hard to prove a supplementation effect if some other effect (e.g., an increase in smolt-to-adult survival due to passage improvements) is occurring at the same time. Without spatial controls, the design does not permit a test for a streams-by-treatment interaction. The implication is that we would not be able to conclude with certainty that the observed effects result from supplementation and do not simply reflect biases caused by non-random stream selection or the influence of extraneous temporal variables. These problems can be partially overcome by limiting inferences to the supplemented streams (rather than assuming that the streams are representative of a larger stream "population"), using covariates to explain additional sources of variability, and applying a (less powerful) non-additive model if stream-treatment interaction effects are present (Tukey 1949)

Table 7 ANOVA table for NPTH randomized block design (streams are blocks). This design is diminished by a lack of spatial controls.

	Source	df	E(MS)
p = 2	Treatment levels (Supplementation)	p - 1 = 1	$\sigma_\varepsilon^2 + n\sum \alpha_j^2/(p-1)$
n = 6	Blocks (Streams)	n - 1 = 5	$\sigma_\varepsilon^2 + p\sigma_\pi^2$
	Residual	(p - 1)(n - 1) = 5	σ_ε^2
	Total	np- 1 = 12	

A rough idea of the power (i e., the probability of correctly rejecting a false H_0) of the above design given the number of streams available for study can be had by rearranging the F statistic formula. However, because the magnitude of the expected treatment effect and associated error variance is unknown, we opted to apply the method described by Kirk (1982, p 145). This approach requires estimates of:

1 a, the probability of rejecting the null hypothesis when it is true,

2 p, number of treatments,

3 v_1 and v_2, degrees of freedom for treatment and error effects, respectively [v_1 = (p - 1) and v_2 = (n- 1)(p - 1)], and

4 The largest difference between Before-After response variable means expressed as a multiple C, of the unknown error variance, σ, measured as the mean square error of the residual

Kirk (1982, p 840) provides a table that indicates the minimum sample size needed to ensure a given power. We estimated sample sizes required to achieve a power of 0.7 and 0 8, given α = 0.10, 0 05, and 0.01 for values of C ranging from 1 0 to 3.0 (Table 8)

Table 8 Sample sizes needed to ensure a power of 0 7 - 0 8 under an RBH-2 design

a	C: 1.00	I.25	1.50	1 70	2.00	2 50	3 00
	$1 - \beta = 0.70$						
0 10	11	7	6	4	4	3	3
0.05	14	9	7	6	5	4	3
0.01	21	15	11	9	7	5	5
	$1 - \beta = 0.80$						
0 10	14	9	7	5	4	3	3
0 05	17	12	9	7	6	4	4
0.01	26	17	13	10	8	6	5

Regardless of the response variable selected, if Before-After differences are 1 5 to 2 times greater than the mean square residual error. then approximately 4 - 7 streams need to be sampled to ensure a 70-80% chance of correctly rejecting a false H_0. Six streams were identified in the Master Plan for supplementation with spring chinook salmon. If C has been overestimated, or if higher power is desired. an (impractically) larger sample size will be required. Power can be increased by judicious selection of response variables, data transformation techniques, covariate analysis to minimize residual error, specifying one-sided rather than two-sided tests for significance, and increasing the alpha level. Bowles and Leitzinger (1991) were able to significantly improve the power of the split plot design proposed for Idaho Supplementation Studies by applying a logarithmic transformation to redd count data that had been standardized using adult returns to Ice Harbor Dam

3.2.2 Before-After, Treatment-Control (BATC) Experimental Design

A repeated measures design involving pre- and post-treatment sampling of suppiemented and control streams is preferred over designs lacking spatial controls Conclusions from this type of experiment. called a Before-After. Treatment-Control

(BATC) experimental design, are generally more reliable and less controversial Skalski and Robson (1992, p 179) state the problem thusly

> *"The detection of differences in fauna1 abundance between control and treatment stations or between pre-operational and operational phases of monitoring IS insufficient evidence alone for assigning causation to population change."*

BATC designs assume that n pairs of Supplemented and Control streams can be sampled during Before and After Supplementation periods. Control streams reflect ambient conditions; Supplemented streams reflect the same conditions plus supplementation effects, if any. This approach is analogous to an impact assessment study design, except that the "impact" (supplementation) will not be haphazardly applied; we have prior knowledge of where and when supplementation will be applied, and can specify the number of streams to receive treatment The potential for experimental manipulation greatly enhances statistical power and the validity of inferences to target and non-target streams alike. By manipulation we mean:

1. Selecting streams that are representative of the stream "population" (i.e., They are true replicates),
2. Pairing streams that are similar in habitat, productivity, etc., And. apart from supplementation, are influenced by large-scale natural phenomena (e.g , Weather, fishing pressure) approximately equally, and
3. Randomly assigning supplementation to one stream in each pair

BATC designs test the general hypothesis: "Has the proportional abundance of chinook populations in supplemented-control streams changed following supplementation?" Proportional abundance, K, is computed as N_S / N_C for each treatment-control stream combination for each sampling time The use of K eliminates potentially non-additive confounding effects (e.g., autocorrelation) on population abundance (McKenzie et al. 1977, cited by Skalski and Robson 1992. p. 212).

When treatments are randomized, there are two hierarchical approaches to BATC designs. The simplest approach is the "odd's ratio design," which consists of two Before (N_{BSi} and N_{BCi}) and two After (N_{ASi} and N_{ACi}) measurements of chinook abundance taken of the i^{th} pair of treatment and control streams (i = 1, 2, . n) Thus,

$$K_B = \frac{N_{BSi}}{N_{BCi}} \text{ . and } \qquad K_{Ai} = \frac{N_{ASi}}{N_{ACi}}$$

A test of supplementation effects for each stream pair is based on the odd's ratio

$$D_i = \frac{K_{B_i}}{K_{A_i}}$$

A mean odd's ratio, $\overline{D}$, is calculated as the average of treatment-control stream pairs. The null hypothesis tested is $H_0: \bar{u}_D \leq 1$ (or, if the natural log transformation is used, $H_0: \bar{u}_D \leq 0$). A one-tailed test is appropriate since supplementation is expected to result in an increase in population abundance.

Absolute abundance (e.g., adult escapement to weirs) and population indices (e.g., redd counts) can both be used as response variables, although model-dependent assumptions related to the latter are more difficult to satisfy. Results can be pooled across treatment-control pairs if the assumption of inter-population homogeneity is met. Skalski and Robson (1992, p. 166) suggests alternative tests of pairwise and between pair homogeneity to determine whether population indices may be used and whether pooling is appropriate. Assuming that measurements are homogenous across stream pairs, the statistic to test the odd's ratio null hypothesis is:

$$d = \frac{\frac{1}{I}\sum \ln \hat{D}_i}{\sqrt{\frac{S^2_{\ln \hat{D}}}{I}}}$$

where d is approximately t-distributed with (n- 1) degrees of freedom (Skalski and Robson 1992, p 166).

The odd's ratio design has the desirable characteristics of being straightforward and easy to calculate, it requires only one set of Before and After measurements, and it provides a valid test of supplementation even in the absence of randomization. It represents a safeguard against the possibility that stream selection and monitoring activities may not fulfill the requirements of the more powerful factorial treatment BATC design, discussed next.

The second BATC approach relies on the use of ANOVA techniques applied to a factorial treatment design in which repeated yearly measurements are made of chinook abundance in treatment and control streams during Before and After phases An effect due to supplementation is defined as a significant increase in the proportional abundance of chinook salmon in treatment and control streams between pre- and post-treatment periods The chief advantage of the factorial treatment design over the corresponding odd's ratio design is that it eliminates potential sources of error and hence increases statistical power under most circumstances

Under a factorial treatment design, smaller sampling errors are achieved by sampling many times during Before and After time periods. Replication over time can be explicitly incorporated into the statistical model, as was done in the Idaho Supplementation Studies (ISS, Bowles and Leitzinger 1992) [9] Under the ISS, "years" were considered a treatment in the Split Plot Factorial (SPF) repeated measures design (see their Table 6) For each of the two groups of streams, the two levels of Treatment A (Supplementation and Control) should be observed under *all* levels of Treatment B. This will clearly not be possible under the ISS design since both groups of streams will be observed for a period of time (e.g., Years b_1 through b_5) during which no supplementation occurs Level one of Treatment A - Supplementation - is not applied in all years to the streams (experimental units) within the group. Thus, the block and treatment combinations specified by Bowles and Leitzinger (1992) do not permit a ready test of H_0: "no change following supplementation." It is exactly this possibility that we want to test for statistically. We have therefore explored alternatives to the ISS model that permit explicit testing of both Before-After and Treatment-Control hypotheses using an ANOVA model.

The first alternative is also an SPF design (Table 9), but in this case Years are blocked within Before and After Supplementation periods, corresponding to two levels (a_1, a_2) of Treatment A (Supplementation). Treatment B is Stream, also having two levels (b_1, b_2) - Supplemented and Control This is *not* a repeated measures design. For a given year, observations from different streams would be combined to obtain two mean values - one representing Supplemented streams and the other Control streams Under the proposed design, effects attributable to Supplementation will be completely confounded with the effects of Years, but should not affect the interpretability of treatment effects as long as the usual ANOVA assumptions are met (e.g., normality, homogeneity of variances, independence of error effects). The advantage of the proposed design is that the degrees of freedom depends on the number of temporal replicates, not the number of streams sampled. Thus, a smaller number of streams can be sampled to estimate annual mean values Sample sizes can vary between years.

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[9] Bowles and Leitzinger (1992) indicated that a profile analysis of repeated measurements of dependent variables in ISS Supplemented and Control Streams would be performed It should be pointed out that profile analysis uses Mulitivariate Analysis of Variance (MANOVA) to evaluate treatment effects. whereas SPF uses ANOVA. The distinction is important. since MANOVA is less powerful This can be seen by comparing the within-blocks error degrees of freedom of the SPF design [using the ISS example $p = 2$. $q = 15$. and $n = 9.5$. Error B $df = p(n-1)(q-1) = 238$) with the corresponding df in the multivariate design $df = p(n-1)-q+1 = 4$ (Johnson and Wichern 1982)]. The power of the test of Years and Years x Treatment interaction terms will be nowhere as high as implied in the analysis of Bowles and Leitzinger (1992)

The disadvantage, of course, is that the sample means may not accurately reflect the true means Small sample sizes become problematic when within-year variation among streams is high. We expect this to be the case, so do not recommend this experimental design

Table 9 ANOVA table for SPF design in which Supplementation (Before and After) and Streams (Treatment and Control) are treatments, and Years are Blocks

	Source		*df*		*E(MS)* •
1	Between blocks				
2	A (Supplementation)	p = 2	p - 1 = 1	[2/3]	$\sigma_\varepsilon^2 + q\sigma_\pi^2 + nq\sum \alpha_j^2/(p-1)$
3	Blocks w A (Years)	n = 5	p(n - 1) = 8		$\sigma_\varepsilon^2 + q\sigma_\pi^2$
4	Within blocks		np(q - 1) = 10		$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2 + np\sum \beta_k^2/(q-1)$
5	B (Stream)	q = 2	q - 1 = 1	[5/7]	$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2 + n\sum\sum(\alpha\beta)_{jk}^2 (p-1)(q-1$
6.	AB		(p - 1)(q - 1) = 1	[6/7]	$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2$
7	B x blocks w A		p(n - 1)(q - 1) = 8		
8	Total		npq - 1 = 20		

A hierarchical randomized block (RBH) design, in which different Years (Treatment B) are nested within levels of Supplementation (Treatment A), is more efficient than the split plot experimental design employed by Idaho Supplementation Studies researchers Because RBF designs are more efficient than split plot factorial designs in detecting main treatment (i.e , Supplementation) effects (Kirk 1982), it is worth examining their potential use in the NPTH context *We recommend use of a RBH design in NPTH studies. assuming that suitable treatment-control stream pairs (blocks) can be found.*

A block diagram for the proposed RBH design is shown in Figure 5 Levels of Treatment A (Supplementation) correspond to Before (a:) and After (a.) periods Treatment B (Years) consists of eight annual samples divided equally between a. and a.. Both treatments are fixed. Blocks represent Supplemented-Control stream pairs. and k. the observed proportional abundance N_S / N_C

Figure 5 Block diagram for the proposed RBH design Treatment A (Supplementation) is applied during Before (a1) and After (a2) periods Treatment B (Years) consists of eight annual samples divided equally between a1 and a2 Dependent variable k is the proportional abundance measured in each Treatment-Control stream pair (block)

	a_1 b_1	a_1 b_2	a_1 b_3	a_1 b_4	a_2 b_5	a_2 b_6	a_2 b_7	a_2 b_8
Block 1	k_1	k_1	k_1	k_1	k_1	k_1	k_1	k_1
Block 2	k_2	k_2	k_2	k_2	k_2	k_2	k_2	k_2
Block 3	k_3	k_3	k_3	k_3	k_3	k_3	k_3	k_3
Block 4	k_4	k_4	k_4	k_4	k_4	k_4	k_4	k_4
Block 5	k_5	k_5	k_5	k_5	k_5	k_5	k_5	k_5

The recommended **RBH-*pq*(A) ANOVA** design is based on an additive model (Table 10); we assume that Stream Pairs (Blocks) will not interact with **Supplementation** (Treatment A) or Year (Treatment B). Treatments A and **B** are considered fixed.

Table 10. **ANOVA** table for **RBH-*pq*(A)** design.

Source		*df*		*E(MS)**
1. Blocks (Paired Streams)	n = 5	n - 1 = 4	[1/4]	$\sigma_\varepsilon^2 + pq\,\sigma_\pi^2$
2 A (Supplementation)	p = 2	p - 1 = 1	[2/3]	$\sigma_\varepsilon^2 + n\left(1-\frac{q}{Q}\right)\sigma_\beta^2 + nq\,\sigma_\alpha^2$
3 B(A) (Years w A)	q = 5	p(q - 1) = 8	[3/4]	$\sigma_\varepsilon^2 + n\sigma_\beta^2$
4 Residual		(n - 1)(pq - 1) = 36		σ_ε^2
5 Total		npq - 1 = 49		

This design has the advantage over previously discussed designs in that samples from Supplemented and Control streams can be replicated in time. We assume that proportional abundances will not change appreciably within pre- and post-treatment periods (i.e., the effects of time on N_S / N_C are additive), and that measurements in time are uncorrelated.[10] The first assumption is the most tenuous since supplementation is expected to be self-augmenting All else being equal, the difference between treatment and control streams should continue to increase over time after supplementation begins. The rate of population increase should gradually decrease and eventually stop altogether once carrying capacity is reached. Although this pattern of population growth is desirable from a production standpoint, the variability it represents makes it more difficult to reject the null hypothesis of no effect.

There are two time intervals within the post-supplementation period in which proportional abundances in treatment-control streams may remain relatively constant. These are during the first four or five years after project startup (i.e., before the effects of supplementation begin to snowball), and later, when population sizes in supplemented streams should be held in check by density-dependent feedback processes. Emphasis should be placed on the time period immediately following supplementation for practical reasons. (1) the project will be evaluated and managed on the basis of its short term impact, (2) unless prevailing sources of density-independent mortality are reduced or eliminated, supplemented populations may be slow to reach carrying capacity, and (3) after a long period of post-implementation monitoring, before-after type comparisons will probably become less relevant than analyses of long-term trends operating on treatment and control streams.

Given the foregoing sampling constraints and expected temporal variability, how many years should we sample Before and After Supplementation? We consider one generation of chinook salmon (4-5 years) to be adequate. If this length of time cannot be devoted to pre-treatment sampling, or if tangible results do not occur within the first generation following supplementation, we recommend that multivariate profile analysis (see below) of Supplemented and Control Stream responses be used to investigate long-term trends.

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[10] Chinook population sizes are expected to be correlated through time, leading to a lack of independence and a violation of the hierarchical randomized block (RBH) design This problem is lessened, but not eliminated, by restricting sampling to one life cycle (i e 5 years) during pre- and post-implementation periods

The impracticality of spatial replication and randomly assigning treatments among representative streams means that it may not be possible to draw broad inferences regarding supplementation from NPTH studies. At best, we will be able to detect whether supplementation works for the streams/populations of interest that we are investigating. Extrapolation of our results to other situations or times may not be tenable The main objection to nonrandomized experiments is that the streams being supplemented are not representative of other streams that might be supplemented (i e., the "population" of streams). Bias may enter either through the choice of streams or through spurious effects due to causes other than the treatment. This objection does not apply with full force to NPTH The streams/stocks selected for supplementation, the times at which samples are taken, are the only populations and time periods of interest; neither time nor place can be considered unrepresentative in this sense.

3.2.3 Alternative Experimental Approaches

3.2.3.1 Paired Regression Analysis

Another approach to identifying supplementation effects is to develop a regression relationship between paired treatment and control streams for baseline and post-implementation periods. A significant difference in slope between the two regression equations is taken as evidence for supplementation effects.

3.2.3.2 Multivariate Analysis of Variance

All of the designs discussed thus far can be adapted to evaluating two or more dependent variables simultaneously by using the multivariate equivalents of the univariate statistical tests. Multivariate techniques are particularly apt if the dependent variables are correlated. The use of multivariate analysis of variance frequently is limited by small sample size (Johnson and Wichem 1982).

If enough pre- and/or post-operational samples of population abundances can be obtained, MANCOVA (profile analysis) can be used to compare differences in the sample means of the two temporal sequences An advantage of profile analysis is that it can be used in the absence of pre-operational data Figure 6 illustrates hypothetical post-operational "profiles" for response variable measurements that have been averaged for supplemented and control streams

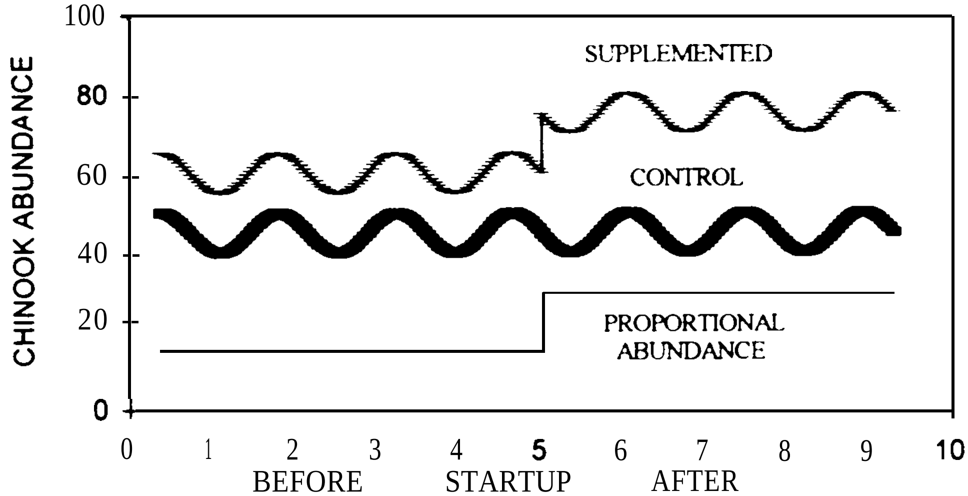

Figure 6. Hypothetical profiles of chinook abundance under a successful Before-After, Treatment-Control stream experiment.

Profile analysis addresses the following questions (Johnson and Wichem 1982):

1. Are the profiles parallel? That is, do supplemented and non-supplemented streams exhibit similar patterns, apart from the effects of supplementation?
2. Are the profiles coincident? Is the magnitude of the responses the same?
3. Are the profiles level (flat)? Are all the mean delta Y's constant within the period of interest?

The hypotheses are hierarchical; i.e., the test for coincident profiles is contingent on their being parallel and the test for level profiles assumes that the profiles are coincident. We can pool observations from Before and After periods, but are most interested in whether the hypotheses hold true separately for both periods. Therefore. tests yielding significant results should be followed by simple contrasts of means from each period. Pre- and post-treatment periods do not need to be of equal length. Post-treatment stream profiles can be reanalyzed each year as additional observations are obtained; however, power is lost as the number of years sampled increases relative to the number of spatial replicates. The comparison of Supplemented versus Control Stream responses will be improved more by increasing the number of Stream replicates than by increasing the number of years sampled

3 2 3 3 Nonparametric Statistical Methods

If parametric statistical assumptions are badly violated, a nonparametric split plot analysis may be tenable. Nonparametric methods are robust (e.g., they do not require that the data be normally distributed), they are suitable for analyzing small samples. but they give up power relative to parametric tests (Hollander and Wolfe 1973).

3.2.4 *Experimental Units*

From a consideration of NPTH goals, experimental design requirements, and information regarding their physical and biological characteristics, 11 streams have been tentatively selected as spring chinook experimental streams (Table 11). Ten of these streams will form the 5 paired treatment and control streams required for the NPTH supplementation experiment. Meadow Creek has been excluded from the BATC design because it lacks an adequate control It will be used as a test site for chinook release studies.

All of the spring chinook study streams are located in the Clearwater River subbasin; all possess physical characteristics typical of chinook-bearing streams in Idaho (Rich et al. 1993). Water quality is uniformly good. Lolo Creek, Newsome Creek, and Johns Creek are among several streams currently being monitored as part of the Idaho Supplementation Studies (Bowles and Leitzinger 1991). Sampling will continue in those streams to fulfill the data needs of both the ISS and the NPTH monitoring and evaluation program. Tribal biologists will begin to gather baseline data and provide more detailed descriptions of the remaining study streams during the pre-operational period.

A balanced design (i.e., equal number of treatment and control streams) is very important because it results in a test statistic that is robust to heterogeneity in treatment variances and because test procedures for unbalanced data are exceedingly complex (Kirk 1982). For each treatment stream, a control stream should be selected whose response to seasonal changes is expected to be similar to that of the treatment site. The BATC design does not require exact pairing; populations simply need to "track" each other, i e., maintain constant proportionality, within pre- and post-treatment periods Final pairing of treatment and control streams should be determined after baseline data have been collected and analyzed as follows (Manley and Wright 1982). Identity a reliable measure of current chinook abundance or production potential for each stream. Designate this measure the dependent variable Y. Identity several environmental variables X_1, X_2, .., X_n that are thought to somehow influence Y Measure these variables on repeated occasions in each stream. Perform a regression analysis to predict $Y = f(X_1, X_2, \dots X_n)$ for each stream. Pair streams that have similar r^2 values

Table 11 Selected physical and biological characteristics for Meadow Creek and ten treatment and control streams that will be used to evaluate spring chinook supplementation success under the NPTH experimental design (Source: NPT; MEG 1989)

Stream	Treatment or Control	ISS Stream[1]	Distance from the Ocean (RM)	Elevation (ft)	Miles of Usable Habitat (mi)	Juvenile Chinook Capacity: Parr Capacity	Juvenile Chinook Capacity: Smolt Capacity	Land Ownership	Geology	Habitat Quality Rating (Percent in Category[2,3]) 1	2	3	4	Channel Type[4]	Species Composition	Outplant History
Non Experimental Streams																
Meadow Cr (Selway)	N/A	N	580	1,760	105.0	497,182	333,112	NPNF	Gn/S/Bath	26%	19%	55%	0%	B/C	SHD, CHS, WF, CUT, BUT	Low
Experimental Streams																
Lolo Cr	T	Y	521	1,079	84.0	234,989	157,443	NPT, PRIV, CNF, BLM, ST	Bas	0%	31%	17%	52%	B/C	SHD, CHS, WF, CUT, BUT, BRK	High
Eldorado Cr	C	Y	561	2,840	18.0	97,194	65,120	NPT, PRIV, CNF	Bath	0%	100%	0%	0%	B/C	SHD, CHS, WF, CUT, BUT, BRK	High
Mill Cr	T	N	570	2,240	14.8	N/A	N/A	NPNF, PRIV	Gn/Bath	N/A	N/A	N/A	N/A	B/C	SHD, CHS, WF, CUT, BUT	Low
Johns Cr	C	Y	578	2,402	47.0	50,235	33,657	NPNF	Bas/Gn/S	0%	0%	100%	0%	B/C	SHD, CHS, WF, CUT, BUT	Low
Meadow Cr (South Fork)	T	N	571	2,330	13.5	32,832	21,997	NPNF, PRIV	Gn/Bath	0%	0%	100%	0%	B/C	SHD, CHS, CUT	Med
Newsome Cr	T	Y	596	3,619	62.0	71,367	47,816	NPNF	Gn/S/Bath	0%	62%	38%	0%	B/C	SHD, CHS, WF, CUT, BUT	High
Tenmile Cr	C	N	585	3,000	25.5	60,313	40,410	NPNF, PRIV	Gn/Bath	0%	50%	50%	0%	B/C	SHD, CHS, WF, CUT, BUT	Med
Boulder Cr	T	N	581	2,050	12.0	98,889	66,256	CNF	Bath	0%	100%	0%	0%	A	SHD, CHS, CUT, BRK, BUT	Low
Fish Cr	C	N	579	2,000	41.4	169,718	113,711	CNF	Bath	15%	77%	9%	0%	A/B/C	SHD, CHS, CUT, BRK, BUT	Low
Warm Springs	T	N	606	3,080	22.4	25,303	16,953	CNF	Bath	0%	100%	0%	0%	NA	SHD, CHS, CUT	Low
Brushy Fk Cr	C	N	N/A	N/A	N/A	45,664	30,595	CNF	Bath	N/A	N/A	N/A	N/A	A,B	SHD, CHS, CUT, WF, BUT	Low

[1] Idaho Supplementation Study streams (Bowles and Leitzinger 1992)
[2] NPPC Presence Absence database
[3] Habitat quality categories 1 Excellent, 2 Good, 3 Fair, 4 Poor
[4] Rosgen (1985) stream (reach type) classification system
NPT Nez Perce Tribe Reservation, NPNF Nez Perce National Forest CNF Clearwater National Forest, PRIV Private, ST State of Idaho, BLM Bureau of Land Management
Bas Basalt Gn Gneiss, S Schist, Bath Idaho Batholith (granitic)
CHS Chinook Salmon, SHD Steelhead trout, CUT Cutthroat trout, BRK Brook trout, BUT Bull trout, WF - Mountain Whitefish

According to Hilborn and Walters (1992, p 508-509), the factors to consider in choosing the number of treatment and control streams include:

1. The cost of monitoring
2. The effect of sample size on the time required to reliably evaluate the hypothesis or model in question, and
3. Variability among streams and the difficulty of finding suitable replicates

The first factor - cost - is dependent on the other two; costs increase as sample size and variability go up. Costs can be contained by judicious selection of performance measures and planning for efficient sampling. Although not explicitly incorporated into the decision of how many streams to sample to monitor NPTH impacts, costs were considered in the selection of dependent variables. We feel that as long as costs can be held to acceptable levels, sample sizes should be governed by the particular requirements of the experimental or observational studies that were devised to address major uncertainties.

3.3 How Should Fish be Released?

The experimental designs presented above consider "supplementation" to be the treatment of interest. Just what forms of supplementation (i.e., age and size of fish, method and time of release, and stocking densities) would produce the greatest benefits remains uncertain. To resolve this uncertainty, the Master Plan proposed to supplement NPTH streams with three life stages of chinook salmon - fry, pre-smolts, and smolts. The BATC experiment does not differentiate among these treatments, but lumps them all under "supplementation." If any of these release techniques fail, or if there is large variability in the results they produce, then it may be difficult to prove that supplementation represents a significant improvement over the alternative strategy of natural rebuilding (non-supplementation).

It will not be possible to evaluate the relative performance of groups of fish released as fry, presmolts, and smolts using the statistical techniques described earlier because of the lack of opportunity for replication and randomization. We expect to see a positive and uniform response in supplemented streams in comparison to controls following supplementation, regardless of the life stage used. Differences among groups of fish released at different times and ages are not likely to mask this response[11] Nevertheless, for the sake of fine-tuning and possibly reducing the costs

[11] Varying release strategies across streams, should they provoke an uneven response, will complicate matters considerably It would be be prudent to randomly assign age-at-release treatments among streams rather than sticking with a single treatment for each stream

associated with supplementation, the question of how to release fish will be addressed through studies conducted over time in Meadow Creek

3.3.1 *Meadow Creek*

An experimental study is currently underway in Meadow Creek that seeks to test two key hypotheses.

H_0: Hatchery chinook fry outplanted in the upper, low gradient reach of Meadow Creek are less likely to emigrate or die than are fry outplanted in high gradient sections of the lower river,

and

H_0: Hatchery chinook fry distributed over a large area at low densities are less likely to emigrate or die than are fry released in high concentrations in confined areas.

Experimental units are 500 m sections of stream located within larger, uniform reaches and representative of conditions within those reaches. These hypotheses will be evaluated using a repeated measures cross-over experimental design in which treatments are applied sequentially to each experimental unit so that comparison is made within each unit (i.e., each unit acts as its own control) (Crowder and Hand 1990). For two treatments (A and B), the presentation would be:

Reach	Study Section	Year 1	2	3	4	5	6
Upper	1	A	B	A	B	A	B
	2	B	A	B	A	B	A
Lower	3	A	B	A	B	A	B
	4	B	A	B	A	B	A

The Meadow Creek study has several subobjectives:

1. Quantitatively describe the post-release behavior, dispersal patterns, migration rates (distance traveled per unit of time) and timing, and feeding success of hatchery chinook fry,
2. Estimate the numerical and behavioral responses of other species of fish, and

3 Quantify the availability and relative use of different habitat types by chinook fry and resident salmonids in different stream reaches

The Meadow Creek experimental design, sampling protocols, and results from the first year of study are described in Steward and Johnson (in preparation)

3.4 Small-Scale Experiments

Although efforts will focus primarily on the large-scale experimental and monitoring and evaluation needs, additional small-scale and/or short-term studies will be conducted to address specific issues. Many of these studies relate to release methods and impacts; some are already underway on Meadow Creek. Other experiments will be possible only after hatchery facilities are in place. For example, construction of acclimation ponds will enable comparisons of survival of acclimated, volitionally released pre-smolts with fish released directly into streams.

Small scale studies may include investigations of possible cause and effect relationships which characterize observed biological responses, especially at the individual or sub-individual (e.g., physiological, anatomical) level. Small-scale manipulation experiments provide a way of isolating the effects of a few important ecological processes and components from more complex ecological interactions (Peterman 1990). Examples include recent studies of courtship behaviors and comparative reproductive success of hatchery and wild coho salmon (Fleming and Gross 1992 1993). The selection of specific hypotheses to be examined through small-scale, short-term studies and the implementation of requisite research will be an ongoing process that will begin during the pre-operational period.

3.5 Observational/Correlational Studies

Some critical uncertainties, particularly those dealing with ecological interactions and environmental quality, do not lend themselves to statistical testing since a classical experimental design cannot be used or the processes contributing to observed patterns are not easily discerned. In these instances, it may be better to examine causal relationships and the interaction of variables, rather than attempt to state the process in the form of mutually exclusive, alternative hypotheses.

In the present context, we desire to know what characteristics of the stream, population, and resident biota have changed concomitant with supplementation. Monitoring data will be used to examine the statistical association between fish performance and the environmental variables thought responsible for that performance This information will be gained from observational data collected under a sample suney design The data will be examined using correlational and trend analyses Patterns will be examined and assumptions appraised using methods that are less rigorous than those associated with inferential statistics. While these types of analyses cannot prove causality, they allow one to focus on associations between variables and plausible causes for observed patterns Where causal relationships are suggested, more exacting research will be conducted.

Another reason for environmental monitoring is to measure natural variability due to sources other than supplementation, such as habitat quality, climatic fluctuations, and other resource management actions. These data will be analyzed by regression techniques to determine whether some aspect of the ecosystem changes importantly over time. Regression analysis can be used to identify causal influences of various factors on the observed variable Project feasibility will be reassessed if the observed change is inimical to project goals If the change does not pose an unacceptable threat, and if it coincides with or is correlated with supplementation patterns, then the data will be analyzed to see if their inclusion in the experimental design (described earlier) helps reduce experimental error. Through analysis of covariance, it may be possible to adjust estimates of statistical means and increase power if monitoring data allow corrections for non-supplementation effects. It is likely, for example, that adult escapement will vary with changes in changes in passage conditions and ocean survival. Statistical control over the effects of these variables will enable a more powerful test of supplementation hypotheses.

Habitat variables form an important category of observational data. They will be measured to refine carrying capacity estimates, to identify potential limiting factors, and to determine whether differences among streams are partly responsible for differences in their response to supplementation. We expect streams to respond similarly to supplementation, but not necessarily at the same rate or magnitude.

4. STRATEGIES

This section discusses monitoring and evaluation strategies with reference to pre-operational (baseline) and post-operational periods, recommendations of the Regional Assessment of Supplementation Project (RASP), and various monitoring objectives (e.g , risk containment monitoring and event-triggered sampling and monitoring)

4.1 Pre- and Post-operational Monitoring

NPTH monitoring and evaluation activities will take place in either pre-operational or post-operational periods. The primary goals of pre-operational monitoring and evaluation are to develop a retrospective or historical context for evaluating project goals and objectives, and to perform a quantitative assessment of the current status and future potential of spring and fall chinook salmon production in streams selected for long-term monitoring. Specific objectives are to:

1 Collate existing data (aerial photographs, maps, habitat, hydrologic, water quality), assemble source and reference documents, consult with other entities, and satisfy regulatory requirements;

2. Characterize the historical, current, and probable future status of chinook salmon populations and their associated ecosystems using Patient Template Analysis (see below), historical, current, and future status will be compared to "optimal" conditions. such as smolt production at stream carrying capacity

3 Describe the primary climatological, hydrological, physical habitat. and other abiotic properties of the streams and the watersheds in which they reside,

4 Characterize the biological condition of the ecosystems occupied by chinook salmon by measuring indicators of species composition, structure. and function;

5 Identify and assess the effectiveness of various performance variables and methods for measuring project impacts in terms of chinook population status, ecological interactions, and environmental health;

6 Perform simulations using expected values for performance variables and proposed data analysis and interpretation techniques

7 Locate suitable acclimation, recovery, release, and monitoring sites,

8 Conduct pilot studies to test relevant hypotheses. develop sampling techniques, and estimate sampling sizes and variances. and

9. Provide a detailed evaluation and refinement of project goals and objectives prior to full implementation

In the post-operational context, ***monitoring*** refers to measurements that enable accurate assessment of the effects of supplementation on chinook status and, more generally, on ecosystem structure and function, using baseline or control data for comparison. This information can be used to refine production targets. evaluate impacts, and identify plausible causes for project success or failure. Monitoring also encompasses observations of effects on the project that arise from external sources, such as management decisions relating to endangered species.

Evaluation is the process of analyzing data, comparing results, and assessing risk It entails hypothesis testing, trend analysis, deductive reasoning, risk evaluation, and other scientific approaches to understanding causes and relationships. Evaluation will benefit from *a priori* knowledge gained through baseline studies and the compilation and analysis of existing data.

The specific objectives of post-operational monitoring and evaluation are as follows:

1 Quantify trends in the status of hatchery and natural stocks of chinook salmon within supplemented and control streams in terms of genetic characteristics. life history types, and population viability;

2. Quantify the impacts of supplementation in terms of intra- and interspecific interactions;

3. Identify and, if possible, characterize associations between supplemented stocks and limiting environmental factors;

4. Assess the effects of other management policies and large-scale environmental disturbances on the effectiveness of supplementation; and

5 Provide regular statistical and interpretive (e.g., risk) assessments of project impacts that are suitable for diagnostic analyses and adaptive decision-making.

In situations where monitoring represents a continuation of baseline sampling activities over time, the same sampling methods and performance variables should be employed.

4.2 The RASP Paradigm

In setting project goals, NPTH planners made a variety of assumptions about chinook salmon populations - their rates (birth, growth, and mortality), migratory processes, and structure (density, age and size classes, genetic characteristics) Assumptions were also made about the carrying capacity of freshwater and marine ecosystems. the spatial units which comprise them, and factors limiting production Biological and physical assumptions were incorporated into simple models that served as useful starting points for project planning. The reliability of such constructs, however, depended upon the accuracy and availability of information and opinion used in their formulation. Because they lacked important information, planners were unable to specify with certainty the numbers of fish to be produced, how they were to be treated, and the probability that supplementation goals would be attained.

Obviously, uncertainty and imperfect knowledge are not limited to the NPTH but are common to most applied fisheries programs. Biologists working on the Regional Assessment of Supplementation Project (RASP 1993) recently devised a conceptual strategy called Patient-Template Analysis (PTA)" for acquiring and interpreting *a priori* data on population rates, structure, and patterns of resource use by anadromous salmonids with the goal of facilitating supplementation planning. The Patient is the existing ecosystem and its constituent biota, with emphasis on chinook salmon. The Template is the same ecosystem as it existed before being substantially altered by man PTA considers the biological and physical properties of the ecosystem from historical and contemporary perspectives in order to better define environmental carrying capacity and identify factors that limit production, along with the mode, magnitude, location, and timing of their effect.

4.2.1 *Patient- Template Analysis*

Patient-Template Analysis (PTA) has been defined in conceptual but not in operational terms, and thus there is uncertainty regarding the exact methods and level of effort required to complete the analysis (RASP 1993, Lichatowich and Watson 1993). The method is undergoing further refinement on a variety of fronts (L. Mobrand, personal communication). NPTH biologists are contributing to these efforts and will continue to apply promising PTA methods and concepts. We will rely as much as possible on proven technologies to sample and quantitatively describe historical and existing conditions, consistent with the RASP planning approach.

To achieve maximum effect, Patient-Template Analysis should be performed prior to project implementation; however, a final analysis is neither essential nor is it likely to be completed before supplementation begins. This is because uncertainties or gaps in empirical knowledge identified by the process may not be resolvable in the short-term, the characteristics of the Patient and Template often are not known or cannot be

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[11] RASP draws upon clinical medicine terminology in its use of terms such as "Patient." "Symptoms." and "Diagnosis" The implication is that supplementation can be used as part of the "cure" of a dysfunctional stream/stock system. For further discussion of the application of medical concepts and practices to the diagnosis and rehabilitation of natural systems, see Rapport et al (1981)

readily measured PTA is designed primarily to establish best estimates of historical and current conditions against which to evaluate project goals One of the primary values of PTA is the discussion it generates among project participants. From these discussions flow statements and, hopefully, testable hypotheses about the processes underlying observed patterns of abundance and habitat use. So that readers better understand its application in the NPTH context, we briefly describe the basic steps of a Patient-Template Analysis. Further detail may be found in RASP (1993) and (Lichatowich and Watson 1993).

4 2.1.1 Characterization of Patient and Template

A basic premise of PTA is that historical data offer opportunities for retrospective analysis that can be used to guide management actions in the future. One very practical application of PTA is to evaluate future threats to population persistence in relation to historical causes of decline. PTA attempts to reconstruct the history of antecedents to a project and to describe future probable population-ecosystem states. Such opportunities should be exploited whenever the data meet minimum scientific standards.

The freshwater and marine ecosystems in which chinook salmon evolved possessed a set of characteristics (e.g., physical structure, water chemistry, biological diversity, productivity, and resilience) that were the product of local geology, climate, and historical processes. These fundamental characteristics must be reconstructed and their significance understood if current ecosystem status and management prescriptions are to be described. Emphasis has been placed on freshwater habitats and associated life stages since they are more readily measured and appear to exert a greater influence on population rates than do marine systems (but see Lichatowich 1993).

Very little data exist in the files and reports of regional resource agencies and historical archives that would enable NPTH biologists to reliably reconstruct the historical distribution, abundance, and life history characteristics of chinook salmon that were indigenous to the Clearwater and lower Salmon River drainages. Even less is known of the populations and life history types of chinook that may have occurred in times past Recent efforts by Cramer et al (1993) to estimate historical chinook production within the Clearwater system were hampered by a lack of reliable information from periods prior to the construction of Lewiston Dam in 1927. Accounts by early settlers and by Indians provide strong anecdotal evidence for large runs of fish to the Clearwater River Basin prior to the dam's construction Chinook salmon runs to the Clearwater River were effectively eliminated by the lack of adequate provisions for adult fish passage at the dam

Further compilation and review of historical fisheries data will be conducted by NPTH biologists but is not expected to provide substantial amounts of new information. It may be more profitable to examine stream/stock records kept of other chinook stream systems with demonstrably similar environmental histories. Recent attempts to categorize populations of anadromous salmon in the Columbia River using life history characteristics (e.g., time of entry into freshwater and time of spawning) include works by Howell et al (1985) and Schreck et al. (1986). Additional information has come to light through status reviews, biological opinions, and recovery plans developed for threatened and endangered salmon in the Columbia River (Johnson et al. 1991, Matthews and Waples 1991, Waples et al. 1991).

Although fisheries data are scarce, it should be possible to add substantially to our knowledge of the biophysical characteristics of the Clear-water River ecosystem as it existed historically and today. Baseline data collection and preliminary analyses should attempt to describe the system in enough detail to be able to evaluate its future state. Information can be gleaned from several sources (Table 12).

A framework is needed for storing, organizing, analyzing, and reporting data collected through PTA and project monitoring activities. Geographic Information System (GIS) technology offers database management, analytical, and mapping capabilities that will adequately address project needs. The Nez Perce Tribe, USFS, the State of Idaho, and the Idaho Cooperative Fisheries Research Unit have developed GIS-based resource inventory systems. Existing GIS maps of the Clearwater subbasin should be used if they are available. NPTH monitoring data can be integrated into these databases and examined for past and present relationships between chinook distribution, abundance, movement, environmental variables, and human impacts.

Based on the compilation and interpretation of historical records and current information, biophysical processes that play important roles in shaping past, present, and future conditions can be identified This step will attempt to explain the natural and anthropogenic processes that directly or indirectly affect chinook and their associated habitat in the Clearwater River. Important phenomena include.

1. Fluvial processes and the mosaic of landforms, channels, and aquatic habitats they create within the valley floor;
2. The succession of terrestrial plant communities that establish themselves along the land-water interface;
3. The frequency and impacts of fire and geomorphic disturbances on riparian vegetation, streamflow, temperature, and sediment regimes; and

Table 12 Potential sources for useful information (Source Anonymous 1993)

Type of Information	Some Potential Sources
Climate	
Rainfall records	Agency records. RAWS stations. hydropower operators schools. private citizens. state climatologist. TV and radio stations
Rainfall depth/duration/freq.	NOAA records. state climatological data. flood control districts
Location of transitional snow zone	Anecdotal accounts. snow surveys
Topography	Digital Elevation Models. slope maps
Hydrology	
Stream gauging records	U.S. Geological Survey. reservoir operators. public water suppliers. irrigation authorities. flood control districts. hydropower operators. agency records
What streams dry up and when	Anecdotal accounts. stream surveys
What areas produce overland flow	Anecdotal accounts
Historic flood peak stages	Anecdotal accounts. old newspapers; USGS records
	diversion volumes and timing
	Reservoir operators. power authorities. irrigation authorities
	dam release protocols
Landslides	
Location, size and age	Aerial photos, Geological Materials Units (GMU)
	Surveys. Road maintenance personnel. old newspapers
Timing with respect to storms	Road maintenance personnel. residents
	NCASI (1985). company and agency records
	Historical photographs. historical societies. long-term residents. old newspapers
Channels	Old surveys. County archives
	Old maps. county archives. college libraries
	Historical cross sections. engineering reports. state and county transportation departments. bridge repair records
	engineering reports. state and county transportation departments
Logging history and methods	Old tax records. county archives. state forestry agency records. aerial photographs. historical societies. long-term residents. old newspapers
Sedimentation	Reservoir infill records. Reservoir operators. Dendy and Champion (1978). stock-pond infill. aerial photographs

(Table 12 continues on next page)

Table 12 (continued) Potential sources for useful information

Type of Information	Some Potential Sources
Erosion rates	Larson and Sidle (1980). soil surveys
Roads	Construction records. State and county transportation departments maintenance records
Water use	Location of domestic supplies utility districts. state and county agencies. location of power generation use. power authorities
Fisheries state and	Population surveys, spawning surveys. Tribal records, federal agencies. universities. catch records. oversight agencies. universities
Recreational use	Chambers of Commerce. residents. outdoor stores. outfitters, fishing stores. guides. police departments
Development history	Project records. construction logs, silvicultural records. NEPA documents. aerial photographs. county records
Species presence and distribution	Birding enthusiasts. Audubon chapters. Heritage data base. native plant societies. mushroom clubs. other special interest groups
Integrated Ecological Units	Ecological Unit Inventories
General and serendipitous	SCS River Basin Reports. retired forest officers long-time forest visitors. residents. recreational users. students
Water Quality	State Water Quality agencies. universities. STORET
Aquatic Life	State Environmental agencies. universities. environmental organizations

4 The formation of aquatic habitat from the interaction of valley landforms, channel morphology, riparian vegetation, and fluvial processes

The importance of performing a Patient Template Analysis is underscored in the following example The effect on salmon production of the construction of Dworshak Dam in 1972 on the North Fork Clear-water River was decisive: anadromous fish were immediately cut off from historical spawning and rearing areas upstream. But there were more subtle effects as well. hypolimnetic releases of water from Dworshak have altered water temperatures downstream of the dam so that are now cooler in the summer and warmer in the winter compared to historical levels (Pettit 1976, Conner 1989; Arnsberg et al. 1992). Before the dam began operation, water temperatures in the lower mainstem Clearwater River were probably too warm to support significant production of chinook juveniles during late summer periods. Ice buildup and scour during the winter months may have limited its value as overwinter habitat. The operation of Dworshak Dam may have ameliorated these effects, so that greater production is now possible in lower mainstem reaches.

4.2.1.2 Diagnosis. Prescription. and Prognosis

Even if it is possible to accurately specify both Template and Patient, there remains the problem of meaningful comparison of the two states. Diagnosis is the process of comparing Patient and Template data at as fine a scale as possible to identify factors which currently limit natural production or might conceivably do so at some future time. An appropriate management action - supplementation, habitat improvement, barrier removal, or some other form of human intervention - can then be prescribed to remove or circumvent the limitation.

RASP (1993) grouped diagnostic questions into three categories: those pertaining to the stream ecosystem and its capacity, those describing the performance (production) of the target population, and those describing environmental limiting factors. Since these questions are central to the RASP planning process, they are reproduced in Table 13. Note that the subjects of these questions are fully encompassed by the NPTH Stock Status, Ecological Interactions, and Natural Environment Categories.

Answers to the questions in Table 13 lead to one of four conclusions (RASP 1993)

1. A recognition that there is not enough life history-habitat information to adequately describe the Patient;
2. A recognition that the population is at its natural production capacity;
3 A recognition that production targets need to be revised; and
4. A recommendation to implement specific management activities to remove or circumvent the limitation in natural production

Table 13. Diagnostic questions used in the RASP planning process to facilitate Patient-Template Analysis (Source: RASP 1993).

CAPACITY/ECOSYSTEM DESCRIPTION

1 Can Ihc tcmplate/paticnt bc dcscribcd with sufficicnt dctail to idcntify thc factor(s) prcvcnting the paticnt from achieving thc objcctivc? If ycs, continuc. If no, scc Conclusion A.

2 Docs thc tcmplate/paticnt comparison suggcst that currcnt natural production is lcss than historic? If no, scc Conclusion B. If ycs, continuc.

3 a. Arc thc historic lifc history pattcrns prcscnt in Ihc paticnt population?

b. Has thc quality and quantity of abiotic and biotic habitat bccn altcrcd?

c. Is thc diffcrcncc bctwccn tcmplatc and paticnt duc to fishcry managcmcnt activitics?

d. Is thc diffcrcncc bctwccn tcmplatc and paticnt duc to factors outsidc thc basin such as passagc?

4. Dcscribc thc factors abovc (3a-3d) that contributc to thc diffcrcncc bctwccn tcmplatc and paticnt. Procccd lo thc ncxt sct of qucstions

PERFORMANCE OF THE TARGET POPULATION

5. a. Is thc habitat fully sccdcd al cach lifc history stagc?

b. Arc dcnsity, growth, survival, by lifc stage in thc paticnt comparablc lo othcr populations rcportcd in the litcraturc?

c. Has the distribution of thc targct population within thc subbasin bccn rcduccd?

d. Can thc adult stock production function bc dcscribcd?

c. Is the population controllcd by density indcpcndcnt or dcnsity dcpcndcnt factors at each life stagc?

6. Do thc answers to 5a-5c suggcst the potential lo increase natural production? If no, scc Conclusion B. If yes, continuc.

7. Do thc answcrs to 5a-5c gcncrally support the targct population size containcd in the objcctivc? If no, scc Conclusion C. If yes, conlinuc.

POPULATION LIMITING FACTORS

8. a. Has the timing of life history cvcnts changcd putting Ihcm out of synch with flow and tcmpcraturc pattcrns?

b Havc flow and Icmperature changed in a way that is dctrimcntal to the completion of tcmplatc lifc history pattcrns?

c Are there biotic intcractions limiting production of thc targct population?

d Arc Ihcrc full or partial migration blocks (juvcnile and adult) that wcrc not prcscnt in thc tcmplatc?

c. Can spccific mortality factors be idcntificd such as line sediment in spawning gravels or improperly scrccncd divcrsions?

f. Would the planting of hatchery fish crcatc a bottlcncck at a later life history stagc/habitat?

g Havc fccundity, scx ration, or rcproductivc success changcd?

h Arc there genetic changcs that might account for the diffcrcnces in tcmplate and patient.

9. Arc thc limiting factors corrcctablc? If ycs, see Conclusion D. If no, see Conclusion C.

CONCLUSIONS

A) Implcmcnt ficld survcys and/or litcraturc rcvicw to obtain thc information.
B) Thcrc appcars lo bc no problcm for which attcmpts lo incrcase nalural production arc a logical solution.
C) Rcvisc objcctivc and continuc diagnosis.
D) Implcmcnt appropriatc managcmcnt activities to achicvc objcctivc.

Table 13 Diagnostic questions used in the RASP planning process to facilitate Patient-Template Analysis (Source RASP 1993)

CAPACITY/ECOSYSTEM DESCRIPTION	PERFORMANCE OF THE TARGET POPULATION	POPULATION LIMITING FACTORS
Can the template/patient be described with sufficient detail to identify the factor(s) preventing the patient from achieving the objective? If yes, continue If no, see Conclusion A	5 a Is the habitat fully seeded at each life history stage?	8 a Has the timing of life history events changed putting them out of synch with flow and temperature patterns?
Does the template/patient comparison suggest that current natural production is less than historic? If no, see Conclusion B If yes, continue	b. Are density, growth, survival, by life stage in the patient comparable to other populations reported in the literature?	b Have flow and temperature changed in a way that is detrimental to the completion of template life history patterns?
a Are the historic life history patterns present in the patient population?	c. Has the distribution of the target population within the subbasin been reduced?	c Are there biotic interactions limiting production of the target population?
b Has the quality and quantity of abiotic and biotic habitat been altered?	d. Can the adult stock production function be described?	d Are there full or partial migration blocks (juvenile and adult) that were not present in the template?
c Is the difference between template and patient due to fishery management activities?	e. Is the population controlled by density independent or density dependent factors at each life stage?	e Can specific mortality factors be identified such as fine sediment in spawning gravels or improperly screened diversions?
d Is the difference between template and patient due to factors outside the basin such as passage?	6 Do the answers to 5a-5e suggest the potential to increase natural production? If no, see Conclusion B If yes, continue	f Would the planting of hatchery fish create a bottleneck at a later life history stage/habitat?
Describe the factors above (3a-3d) that contribute to the difference between template and patient Proceed to the next set of questions	7 Do the answers to 5a-5e generally support the target population size contained in the objective? If no, see Conclusion C If yes, continue	g Have fecundity, sex ration, or reproductive success changed?
		h Are there genetic changes that might account for the differences in template and patient
		9 Are the limiting factors correctable? If yes, see Conclusion D If no, see Conclusion C

CONCLUSIONS

A) Implement field surveys and/or literature review to obtain the information
B) There appears to be no problem for which attempts to increase natural production are a logical solution
C) Revise objective and continue diagnosis
D) Implement appropriate management activities to achieve objective

If the project remains a viable alternative. a prognosis should be made wherein the prospects for success or failure are defined with respect to the properties of the environment in which it will occur in the future. The prognosis should attempt to describe the future status of the ecosystem in the presence and absence of the specified management action. One or more of the following conditions may prevail.

1 The existing disturbance regime will continue;

2 The rate and/or magnitude of destructive disturbances will increase;

3 Protective measures and restrictions on development will be imposed, and

4. Additional enhancement or restorative measures will be implemented

The ecosystem and its biota will in all likelihood undergo further change as the human population grows and places increasing stress and demand on its resources. NPTH managers should endeavor to predict how existing and projected land use activities might affect chinook populations and their habitat in the future. An excellent discussion of the methods available to describe environmental impact trends is found in the report entitled *A Federal Agency Guide for Pilot Watershed Analysis. Draft: Version 1.2*. (Anonymous 1993).

To summarize, PTA can be conducted during the pre-operational period to describe historical, current, and probable future states of the ecosystem, focusing on chinook salmon life histories and habitats. This information can be compiled for each of the performance criteria identified under NPTH Stock Status, Ecological Interactions, and Natural Environment Categories. Primary and derivative data compiled under PTA and long-term monitoring activities should be organized in a computer-based GIS system.

4.2.2 RASP and CHASM Models

Much of the data gathered through Patient-Template Analysis can be used to parameterize a model developed specifically to analyze supplementation impacts (RASP 1993). The RASP supplementation model can be used during the pre-operational period to perform sensitivity analyses, identity critical uncertainties, and suggest ways of reducing levels of risk associated with incorrect assumptions. Five component life-stages - egg-to.-fry, fry-to-parr, parr-to-smolt, smolt-to-smolt and smolt-to-adult will be evaluated to determine their sensitivity to factors that regulate survival and production. We will also seek to identify factors and associated threshold values which act to limit production under a variety of project scenarios This information can be incorporated into the project prognosis.

A second model, CHASM, might be used to estimate existing and potential production of NPTH streams under baseline and future conditions Like the RASP model, CHASM uses a multistage life history analysis to evaluate habitat capacities and life stage-specific stock-recruitment relationships (Lestelle et al. 1993).

4.3 Risk Containment Monitoring

Risk containment monitoring is a form of environmental surveillance that attempts to gage the effects of supplementation (and other extrinsic factors) on the ecosystem and to interpret the significance of those effects in light of the critical uncertainties identified for the project. Risk containment monitoring differs from other monitoring and evaluation activities that comprise the formal risk assessment methodology used by NPTH managers in its emphasis on environmental variables and processes that do not lend themselves to simple definition or measurement of risk.

Two types of risk containment monitoring are distinguished: Trend Monitoring and Event-Triggered Monitoring

4.3.1 Trend Monitoring

In general, preferred risk containment monitoring variables are those that are likely to change significantly and rapidly if the impacts of concern are occurring. By routinely monitoring sensitive variables and processes, we increase our confidence, not necessarily in the appropriateness of our actions, but in knowing that they are not having unwanted effects. The more reliable and timely the information, the less risk involved.

Sampling activities that subtend risk containment monitoring will compete among themselves and with other project activities for finite resources. It is important, therefore, that risk containment monitoring provide high quality information on the current status and long-term trends in ecological condition. Status assessment favors taking many samples over the short term whereas trend detection requires fewer measurements over extended time periods. It may be possible to optimize sampling allocation by reducing the number of measured variables to an essential few, and by collecting data under an interpenetrating sampling design. This design requires sampling NPTH streams infrequently (the frequency depending on the variable or trend under observation), cycling among streams from year to year.

One objective of risk containment monitoring is to collect data that can be compared to *performance standards* (thresholds) to determine whether environmental quality is within acceptable limits in the short-term. Just what is "acceptable" is open to interpretation, but includes the normal ecological forms and processes of a healthy ecosystem. Karr et al. (1986) considered an aquatic ecosystem healthy "when its inherent potential is realized, its condition is stable, its capacity for self-repair is preserved, and minimal external support for management is needed." There are also questions of scale and limits. Should the same thresholds apply to all like-components (e.g., streams) within an ecosystem? Or is each component assigned its own threshold based on knowledge of its current or former condition?

In addition to monitoring current ecological conditions, we also want to know whether conditions have changed and, if possible, what environmental factors correlate with observed temporal patterns. Our intent is not to prove causality, but to look for symptoms of deteriorating ecosystem health so that steps can be taken to avert further degradation and to restore ecological integrity.

4.3.1.1 Variable Selection and Evaluation

We identify in a later section (Natural Environment, Section 5.3) several risk containment monitoring performance variables that have potential as short and long-term measures of ecosystem health. Final selection will depend on the condition or trend being evaluated - its magnitude, pattern, and mode of expression. Higher priority will be given to variables that give reliable indication of current ecosystem status and trends. It is more important to allocate resources to monitoring the effects of chronic, low-level environmental disturbances than to monitoring the effects of acute (and more readily observed) environmental stressors such as fire and flood. Many of the variables selected for risk containment monitoring will be monitored during both pre- and post-operational project phases. We recommend that the final selection of performance standards be deferred until baseline sampling results and a more thorough literature review has been completed. Performance variables should continue to be reviewed and updated periodically as new monitoring techniques become available or as new information on previously examined variables warrants.

Of the various performance variables available for risk containment monitoring, several are ratios or indices that integrate information from measurements of several primary variables. It is not necessary that the variables have a common unit of measurement. Indices have the advantage that they can combine variables measured at different hierarchical levels (e.g., genetic, population, species, and community). However, most indices were specifically devised for a particular level, such as fish health. It is important that associations or predictions based on these indices be limited to the level for which they were developed.

Another approach is to apply multivariate classification and analytical techniques to baseline data to describe present conditions. Cluster analysis can be used to identify streams, populations, etc. with similar characteristics and response patterns. Canonical correlation analysis can be used to identify multivariate factors that reflect common characteristics and that can be related to other multivariate factors informative and parsimonious set of performance variables. The degree and significance of change can be determined by reference to the earlier conditions.

Data collected in surveys conducted by other agencies may prove extremely valuable to NPTH risk containment monitoring goals. First and foremost are the data collected under the Idaho Supplementation Studies. Much of the information developed under Idaho Supplementation Studies can be used to assess present ecological conditions and to corroborate trends observed for NPTH streams. Other relevant data can be compiled from existing USFS datasets. These data should be reviewed during baseline sampling. NPTH managers should attempt to cooperate and coordinate future monitoring activities with appropriate state and federal agencies. Coordination and exchange of information is best accomplished through clear statements of purpose, and by providing opportunities for review, comment, and discussion of proposals and findings.

4.3.3 Event-Triggered Sampling and Monitoring

It is important to devise monitoring plans that will be triggered by unanticipated, widespread, and potentially catastrophic events. For example, forest fires within the Clearwater drainage are highly probable but the location and magnitude of their impact is largely unknown. It is only a matter of time before a major chemical spill on Highway 12 kills large numbers of fish within the adjacent Lochsa and Clearwater Rivers. The threat of catastrophic losses caused by fires and chemical spills looms large, but cannot be easily quantified. If a catastrophic event should occur, rapid monitoring and assessment will necessary to ameliorate environmental impacts (e.g., increase discharges from Dworshak Reservoir) and to provide NPTH managers with information that can be used to revise project operations.

5. PROTOCOLS

This section outlines critical uncertainties and performance variables for each performance criterion, organized by category and subcategory. For each performance variable, we describe why it was selected, how and when it is to be measured, the units (fish, sites, streams, etc.) to be sampled, and the analytical procedures to be applied to the data. The tasks and subtasks that comprise these activities are presented in flow charts. Information gained from monitoring and evaluation will provide meaningful and cost-effective assessment of environmental events and non-project management activities that might affect project status and impacts.

5.1 Stock Status

5.1.1 *Genetic Resources*

Implementation of the NPTH supplementation program should be guided by sound scientific principles, with emphasis on the conservation of species integrity and evolutionary potential. The purpose of monitoring and evaluating genetic resources will be to:

- Implement a systematic monitoring program using protein electrophoresis and other techniques to evaluate genetic relationships, variability, and adaptedness among NPTH hatchery and wild populations;
- Routinely collect and analyze allelic and polygenic data for evidence of genetic differences between and temporal changes within NPTH hatchery, treatment, and control populations;
- Determine the potential for adverse effects resulting from exposure to unnatural selection pressures, increased inbreeding, outbreeding depression, and homogenization of formerly distinct gene pools;
- From a comparison with out-of-basin chinook populations and NPTH baseline data, determine whether supplemented populations are adapted or have the potential to adapt to local environments; use this information to control gene flow among populations and to guide hatchery broodstock selection, mating, rearing, and release practices;
- Integrate genetic monitoring and evaluation conducted under the Stock Status Category with similar activities conducted under the Hatchery Environment Category; and

- Coordinate NPTH data collection and analyses with other genetic monitoring programs currently underway in the Snake River Basin.

5.1.1.1 Background

The general consensus is that chinook salmon indigenous to the Clearwater River subbasin were extirpated by Lewiston Dam, which was constructed in 1927 and remained in operation until its removal in 1972 (Cramer 1995). The dam was impassable to chinook until 1940, when adequate provision was made for late summer adult salmon passage. The naturally-spawning populations of chinook living found in the system today are the products of extensive reintroduction efforts made these past 50 years. In their status review of upriver stocks of Snake River chinook salmon, Matthews and Waples (1991) concluded that genomes of the original Clearwater chinook populations, even if the fish managed to avoid extirpation, were probably altered if not eliminated by hatchery outplants. Nonetheless, the fact that hatchery populations became established and persisted over several generations suggests that they were not unsuited to begin with or that they rapidly adapted to environments of the Clear-water system.

Waples et al. (1991, 1993) have for the past five years collected genetic data on spring chinook populations residing in several Snake River basins. Although Clearwater populations were not sampled, the results give some indication of the pattern of genetic relationships that may have existed at one time in the Clearwater. Electrophoretic analysis of protein variation at 35 gene loci revealed spatial and temporal variability among populations. Spring and summer chinook displayed little genetic differentiation. Genetic dissimilarities in hatchery and wild populations were influenced by the length of time that the hatchery has been in operation and broodstock collection practices.

None of the streams considered for supplementation under the NPTH currently support healthy populations of chinook salmon and are therefore incapable of serving as a source of broodstock. Cramer and Neeley (1992) and Cramer (1995) reviewed available information on the origins and ecological characteristics of naturalized populations within the Clearwater system and concluded that Red River, Sawtooth, and Dworshak hatchery populations (all are derivatives of Rapid River Hatchery stock) would suffice as spring chinook donor stock. Dworshak was least preferred due to past introgression with Kooskia Hatchery fish (a non-local strain of spring chinook started from Carson Hatchery stock).

Naturally spawning fall chinook are currently limited to the lower mainstem Clear-water River. This population was probably established by Snake River strays but is presently self-sustaining. Electrophoretic studies indicate that all fall chinook in the Snake River comprise a single population. This would include Lyons Ferry Hatchery fall chinook, which have been identified as the preferred brood source for the lower

Clearwater mainstem   From a consideration of ecological and life history information, Cramer (1995) concluded that fall chinook salmon are not suited to upper reaches of the Clearwater River. He recommended that Wenatchee River summer chinook be used as donor stock for lower Meadow Creek and Selway River supplementation. Wenatchee River origin summer chinook spawn earlier than do Lyons Ferry fall chinook (October versus November), yet exhibit the “ocean type” life history (i.e., subyearling outmigration) typical of falls.

Critical Uncertainties

We consulted the Master Plan (Larson and Mobrand 1992), the Genetic Risk Assessments (Cramer and Neeley 1992, Cramer 1995), and other documents to compile a list of critical uncertainties (Table 14). As stated, the uncertainties differ in scope and level of detail but this forced project biologists to evaluate attendant risks at several scales and therefore proved more help than hindrance. It is important to remember that the process of identifying, refining, and/or resolving critical uncertainties is an iterative one. The type and level of risk associated with each uncertainty was assessed prior to identifying key hypotheses and performance variables.

Cramer and Neeley (1992) reviewed genetic risks inherent to supplementation, identified sources of hatchery broodstock for the NPTH, and recommended several species-specific monitoring activities for detecting unwanted genetics effects. Four general categories of genetic risk were described (Busack 1990):

1. Risk of population extinction caused by demographic processes, environmental factors, or catastrophic events;
2. Loss of within-population genetic variability caused by inbreeding and genetic drift,
3. Loss of between-population genetic variability caused by introductions of non-native fish by intent or straying, and
4. Domestication selection and other selective effects resulting from management actions.

The level of risk involved is a function of (1) population sizes, (2) the hierarchical distribution of genetic diversity within individuals, populations, and the species, (3) geographic distribution and spatial patterns (i.e., discrete versus overlapping distributions, etc.), (4) rates of reproductive exchange among populations, (5) environmental variability, (6) selection differentials, and (7) the degree of control that can be exerted over the above-named factors.

Table 14. Genetics assumptions and associated levels of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Adaptedness	1	Existing populations are indigenous or, if introduced, have successfully adapted to local conditions	3
	2	Adaptation results from interactions between genes and the environment, and is reflected by changes in genotype, phenotype. and life history	1
	3	Past selective forces acting upon populations are still operative	1
	4	Broodstock can be located that are adapted to local conditions, or can produce offspring that adapt rapidly enough to perpetuate the populations	3
	5	Interbreeding between hatchery and natural fish does not reduce adaptedness	4
	6	Straying of fish between populations does not reduce adaptedness	3
	7	Hatchery practices do not alter heritable traits that are adapted to local natural conditions	4
	8	The time required for chinook to adapt to hatchery environments exceeds one generation	3
	9	Sources of mortality in the hatchery are insensitive to genotype	3
	10	Suitable measures of adaptedness can be found and applied via monitoring and evaluation	2
Variability	11	Genetic variation can be partitioned into intra- and inter-population components	1
	12	Maintenance of genetic diversity is a prerequisite for successful supplementation	1
	13	A minimum effective population size of 25 spawners per stream is adequate to avoid significant short-term loss of genetic diversity due to genetic drift	4
	14	Genetic diversity will not be reduced through decreases in population size. hybridization, or artificial selection	4
	15	Biochemical techniques can be used to quantify genetic variation and detect unwanted changes	1
	16	Current indices of genetic diversity are adequate as a basis for risk containment monitoring	1
	17	Genetic variability, if lost, can be regenerated through selective breeding	3
Relatedness	18	Chinook populations in separate tributaries are genetically distinct	2
	19	Genetic uniqueness is conferred by presence of rare alleles or genetic combinations	1
	20	Hatchery and natural stocks are genetically compatible	4
	21	Spring and summer chinook comprise the same gene pool	3
	22	The potential for gene flow from hatchery to non-target wild populations is low, and in any case will not harm them	3
	23	The potential for genetic divergence or homogenization is low	3
	24	Electrophoretic differences reflect genetic differences and can be used to discriminate among different populations	2

5.1.1.3 Performance Variables

If successful, the NPTH will establish a mosaic of locally adapted chinook populations which serve as "centers of propagation" for the species within the Clear-water subbasin. Natural selection is expected to result in differential reproductive success among individual chinook, thereby favoring locally adapted genotypes. However, these populations will be continually infused with new genetic material via reproductive exchange with each other and through further introductions of hatchery fish.

Genetic monitoring will be the primary means of determining whether

1. Genetic similitude exists between hatchery and wild populations,
2. Genetic variability is sufficient to maintain adaptability and population fitness,
3 Genetic change has occurred over time, and
4. Observed genetic patterns correlate with measured differences in ecological and life history characteristics.

Although genetic monitoring has been assigned high priority due to its role in delineating population structure and the potential risks associated with hatchery production, its utility should not be overemphasized within the overall NPTH monitoring and evaluation program. This is because current methods used to monitor and evaluate salmonid genetic resources are relatively imprecise, expensive, and yield somewhat ambiguous information. We strongly recommend that NPT managers solicit further expert opinion as to the relative importance of genetic monitoring, and to consider seeking outside assistance in the collection and interpretation of genetic information.

5.1.1.3.1 *Genetic Adaptedness*

Recommended performance variables:

1. Non-random mortality across genotypes and phenotypes
2. Changes in the expression of adaptive traits having an apparent genetic basis
3. Shift in allelic frequencies

Application

The key questions addressed by this performance criteria are:

1. Do hatchery and wild chinook possess similar adaptive traits?

2. Do hatchery fish undergo selective mortality at time of release?
3. Do directional changes in genetic and phenotypic characteristics occur that can be detected and interpreted as evidence for increased or decreased adaptedness?

The potential for adaptation to the hatchery environment will be addressed through the Hatchery Environment Category. It is important to monitor and adjust hatchery breeding and rearing techniques to ensure that unwanted genetic changes do not occur. The possibility that excessive gene flow from hatchery and unrelated populations might impede local adaptation is discussed in Section 5.1.1.3.3 (Genetic Relatedness).

The variables and monitoring activities associated with this performance criteria are designed to detect changes in genetic and phenotypic traits which presumably have adaptive significance and therefore warrant special attention. Of the genetic performance criteria considered, adaptedness is unquestionably the most difficult to measure at the gene level since proof of adaptation requires evidence for selection and identification of underlying genetic causes. Electrophoretic data are of little use in defining adaptation to local environments. As Utter et al. (1993) noted, "The apparent selective neutrality of most biochemical genetic variants gives a different time scale to relationships indicated by these characters contrasted with those that have strong adaptive implications such as timings of spawning and migration, and temperature sensitivities. If the latter characters are strongly influenced by differential selection, the time scale for genetic change is much shorter."

Most claims of adaptation by salmonids to hatchery or fisheries selection pressures, with corresponding genetic changes, have not been proven. Salmonids exhibit remarkable phenotypic plasticity. It is very difficult, in most cases, to distinguish genetic change from a non-genetic compensatory response to environmental conditions. In this project, a directional change of gene frequency within hatchery or wild chinook populations will be taken as evidence for a potential change in adaptedness.

We propose to monitor differential mortalities, ecological/life history traits, and protein variations to qualitatively estimate the effects of natural selection on chinook populations. The extent to which shifts in phenotypes and allele frequencies reflect short-term adaptation within populations is unknown. However, using baseline measurements as a point of reference, evolutionarily significant changes that occur through adaption, introgression, founder effects, and genetic drift will be detected.

Three types of data will be collected and examined for evidence for directional and presumably adaptive selection. Firstly, observations of mortalities that appear to be non-randomly distributed among phenotypes (and possibly genotypes) within broodyears will be taken as partial evidence for selection. Secondly, significant shifts over longer time periods (generations) in phenotypic traits having apparent fitness value (but undefined genetic basis) may signify adaptive genetic change (Figure 7). And thirdly, differences in allelic frequencies that are correlated with phenotypic changes will be considered presumptive evidence for adaptation.

It should be emphasized that observations of non-random mortality, phenotypic changes in characteristics such as growth rate, age at maturity, etc., and rapid changes in allelic frequency will not provide conclusive evidence for adaptation. Apparently non-random mortality can arise from stochastic processes, phenotypic expression is often highly variable depending on the infuence of environmental factors, and changes in allelic frequencies may reflect the effects of genetic drift, inbreeding, fluctuations in effective population size, and other processes. None of the performance variables by themselves should be viewed as a reliable measure of adaptation. However, taken together these data will constitute a body of information which may be useful in identifying long-term adaptive changes and potential causal mechanisms.

Measurements

Genetic conservation practices and careful environmental controls are expected to result in high survivorship across genotypes within NPTH hatchery facilities. A primary goal will be to eliminate selective sources of mortality so that genetic stability is maintained during the period of hatchery residency. At the time of release, however, juvenile hatchery chinook will be subjected to intense selection pressures. We would like to know whether natural selection causes rapid shifts in genetic or phenotypic traits by causing differential mortality among hatchery fish after they are

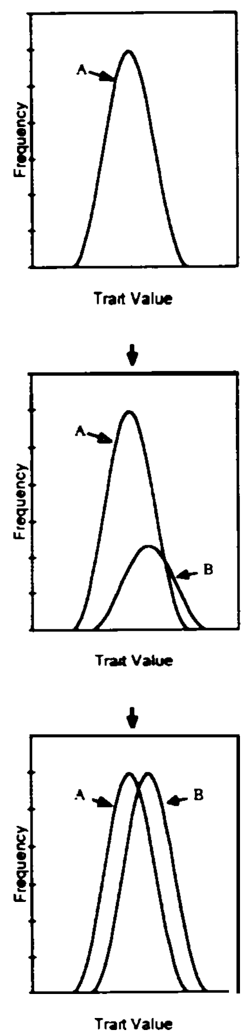

Figure 7. Example of a shift in the frequency distribution of a heritable trait due to non-random mortality. Fish in upper tail of the initial distribution (A) are favored, resulting in a rightward shift in the second generation (B).

released. Genotypic and allelic frequencies will be measured at spawning times, at the time of release, and at the time of outmigration from NPTH streams (either fall or spring). Frequencies measured from the same population on two or more occasions will be compared using a contingency chi-square test to determine whether significant shifts have occurred across life stages and generations.

We propose to individually PIT-tag a fraction of the fry, presmolts, and smolts released from NPTH facilities to determine whether post-release survival is correlated with phenotypic and genotypic characteristics. Individual genotypes will be determined either from known hatchery pedigrees or by electrophoretic analysis of non-lethal samples of muscle tissue and mucus obtained at time of PIT-tagging. If individual genotypes cannot practically be measured, representative samples will be collected from the associated population. Measurements of fish size, condition, pigmentation, and body morphology will be taken concurrently. survival probabilities, migration timing, and travel rates will be determined for individual fish released into different NPTH streams based on PIT-tag detections at downstream smolt traps and mainstem dams.

A review of the literature revealed several fitness-related phenotypic traits thought to be under some level of genetic control. However, these same traits are strongly influenced by environmental factors, and because salmonids live in very diverse and dynamic environments, it is usually impossible to interpret observed phenotypic variation strictly in terms of its genetically-based adaptive significance. We suggest that the following ecological and life history traits be monitored to establish a baseline for comparing future changes in the population, and to evaluate possible relationships with genetic and environmental factors:

Adult age at return	Life stage-specific survival rates
Adult size at return	Meristic characters
Adult travel rate	Body size
Timing of upstream migration	Condition factor
Timing of spawning	Smolt size
Location of spawning	Pigmentation
Sex ratios	Migration timing
Number of eggs per female	Smolt travel rate
Mate selection	
Percentage of jacks/precocious males	

Additional parameters such as incubation rate, average egg size, hatching success, etc. will be monitored only in hatchery populations.

Contingency table chi-square analysis will be used to test for variations in allelic frequencies among life history stages and populations over time. Correlation analysis will be used to test for associations between allele frequencies and phenotypic traits.

Sampling Units and Schedule

Data collection and analysis will be coordinated with other genetic and stock status monitoring activities. Many of the adaptive traits identified above will be monitored under Stock Status and Hatchery Categories. Initial work should concentrate on identifying appropriate phenotypic traits, developing practical techniques for their measurement, and establishing a baseline. The Tribe should seek outside expert assistance in collecting and interpreting electrophoretic and phenotypic data, as discussed below.

5.1.1.3.2 Genetic Variability

Recommended performance variables:

1. Heterozygosity, allelic diversity, polymorphism
2. Effective population size and rate of inbreeding
3. Higher order genetic diversity
4. Fluctuating asymmetry (phenotypic variability)

Application

Effective NPTH management requires information about the organization, temporal stability, and adaptive significance of genetic variation within hatchery and naturalized populations. It is well known that genetic variability is necessary for natural selection to occur, and that cumulative losses of genetic variability are associated with inbreeding depression and an overall reduction in population fitness. The rate at which genetic variability is lost depends on the number, relative reproductive contribution, and genetic similarity of individuals in the breeding population. The greatest genetic risk, by far, of the NPTH supplementation program is the potential for reduced genetic variability in hatchery and naturalized populations as a consequence of small breeding population sizes. For this reason, several performance variables are recommended as a means of monitoring changes in genetic variability.

Indices of genetic variability that will be used to monitor patterns of genetic variability among NPTH subpopulations over time fall into two categories - those that can be estimated from allele frequency data and those obtained from meristic measurements.

The null hypotheses are that levels of genetic variability do not vary among hatchery and wild fish, nor do they change within either subpopulation across years. Initial tests of these hypotheses will be made using chi-square statistics. However, an attempt should be made to analyze data under the Before-After Control-Treatment design. Waples et al. (1993) describe a method for determining whether observed genetic changes can be attributed to genetic drift.

Within-stock genetic variability will be indexed by three metrics, all derived from electrophoretic data:

1. Heterozygosity - the average frequency of heterozygotes per locus per individual;
2. Allelic diversity - the mean number of alleles per locus, expressed as a percentage of the alleles originally present; and
3. Polymorphism - the percentage of loci that are polymorphic (i.e., Having two or more alleles).

Several population parameters related to genetic variability, including effective population size and rate of inbreeding, will also be estimated using techniques described in Freden (1986) and Waples et al. (1993).

Because the probability of adverse genetic effects caused by genetic drift and inbreeding increases as populations decrease in size, Cramer and Neeley (1992) recommended that the number of chinook spawning in NPTH streams be allowed to drop no lower than twelve pairs (25 fish). This number was derived as a short-term performance standard based on theoretical and practical considerations; it is probably inadequate to maintain long-term population viability.[13] The 25 fish threshold was justified by the expected rate of loss of genetic heterozygosity (i.e., the rate of inbreeding, ΔF) per generation as a function of effective population size (N_e):

$$\Delta F = \frac{1}{2N_e}$$

where

$$N_e = \frac{4N_f N_m}{N_f + N_m}$$

[13] The minimum effective population size recommended by most population geneticists is closer to 50 individuals (Soule 1980; Ryman et al. 1993).

The effective size of a population is usually different from, and frequently smaller than, the absolute population size due to unequal reproductive contributions among spawners, skewed sex ratios, and fluctuations among year classes. Furthermore, whereas N_e refers to the effective size per generation, the actual spawning population consists of multiple brood years. These considerations led Waples (1990) to recommend use of the effective number of breeders per year, $N_b = N_e / g$, where g is the average age at spawning.

Alternatively, effective population size can be estimated from observed allele frequency changes. For example, a 2% rate of loss of heterozygosity indicates an effective size of 25 individuals. Waples (1990) describes indirect methods of estimating N_b from measurements of allele frequencies at multiple loci.

Fluctuating asymmetry

Bilateral or fluctuating asymmetry is the morphological variability demonstrated by individual fish. If enough individuals are randomly sampled, fluctuating asymmetry provides a sensitive, inexpensive diagnostic tool for detecting losses of genetic variation within salmonid populations (Leary et al. 1985; Palmer and Strobeck 1986). If this performance variable proves itself as a monitoring tool in ongoing studies by the National Marine Fisheries Service, it should be used as a risk containment monitoring variable, but only in hatchery populations.

Gene diversity analysis

Genetic relationships among NPTH chinook populations will be explored further by partitioning total genetic variation (Ht) into its additive within-population [H_S = individual heterozygosity]) and between-population population (D_{ST}) components, H-r = $H_S + D_{ST}$ (Chakraborty and Leimar 1987). The proportion of genetic diversity due to variation within populations is H_S / H-r is a the proportion of genetic diversity due to variation between populations is D_{ST} / Hr. The relative contribution of hatchery and wild populations to D_{ST} can be estimated. The analysis should be extended to include Snake River chinook populations sampled under Idaho Supplementation Studies (Bowles and Leitzinger 1991) and the NMFS Genetic Monitoring Program (Waples et al. 1993).

Measurements

The NPTH Monitoring and Evaluation subproject will capitalize on genetic monitoring programs already underway in the Snake River Basin. The genetic composition and variability of NPTH chinook populations will be determined from a comparison of frequency differences of alleles at multiple loci, as determined by electrophoretic analysis. NPTH personnel will be responsible for collecting samples following methods and schedules prescribed by NMFS (Waples). If it can be arranged, the NMFS genetics laboratory should be contracted to undertake the electrophoretic analysis. Approximately 63 loci (of which 35 are polymorphic) will be electrophoretically screened from muscle, eye, heart, and liver tissues of juvenile and adult fish. The data will be analyzed using the BIOSYS-1 program (Swoford and Selander 1981) to test for Hardy-Weinberg proportions, and to estimate allelic frequencies, genetic variability, and genetic distances for each sample. The type and frequency of rare alleles (i.e., those occurring in fewer than 0.5% of the sample) will be identified. Estimates of gene flow, rate of inbreeding, effective population size, and hierarchical genetic diversity should be made by a knowledgeable fisheries geneticist.

Initially, only hatchery fish will be sampled and compared to existing baseline data for other chinook populations (Waples et al. 1993). As natural populations begin to rebuild, samples will be collected from both hatchery and target populations.

A minimum of 50 fish will be collected from each sampling population on each sampling date. A sampling population is any group of fish known or suspected to be progeny of interbreeding adults, or a group of fish of the same age that are coincident in time and space. Sample size requirements should be refined using preliminary estimates of inter-population genetic diversity (D_{ST} / H_T) applied to NMFS and NPTH genetic monitoring data. If substantial interpopulation heterogeneity is not observed, sampling efforts can be scaled back in the future. It may be possible, for instance, to select a subset of treatment and control streams for long-term monitoring or to sample populations less frequently. It is also likely that fewer loci will need to be monitored over the long-term to assess the genetic health of Idaho stocks, thereby reducing sampling costs. The proposed research will help identify appropriate long-term genetic sampling strategies.

For each year class and sampling population, we recommend genetic sampling on three occasions:

1. As juveniles, as soon as the fish are large enough to obtain the requisite tissue samples,
2. As smolts, from fish captured in smolt traps or collected in the hatchery just prior to release, and
3. As adults collected either (a) on spawning grounds after spawning is complete (samples may need to be pooled across streams) or (b) at the hatchery at the time that the fish are spawned.

Pre-smolt, smolt, and adult samples will be collected from hatcheries and as available from trapping and field sampling. Wild smolts and adults will be undersampled until weirs and traps have been built. Wild spring chinook parr will be collected from study streams in late summer by electrofishing or seining (see Abundance performance criteria, Section 5.1.3.3.1). Subsamples will be taken from several locations to ensure representative population samples. Juveniles will be frozen on dry ice and shipped to the genetics laboratory for storage and processing.

Adult samples will be obtained from fresh carcasses or spawned-out fish collected during spawner surveys. We are aware of the difficulty of sampling adults on spawning grounds but suggest that an effort be made to do so until a non-lethal sampling techniques can be developed that will permit samples to be collected at weirs. The number of adults sampled from each study population will depend on run sizes and our ability to locate and sample naturally spawning fish.

We propose to routinely measure several bilateral meristic characters (gill rakers on upper and lower first branchial arches, and number of rays in pelvic and pectoral fins) of chinook juveniles collected from hatchery and natural populations. Comparisons will be made of the number of characters for which individual fish are asymmetric, and the magnitude of asymmetry. The objective will be to determine whether differences occur over time within and between hatchery and natural populations. Leary et al. (1985) outlined the rationale and general procedures for using fluctuating asymmetry as a measure of the loss of genetic variability in fish populations.

Sampling Units and Schedule

Juveniles (par-r) will be sampled during late summer from each study population. Samples of adults (spawners), smolts and pre-smolts will be collected from each hatchery stock and on an opportunistic basis from natural stocks. Sample sizes will increase once adult and outmigrant traps are in operation. Samples of two or more life history stages from the same year class will be compared to detect temporal changes in allele frequency. Adults will be aged from scale or otolith samples to determine whether genetic differences occur among year classes. Between-year genetic variability will be more fully analyzed following a second year of juvenile sampling.

Meristic measurements of juveniles from hatchery and natural populations will be made once each year. If high levels of asymmetry are found, sampling frequency will be increased.

5.1.1.3.3 Gene tic Relatedness

Recommended performance variables:

1. Genetic distance
2. Gene flow

Application

This performance criteria seeks to describe genetic relationships and the pattern of gene flow among NPTH and *ex situ* chinook populations and among hatchery and wild components of NPTH populations. Evidence regarding the genetic structure of populations can be derived from a study of the overlap of genetic relationships among populations with their historical and present geographic distribution, taking into account past hatchery introductions, known founder and extinction events, and environmental limiting factors. Information on historical and contemporary relationships has been summarized by Cramer and Neeley (1992) and Cramer (1995). Future monitoring activities proposed under this performance criteria will considerably expand our understanding of genetic relationships and ecological requirements of spring, summer, and fall of chinook within the Clearwater system.

A key uncertainty is whether spring and summer chinook are genetically distinct populations, or whether they are evolving toward a greater degree of reproductive isolation and separate species status. The same question may be asked of Snake River populations of spring chinook in general. Waples et al. (1993) reported statistically significant differences in allelic frequencies in all pairwise comparisons of populations from the Snake River drainage that were sampled in 1989 and 1990. Cramer (1995) interpreted these differences as evidence for restricted gene flow among populations.

Without a better understanding of how much gene flow is “normal” and how much poses an unacceptable risk, it isn’t clear what level of genetic divergence or similarity should be permitted under NPTH. Excessive gene flow can cause the breakup of adaptive gene complexes (outbreeding depression) and inhibit the ability of a population to adapt to local environmental conditions. On the other hand, gene flow into smaller populations is a desirable counterbalance to the effects of inbreeding and genetic drift. Restrictions on gene flow must be sufficient to prevent outbreeding depression and allow for adaptation and genetic differentiation, but not so strict that adaptive genetic traits that evolve in one population are not transferred to other populations.

Given that we do not know what natural levels of gene flow should be, it is important that it be monitored so that risks may be controlled via rapid feedback. NPTH estimates of gene flow will be based on allele frequency data obtained through electrophoretic methods and observed straying rates.

Measurements

The pattern of geographic subdivision among NPTH and out-of-basin populations will be determined from the average “genetic distance” between them based on analysis of allelic frequency data from several (>30) loci. Electrophoretic techniques are described in Section 5.1.1.3.2 (Genetic Variability). Methods of calculating genetic distance are discussed by Nei (1987). Stock-structured genetic heterogeneity will be explored through the use of genetic distance matrices, with relationships analyzed by cluster analysis and summarized in the form of dendrograms. An example from Waples et al. (1993) is shown in Figure 8. This information will indicate whether genetically appropriate hatchery donor stocks are being used to supplement naturalized populations, and whether the differences among NPTH subpopulations are small relative to other populations.

Slatkin and Barton (1989) describe several ways of using allele frequencies in samples from different populations to estimate the amount of gene flow among those populations. Among these are the analysis of FST (Wright's [1943] measure of proportional inter-population genetic diversity), the analysis of the distribution of rare alleles, and maximum-likelihood methods. They recommend the method based on FST which, under the "island model" of migration, is a measure of divergence at individual loci among subpopulations:

$$FST = 1 / (4Nm + 1)$$

where N is the population size and m (the parameter of interest) is the probability of immigration or, alternative, the proportion of genetic exchange among subpopulations.

An average FST can be calculated as the ratio of between-population genetic variation (DST) to total genetic variance (HT, which includes within-population genetic variation [HS = individual heterozygosity]), as discussed under the Genetic Variability performance criteria. If either N or the number of strays *(Nm)* is known or can be estimated, then m can be estimated using the formula

$$m = \frac{1}{4N}\left(\frac{1}{F_{ST}} - 1\right)$$

Sampling Units and Schedule

Samples should be obtained from juvenile chinook salmon from hatchery and wild populations on a schedule that is compatible with other genetic monitoring programs currently underway in the Clearwater and Snake River Basins. Guidelines are presented in Section 5.1.1.3.2 (Genetic Variability).

5.1.1.4 Summary of M&E Activities

Those monitoring and evaluation tasks and activities considered most important to resolving Genetics critical uncertainties and minimizing risk are summarized in Figure 9. The order of their presentation does not indicate priority.

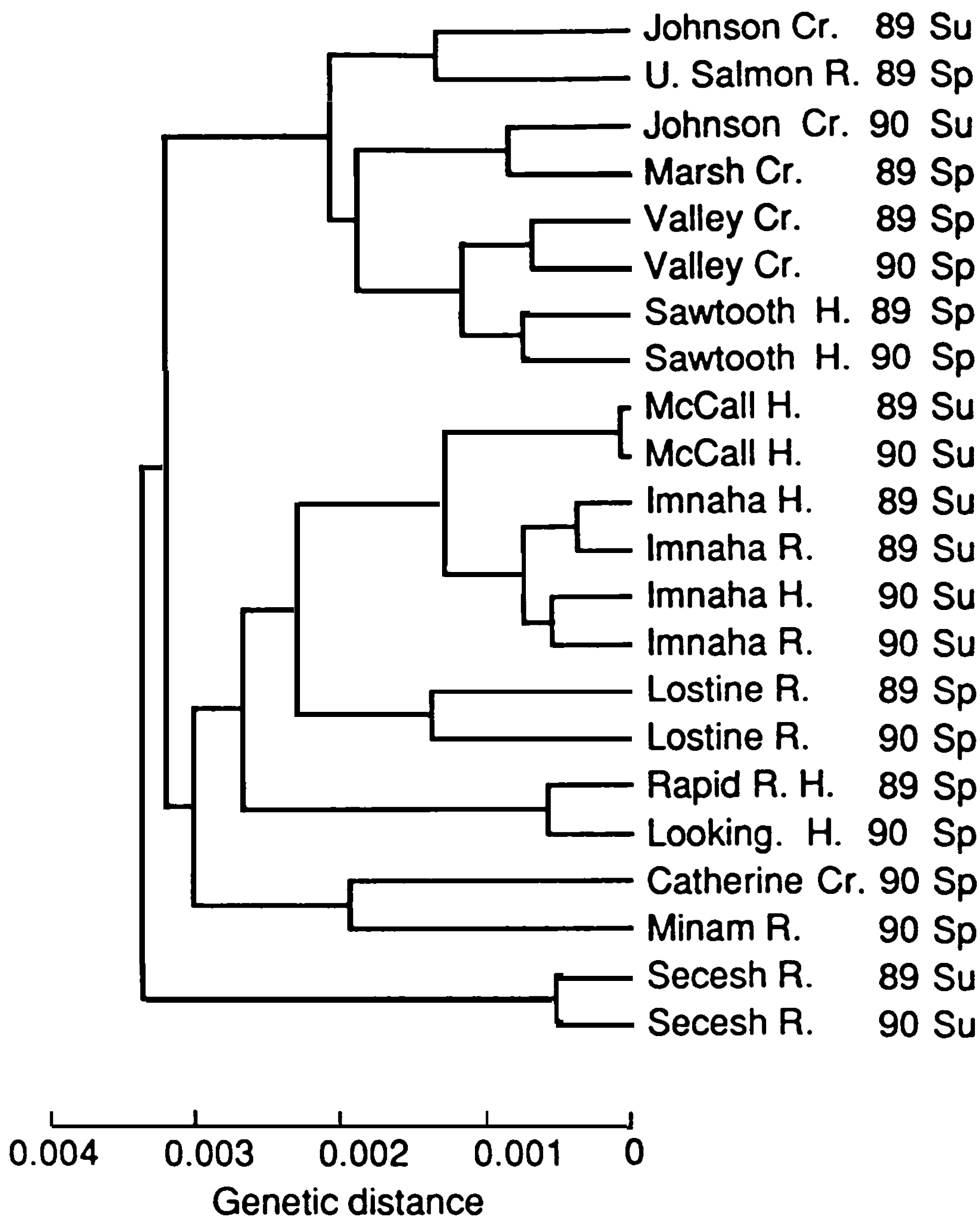

Figure 8. Genetic relationships of spring/summer chinook populations residing in the Salmon, Imnaha, and Grande Ronde subbasins based on electrophoretic data collected in 1989 and 1990 (from Waples et al. [1993]).

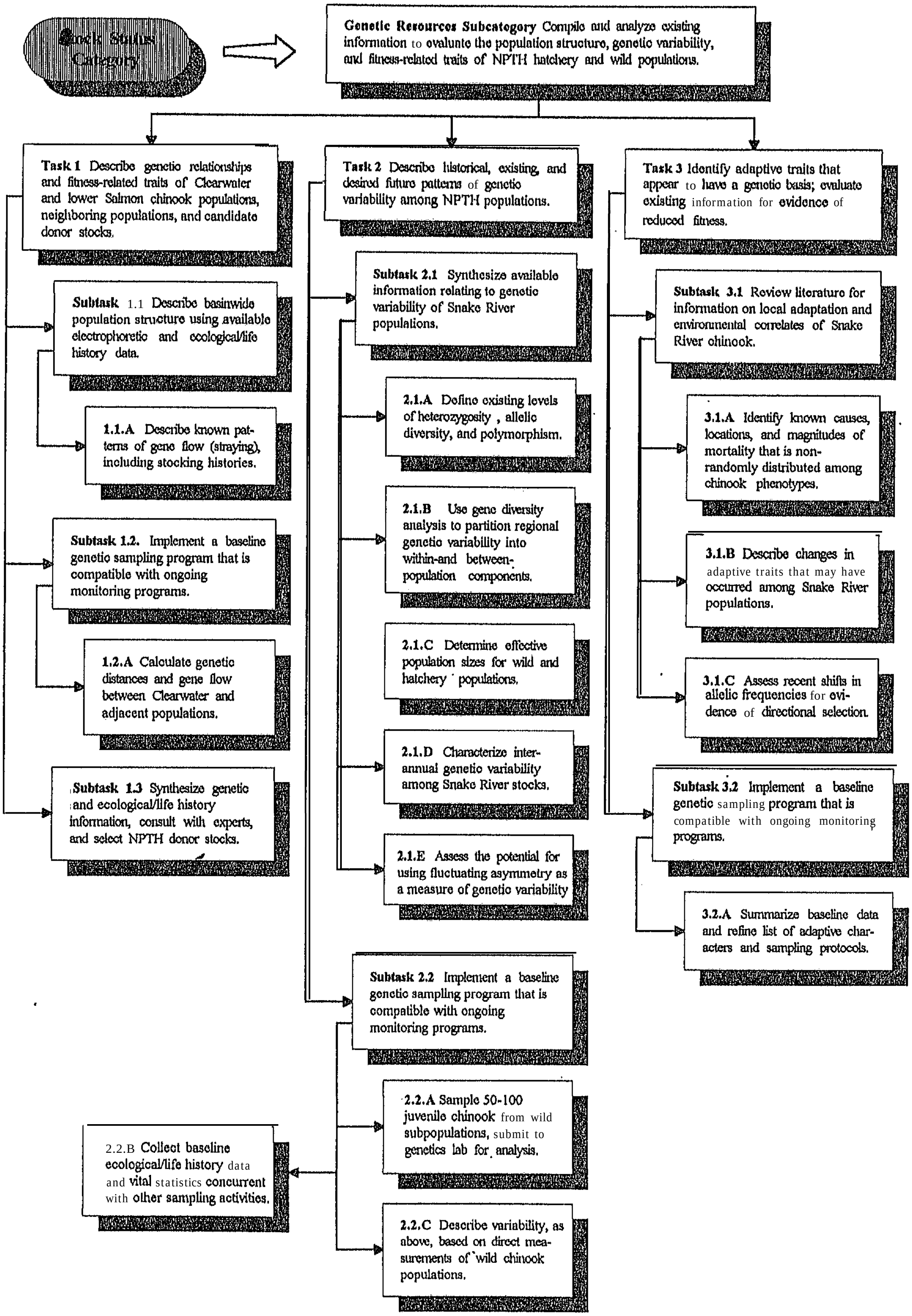

Figure 9. Monitoring and evaluation tasks and subtasks identified for the Genetic Resource Subcategory (Stock Status Category).

5.1.2 Life History

5.1.2.1 Background

Virtually all salmonid species exhibit a variety of life history types which serve to exploit more productive habitats and to maximize survival in environments that are subject to short-term yet potentially severe disturbances (Gross 1985, 1987). The diversity of life history types and associated adaptive traits within a population bespeaks an ability to colonize new areas and to cope with locally variable conditions. Under a supplementation program such as NPTH. it makes sense to identify and to replicate as much as possible the various life stage-environment combinations which comprise the fully integrated system. NPTH managers reconize the importance of multiple life history types and will work to create and maintain the conditions necessary for population stability and persistence. In order to prioritize sampling efforts and to determine whether this objective is being met, several critical uncertainties and performance variables have been identified for monitoring and evaluation purposes.

5.1.2.2 Critical Uncertainties

Life history critical uncertainties are presented in Table 15

5.1.2.3 Performance Variables

5.1.2.3.1 Life History Composition, Distribution, and Key Attributes

Recommended performance variables:

1. Life history diversity
2. Spatial and temporal distribution
3. Key life history attributes

Application

We have suggested in our discussion of Patient-Template Analysis in Section 4.2.1 that the most effective course of action towards rebuilding chinook salmon populations in the Cleat-water River subbasin entails a comparison of existing fish populations and available habitat with the historical population-environment matrix, identification of life history types that would contribute most to population productivity and fitness under anticipated future conditions. and implementation of effective supplementation strategies to create and sustain those life history types within the natural population In conjunction with Patient-Template Analysis, Life

Table 15 Life History assumptions and associated levels of risk

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Composition	1	Different life history types can be distinguished on the basis of differences in movement, distribution, and resource use patterns	3
	2	Life history characteristics are under genetic and environmental control	2
	3	Where they coexist, fish possessing different life history characteristics have different fitnesses	2
	4	A diversity of life history types ensures optimal resource use and buffers the population against environmental disturbances	2
	5	Historical life history types - their relative abundance and ecological importance - can be identified from existing data	2
	6	Individual life stages of different life history types can be identified and characterized	1
	7	Spring and summer chinook represent distinct life history types	2
	8	Life history diversity can be restored and a dynamic equilibrium maintained	4
	9	Techniques exist to differentiate among life history types	2
Distribution and Timing	10	Hatchery fish of differing life history types can be introduced into required habitats at appropriate times to take advantage of seasonal and spatial variations in resource availability	3
	11	Acclimation and volitional migration of hatchery chinook from NPTH satellite holding ponds will favor locally adapted life history types	3
	12	Fry outplanting will result in highly dispersed, locally adapted life history types	4
	13	Habitats required by different life stages are accessible and capable of supporting natural production	4
Key Attributes	14	Adaptive traits can be reliably identified and monitored	3
	15	Populations will remain adapted to local conditions	4
	16	Environmental factors affecting fitness can be identified, quantified, and related to observed changes in fitness	3
	17	Economically and culturally important characteristics of the chinook salmon will be preserved	4

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	6	Individual life stages of different life history types can be identified and characterized	1
	7	Spring and summer chinook represent distinct life history types	2
	8	Life history diversity can be restored and a dynamic equilibrium maintained	4
	9	Techniques exist to differentiate among life history types	2
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	15	Populations will remain adapted to local conditions	4
	16	Environmental factors affecting fitness can be identified, quantified, and related to observed changes in fitness	3
	17	Economically and culturally important characteristics of the chinook salmon will be preserved	4

Measurements

Pre-operational. Spatial and temporal distributions of spawning, rearing, and migratory life stages of indigenous chinook will be reconstructed from available data and comparisons with existing populations within the Clearwater and other Snake River subbasins. Existing data on relevant life history attributes will be compiled and analyzed. The geographic location and temporal distribution of different life history types will be denoted on maps and phenological (life cycle) charts. This information will be incorporated into a report along with a qualitative description of the Template, an updated critical uncertainties database, and recommended research and changes in supplementation strategies.

Post-operational. Once supplementation begins, life history data will be collected at locations and at times that coincide with other monitoring and evaluation activities. The general intent is to collect information on life history parameters useful in comparing different groups or subpopulations of chinook. Marking and sampling protocols will enable comparisons between hatchery and wild chinook, between groups of hatchery fish released at different life stages, and between spring, summer, and fall chinook. Several tagging and sampling techniques will be used to differentiate among groups of fish. Not all life history attributes will be measured for each group or at each sampling site or time.

The diversity, geographical distribution, and timing of life history types within NPTH streams and points downstream will be described from rearing and spawning survey data, trapping records, catch records, and from observations made outside of the Clearwater subbasin. Priority will be given to the measurement of smolt and spawner life stages on the assumption that their movements and survival are likely to account for a large amount of variances in abundance, distribution, and viability of different life history types and subpopulations.

Information on chinook egg and swimup fry life stages will be obtained at the Cherrylane and Sweetwater Springs hatchery facilities. Juvenile life stages will be sampled during population censuses, habitat surveys, and periods when emigrant traps are in operation. Additional information will be collected from fish during their hatchery residency. Data on smolt life history differences will be collected at smolt traps, at lower Snake River dams, and from scale measurements taken from returning adults. Adults will be sampled at adult collection facilities (mainstem dams, permanent weirs, portable traps, and hatcheries) and on spawning grounds.

Scales and tags collected from adult carcasses during spawner surveys will be analyzed to determine origin, age of spawners, time of ocean entry, etc. Composition data facilitates understanding of the environmental factors influencing year-class strength and population dynamics, including factors under the control of NPTH managers. Collectors should identify the location and date/time of recapture, the sex and length of the specimen, and the presence/absence of marks. Scales should be mounted as acetate impressions and examined using standardized scale reading methods, such as those described by Borgerson (1993). The NPT should consider contracting with a qualified research institution to read scales, at least until sampling and analytical protocols have stabilized and a Tribal biologist can be properly trained. Scale reading and measurement is difficult without the assistance of an experienced scale reader working with a digitizing board and computer-assisted data entry and analysis.

Key life history attributes that should be monitored under the NPTH are listed by life stage in Table 16. Those traits to be determined either partially or wholly from scale analysis are marked with an asterisk. Patterns of covariation will be sought among life history attributes such as age and size at smolting, survival, and time of adult return. Concomitant measurements of key environmental parameters (e.g., photoperiod, discharge, temperature, etc) will be analyzed for relationships with essential life history features. The redistribution of chinook into summer rearing, overwinter, mainstem migratory. adult holding, and spawning habitats and its timing relative to environmental conditions is critical to the survival of chinook.

Sampling Units and Schedule

Data on the diversity and distribution of life history types, and the variability of key life history attributes in NPTH populations will be collected at locations and during periods of observation that coincide with other monitoring and evaluation activities. Migration patterns will be determined from trap and survey data. The intensity of life history attribute sampling will vary among populations depending on population and stream sizes, the presence of traps and weirs, and the frequency of related sampling activities. It is anticipated that most life history data will be obtained from Lolo and Meadow Creek populations.

5.1.2.4 Summary of M&E Activities

The Life History subcategory tasks and activities discussed above are presented in condensed form in Figure 10.

Table 16. Key life history attributes of interest in NPTH studies.

Adults / Spawners	**Eggs**	**Smolts**
Origin*	Size	Age at ocean entry*
Age*	Developmental rate	Body size
Size at age and return*	Temperature unit requirements	Weight at length
Marine growth*		ATP-ase levels
Rate of migration	Survival	Body coloration
Timing of upstream migration		Time of passage
		Survival
Timing of spawning	**Juveniles**	Rate of migration
location of spawning		Routes traveled
Pre-spawning mortality	Growth	Ecological interactions
Habitat preferences	Body size	
Sex ratios	Weight at length	
Fecundity	Survival	
Egg size	Habitat preferences	
Mate preference	Behavior	
Incidence of strays	Meristic characters	
Incidence of precocious males	Condition factor	
	Disease/health status	

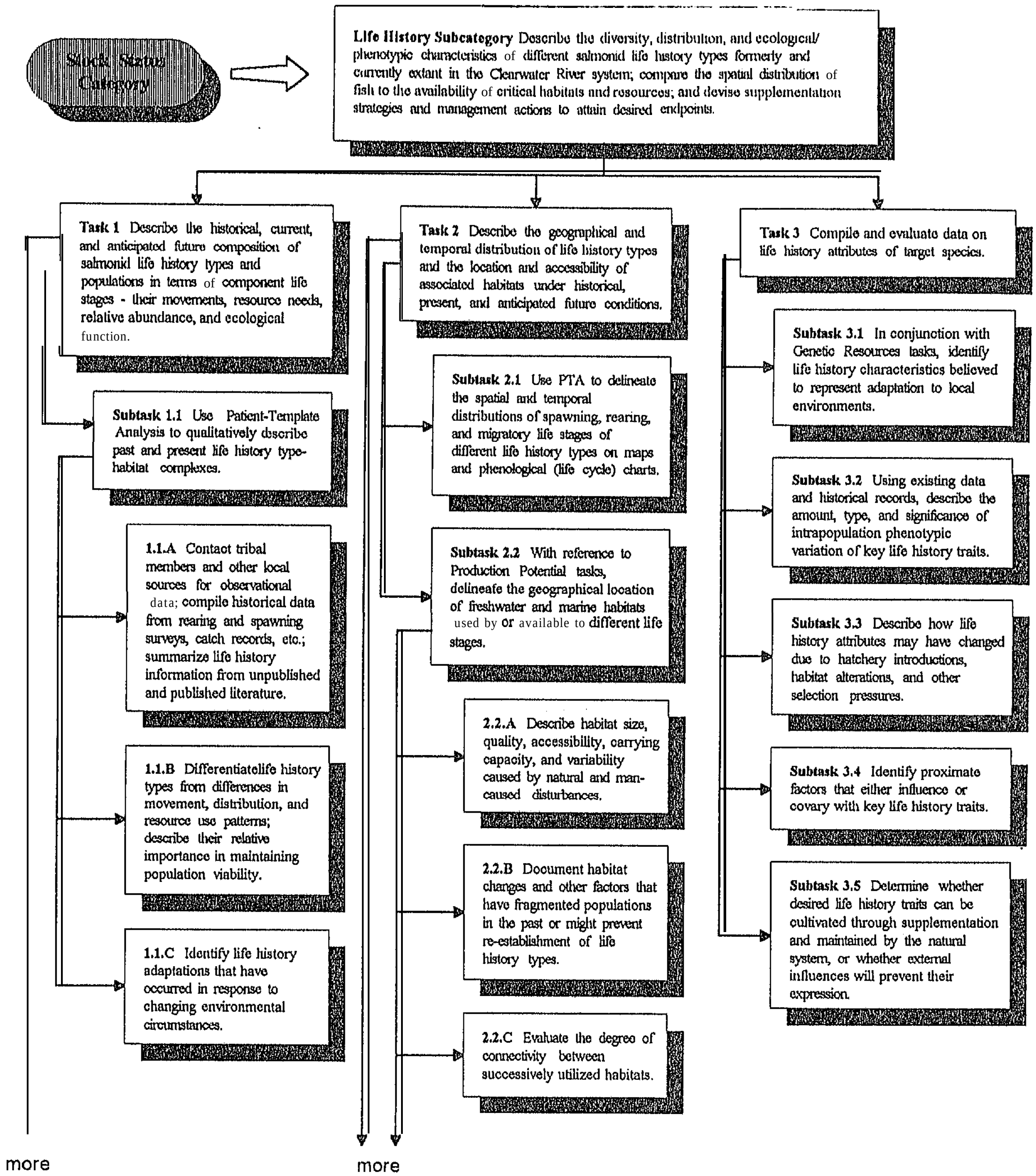

Figure 10. Monitoring and evaluation tasks and subtasks identified for the Life History Subcategory (Stock Status Category).

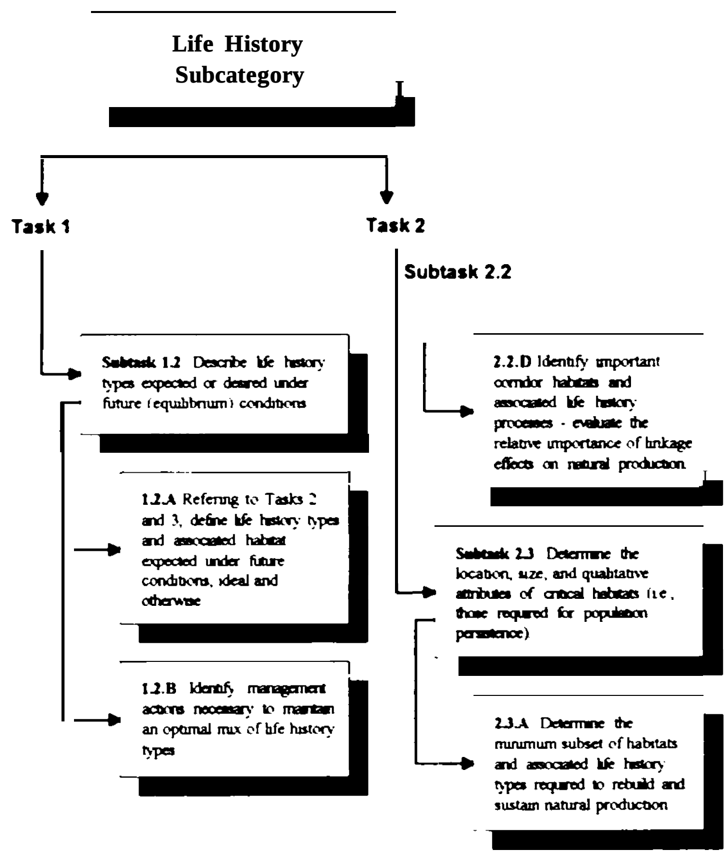

Figure 10 (continued). Life History tasks and subtasks

5.1.3 *Population Viability*

5.1.3.1 Background

Demographic performance variables, because they are less ambiguous and can be measured with relative ease and precision, are far better indicators of stock status than is information on the magnitude and distribution of genetic and phenotypic (life history) variability. Changes in abundance, survival, reproductive output, and long-term fitness reflect responses to supplementation at the population level, and for this reason the variables which permit such assessments have received special emphasis.

Any increase in the numbers of naturally spawning chinook that results from supplementation is desirable, provided that population fitness is not diminished and ecological impacts are within acceptable limits Estimates of the total number of chinook parr and adults in NPTH streams will be used as dependent variables under the NPTH Before-After, Treatment-Control experimental design Once stock abundance is ascertained, those life stages and processes that contribute most to variations in stock abundance should be determined. This will allow NPTH managers to focus on sources of mortality. to refine supplementation strategies. and to implement other forms of mitigation

Survival across life stages and an understanding of the underlying causes of spatial and temporai variation in its magnitude were identified as critical uncertainties. ones with potentially huge implications in terms of population viability and project success. Reproductive success was also considered an important criterion, because it is essential to population growth and persistence, and because differential success among spawning hatchery and wild salmon has been noted in other studies. Lastly. long-term fitness was judged a useful measure of performance since it integrates various genetic, life history, and demographic processes and states over multi-generational time periods. Long-term fitness attempts to answer the question. “Can natural populations sustain themselves in the absence of supplementation?” The long-term perspective enabled by this performance criterion provides contest to the “snapshot” assessments obtained under other stock status criteria.

Accurate monitoring of the viability of hatchery and wild fish populations requires that special attention be given to sampling, marking, detection, and analytical procedures and equipment. The rationale, approaches, and methodological means of obtaining the requisite data are discussed in this section of the report

5 1.3.2 Critical Uncertainties

The critical uncertainties associated with the viability and persistence of chinook populations clearly deserve the highest priority in the monitoring and evaluation program. Mathematically aggregated risk scores and levels are identified in Table 17 for Population Viability assumptions.

Table 17. Population Viability assumptions and associated levels of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Stock Abundance	1	Supplementation will result in the establishment of natural populations where none previously existed	3
	2	Supplementation will increase production in streams where natural production already occurs	4
	3	Variation in population size will remain within acceptable limits (low extinction risk)	4
	4	Variations in abundance will be reflected by changes in parr densities, smolt yield, adult returns, and redd counts	2
	5	Upper limits to population size will be determined by density-dependent factors rather than by density-independent factors	2
Survival	6	Survival from fertilization to release is higher among hatchery fish than among corresponding natural life stages	2
	7	Variation in survival following release is a function of stocking density, the density of wild chinook, and the density of resident salmonids	4
	8	Release strategies will be synchronized with favorable environmental conditions to ensure high post-release survival	4
	9	Placement of hatchery chinook in acclimation ponds will result in increased survival compared with chinook outplanted directly into streams	4
	10	Survival can be accurately estimated for each life stage in freshwater and ocean habitats	4
	11	Causes of mortality can be identified	4
	12	Smolt-to-adult survival currently limits natural production; it must exceed 0.22 for target populations to be self-sustaining	3
	13	Supplementation will need to continue without interruption to offset mortality incurred outside the Clearwater River basin	4
	14	Reducing mortality during overwinter and smolt migration periods offers the greatest potential for increasing smolt-to-adult survival	3
	15	Marks can be used to discriminate hatcher) from natural fish	1

Table 17 (continued)

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Reproductive success	16	The average number of progency produced per spawncr does not differ bctween hatchery and natural fish	4
	17	Courtship behavior and mate selection is not affected by hatchery experience	4
	18	Environmental conditions favor normal and compatible reproductive behaviors among hatchery and natural fish	3
	19	Fecundity sperm and egg viability developmental rates. and other reproductive characteristics do not vary between hatchery and natural fish	3
	20	Naturally spawning hatchery fish can be identified	2
Long-Term Fitness	21	Supplementation does not increase the risk of extinction of natural populations	3
	22	Fitness will not be lowered by inbreeding depression. outbreeding depression. or the introduction of maladapted genes	3
	23	Fitness will not be lowered by changes in environmental conditions	4
	24	Reductions in long-term fitness can be detected by changes in genotype. phenotype, and/or life history	3
	25	Eristing measures of fitness can be used to identify specific adaptations to a local environmcnt	3
	26	Fitness can be indexed by stock productivity over a suitably long time period	3

5 1.3.3 Performance Variables

5.1.3.3.1 *Abundance*

Recommended performance variables:

1. Parr density index
2. Smolt yield
3. Adult escapement
4. Redd counts
5. Sport, commercial, and tribal harvest

Application

Accurate estimates of abundance and escapement are needed to assess whether chinook populations are responding to supplementation and can withstand harvest pressures. Hatchery fish are to be fin clipped and therefore will be differentiated from naturally spawned fish. Chinook parr (age 0) densities and adult escapement to weirs or hatchery facilities are recommended as the primary measures of NPTH spring chinook population abundance and trend. They are the dependent variables to be measured and evaluated under the NPTH experimental design; a comparison of parr and spawner abundances in treatment and control streams before and after supplementation begins will indicate whether populations have benefited from supplementation. Over the long-term, parr density and adult escapement data will be used to evaluate trends in stock productivity, and to set harvest and hatchery production targets

Redd counts and hatchery escapement are recommended as the primary measures of abundance for summer and fall chinook. The determination of whether these species have benefited from supplementation will be based on time trend analyses of redd count data. It may be necessary to use aggregate counts (i.e., both summer and fall chinook) if their is significant overlap in the time and place of spawning. If possible, accurate estimates of sport and/or commercial catches of NPTH summer and fall chinook should be obtained from appropriate agency sources and used as an ancillary measures of abundance for these species.

All four abundance variables are desirable from the standpoint of estimating abundance, survival, stream carrying capacity, and hatchery production needs. Parr density will be a useful indicator not only of abundance, but of location effects and habitat quality as well Parr densities used as an indicator of population size will be measured in preferred reach and habitat types. We assume, as did Cramer and Neeley (1993). that shifts in abundance when populations are small but experiencing accelerated growth will be more readily detected in preferred habitats. By referencing changes in population size to parr densities in permanently established channel units representing preferred reach and habitat types, we seek to increase the precision of our parr density estimates by reducing the confounding effects of physical habitat variability on those estimates. The estimates are not meant to be unbiased, but are intended to accurately reflect changes in population size that can be attributed to supplementation.[14]

The IDFG has assembled an extensive database on spring chinook parr densities in the Clearwater drainage and elsewhere. The sampling strategy proposed here is consistent with the IDFG methodology and sampling design. The addition of parr density data gained through NPTH monitoring and evaluation would complement the IDFG database and strengthen analyses of regional trends in spring chinook abundance.

Counts (not estimates) of adult returns to stream weirs located at the mouth of NPTH streams will provide the most reliable measure of spring chinook spawner abundance. Adult trapping will also enable collection of important life history data for this species The chief disadvantages of counting fences or weirs are that they may be costly to operate, they may alter the distribution and movements of spawners. and they do not necessarily result in accurate estimates of spawning escapement since some of the fish passing the weir may die before spawning. These drawbacks notwithstanding, direct adult counts are considered the best method of quantifying population status and long-term trend

It would probably be too difficult and expensive to try to obtain reliable estimates of smolt yield and redd density on all NPTH streams. Redd counts in index reaches are a key component of Idaho Supplementation Studies and. if undertaken on NPTH streams, would provide comparable information on spawner abundance Compared to direct (not estimated) counts of returning adults at stream weirs, redd counts provide crude estimates of spawner abundance The frequency and timing of surveys, factors affecting the reliability of redd identification and enumeration. and practical constraints on the length of stream that can be surveyed and its accessibility preclude the use of redd counts as a measure of absolute abundance. In the interest of saving time and money, we recommend that the Tribe refrain from routinely conducting spring chinook spawner surveys in NPTH streams. provided that temporary adult counting weirs are built and operated as recommended

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[14] Note that the parr density parameter recommended as an Abundance performance variable is not an estimate of total abundance (number) of chinook parr in the associated reach or stream Other reach and habitat types within each stream will be systematically sampled at least once during the pre- and post-operational periods and expanded to estimate stream carrying capacity (see production estimates in Section 6.3.1).

Since summer and fall chinook are expected to spawn in mainstem reaches of Clearwater River and its principal tributaries, and weirs cannot be constructed and maintained at reasonable cost in the river below these reaches, we consider annual redd counts to be the most reliable means available of estimating the abundance of these species. We therefore recommend that the NPT conduct ground and aerial redd surveys of known or suspected summer and fall chinook spawning areas within the entire Clearwater River Basin for the purpose of monitoring summer and fall chinook spawner abundance. Chinook redd count data are unlikely to lead to unbiased estimates of population size but may nevertheless be sensitive indicators of trends in population status (Cramer and Neeley 1993).

The number of smolts produced by a population is an indication of that population's productivity as affected by biotic and abiotic factors operating over the period of freshwater residency. If it could be easily and reliably measured, smolt production could be used to assess supplementation and environmental effects. However, the practical difficulties and uncertainties associated with measuring smolt production make it unacceptable as a performance variable given the alternative measures available to us. Although we recommend that smolt yield *not* be measured for all NPTH streams, it should be empirically determined in conjunction with juvenile salmon emigrant sampling on Lolo and Meadow Creeks. In addition to enabling smolt production estimates on these streams, juvenile trapping will be used to calculate life stage-specific survival rates, to determine the relative magnitude and timing of emigration, to sample life history characters, and to compare with similar data obtained for other streams.

Plans call for operating smolt traps on Lolo and Meadow Creeks to estimate the number of juvenile chinook emigrating during fall and spring from those streams. Spawner surveys are already conducted each year on Lolo, Yoosa, Eldorado, and Newsome Creeks. Information obtained through these efforts will be used to estimate smolt production and reproductive success, to calculate life stage-specific survival rates, and to compare with smolt yield and redd count databases developed for other streams.

Measurements

Parr density

Spring chinook parr densities will be estimated during the late summer in selected reaches and channel units in all NPTH streams. Low gradient C channels support higher densities of chinook parr than do higher gradient reach types. Pools (scour pools, plunge pools, etc.) are preferred chinook rearing habitat in streams the size of NPTH experimental streams. We expect parr densities in C channel types and in most pool types (scour pools, eddy pools, dammed pools, etc.) to exhibit the most dramatic and immediate response to increases in population size caused by supplementation.

From a sampling standpoint, pool habitats (in small streams) are more easily and accurately censused using underwater observation techniques than are other habitat types. For these reasons, we recommend measuring chinook parr densities once each year in permanently established index reaches and channel units representing various pool types in NPTH streams. Further information on the classification and selection of stream reaches and channel units may be found in the discussion of Macrohabitat and Mesohabitat performance criteria (Sections 5.3.1.3.6 and 5.3.1.3.7, respectively).

The following steps should be followed to estimate parr densities within index reaches/channel units:

1. Each stream will be stratified into distinct reaches by applying geomorphologic and hydrologic criteria developed by Rosgen (1985). A single index reach, approximately 500-1000 meters in length, will be established in a C-type channel segment within each stream The exact location of index reach boundaries and the distance between them will depend on the number and type of habitat units present, as described in Section 5.3.1.3.7 (Natural Environment, Production Potential. Mesohabitat)

2. Channel units within each index reach will be mapped and classified by habitat type Channel units representing scour pools and runs will be tentatively selected as parr density index sampling sites Each of the m habitat types (j = 1, 2 = m) will be represented by n channel units (i = 1 ,2, , n), with the number of units selected of each type being proportional to their size (number) within the associated reach. A minimum of 5 channel units u-ill be sampled for each habitat type The total number of channel units sampled within a given reach is $N = \sum_{j=1}^{m} n$.

3. Surface areas will be measured for the selected channel units and combined to estimate total surface area, $A_j = \sum_{i=1}^{n} A_i$, by habitat type.

4. The number of chinook parr counted in the same channel units will be summed to estimate total abundance, $Y_j = \sum Y_i$, by habitat type. Fish will be censused using underwater observation (i.e , snorkeling) techniques (Dolloff et al 1993, Rich et al. 1993, 1994) or, if conditions dictate, by removal or mark-recapture methods applied to electrofishing (Rodgers et al. 1992). Attention should be given to potential sources of bias in sampling methods (Hillman et al. 1992).

5. Total abundance is divided by total surface area to estimate mean parr density, $\overline{D}_j = Y_j / A_j$, by habitat type.

6. Mean parr density, $\overline{D}$, weighted by habitat type, is calculated for each index reach as:

$$\overline{D} = \sum_{j=1}^{m} \left(\frac{n_j}{N} \overline{D}_j\right)$$

$\overline{D}$ will be used as an estimate of the dependent variable in statistical comparisons of supplementation effects under the Before-After, Treatment-Control experimental design (Section 3.2.2).

Smolt Production

Empirical estimates of the number of smolts produced will initially be limited to those streams in which smolt traps are operated during fall and spring outmigration periods. At present, only Lolo Creek and Meadow Creek are slated for spring/summer chinook emigrant monitoring and evaluation.[15] Screw traps (5 or 8 feet in diameter) will be used, possibly with deflectors or louvered wing panels installed to direct fish into the trap. The traps should be permanently positioned in the thalweg near the mouth of each stream.

The total number of fish emigrating from either Lolo or Meadow Creek will be estimated as the cumulative sum of daily counts (possibly split into day and night time periods), adjusted for trap efficiency. The expected inverse relationship between trap efficiency and instantaneous flow should be determined from least squares regression analysis applied to a dataset consisting of paired measurements of both variables. Trap efficiency should be measured under a wide range of flow conditions by marking (preferably with PIT-tags) juveniles caught in the trap, releasing them far enough upstream so that their probability of capture is representative of the general population (but not so far upstream that fish die before reaching the trap), and then enumerating the number of marked fish recaptured by the trap. Separate flow-efficiency relationships may need to be determined for different seasons and diurnal periods. Assuming that the two variables are significantly correlated, regression equation(s) can be used to predict trap efficiency as a function of stream discharge. The estimated number of juveniles emigrating past the trap during time t is $N = c$ e, where c is the number of fish caught in the trap, and e is the measured or predicted trap efficiency over the sampling period.

No attempt will be made to trap juveniles emigrating from NPTH streams other than Lolo and Meadow Creek. However, the number of smolts produced annually in

[15] **NPTH biologists should evaluate the feasibility of modifying adult weirs/counting facilities to sample downstream migrating smolts in other NPTH streams.**

NPTH streams will be estimated by expanding late summer mean parr densities, stratified and randomly sampled by habitat type, to estimate the total number of fish in each stream, and then applying appropriate parr-to-emigrant (fall presmolt and spring smolt) survival rates. Survival rates and whole stream parr abundance estimates are discussed elsewhere (Sections 5.1.3.3.2 and 5.1.3.3.1, respectively).

Adult escapement

For spring chinook salmon, adult escapement is defined as the number of adult chinook salmon counted at weirs and either taken as broodstock or released upstream to spawn naturally Adults collected elsewhere (e.g., caught by fishermen or taken into hatchery facilities for broodstock purposes) will be included in this estimate as long as they can be reliably identified to stream of origin.

Weirs have been identified as the most efficient and accurate means of enumerating and sampling adult spring chinook salmon returning to NPTH experimental streams. IDFG biologists (Rich et al. 1993, Schrader and Petrosky 1993) recommended maintaining or building weirs on a total of 21 streams in Idaho, among which are included two NPTH streams: Lolo Creek and Newsome Creek. We propose to increase this number by 11 (possibly 9) to accommodate escapement monitoring needs on the remaining NPTH experimental streams (Meadow Creek is the exception).

Anderson and McDonald (1978), Whelan et al. (1989), and River Masters Engineering (1993) describe several low-cost, portable weirs suitable for guiding adult salmon into traps or through passageways where they can be counted. The weirs are designed to be 100% efficient in collecting migrating adults under hydrologic regimes characteristic of third to fourth order salmon streams. River Masters Engineering (1993) also describes more permanent structures that act as velocity barriers, but these do not appear suited to smaller NPTH streams.

The main components of the portable weirs, constructed mainly of wood or metal, are angled guide fences supported by tripod frames. Fence panels consist of closely spaced pickets that run vertically through the frame and contact either a permanent concrete sill or the undisturbed streambed. Upstream migrating adults are directed into concrete or wooden traps where they can be counted by an observer or passively videotaped for later enumeration. The downstream-upstream orientation of most weirs can be reversed so that juveniles can be sampled as they move downstream.

The number of returning adults will be used to calculate smolt-to-adult and adult-to-smolt (or parr) survival rates.

Methods to Discriminate Hatchery and Wild Fish

The ability to accurately discriminate hatchery from wild fish in mixed samples of juvenile and adult life stages is an important monitoring and evaluation and hatchery management requirement. A comparison of the abundance, survival, reproductive success, and life history characteristics of hatchery and wild fish is necessary to fully evaluate the effects of supplementation. The NPTH Master Plan and Genetic Risk Assessment calls for the use of wild fish captured at adult collection facilities as hatchery broodstock so that genetic integrity is maintained. Hatchery fish are to be returned to the stream to spawn naturally. All of these activities require marking and sampling methods that differentiate hatchery from wild fish.

We propose to distinctively mark with binary coded magnetic wire tags and adipose fin clips all spring/summer and fall chinook released from NPTH facilities. If it is not possible to mark all hatchery fish in this manner, estimates of hatchery/wild proportions in a sample can still be obtained as long as a constant fraction of the unmarked hatchery fish are distinctively marked with a third mark prior to release (Hankin 1982). However, this method would lead to higher variances in the estimated proportions which may complicate statistical comparisons.

We also intend to mark a subsample of hatchery and wild fish with PIT tags and possibly visual implant tags to facilitate estimates of smolt survival, travel rates, and time of arrival. Mixtures of marked hatchery fish and unmarked wild fish will be sampled on up to four separate and independent occasions depending on the release strategy employed:

1. As stream-dwelling parr if hatchery fish are released as timed-release fed fry;
2. As smolts if caught in smolt traps, PIT tagged, released, and detected at downstream dams;
3. As recruits in tribal, sport, and commercial fisheries; and
4. As adults returning to weirs, hatcheries, and spawning grounds

Redd counts

Short of exact enumeration of spawning fish, redd counts are the most reliable measure of fall chinook population abundance, as long as counts are not biased by the method used or area sampled. Annual fall chinook redd surveys are currently conducted on a coordinated basis within and outside of the Cleat-water Basin, so a historical database and precedent exist (Arnsberg 1993, Garcia et al. 1993). We propose to expand surveys to include all of the known fall chinook spawning habitat within the Clearwater system. The exact location and distribution of potential spawning habitat should be identified during the pre-operational period from a consideration of historical observations, temperature regimes, channel morphology, and substrates relative to environmental thresholds required for fall chinook spawning. After reviewing available environmental data in light of known spawning and incubation requirements, Cramer (1995) recommended that fall chinook supplementation be limited to the Clearwater River below its confluence with the North Fork The NPT is collecting additional water temperature data to determine whether fall chinook might conceivably spawn in upstream reaches such as the Selway River (B. Amsberg, NPT, personal communication). Full reconnaissance of all known spawning areas is recommended since “index” counts and resulting spawner estimates are likely to be highly variable and biased to an unknown degree. Furthermore, expansion of fall chinook spawning into previously unused areas will be interpreted as evidence of positive supplementation effects.

Summer and fall chinook redd/spawner surveys will be conducted by helicopter at weekly intervals over the 5-6 week fall chinook spawning season (late October through early December). If possible, spawning sites should be visited to confirm redd identities and retrieve dead spawners. The carcasses should be sampled for life history data (see Section 5 1.2.3, Life History performance variables). New redds observed during weekly surveys will be totaled to estimate the number of redds constructed each year. Redds will be multiplied by an appropriate fish-per-redd factor (taking sex ratio into account) to estimate annual spawner abundance. Expansion factors can be either be estimated or obtained directly from spawner:redd ratios measured for other summer and fall chinook populations (e.g., Blankenship and Mendel 1993).

Cramer and Neeley (1 993) recommend using an exponential growth/decay model to estimate extinction probabilities and assess post-recovery trends in spawner abundance for upriver Snake River chinook populations. The same model can be used to monitor fall chinook population response following supplementation. The model is most appropriate when applied to populations that are experiencing accelerated growth or decline in the absence of density-dependent constraints.

Unless it can be shown that the number of spawners per redd does not change from year to year, redd counts should be converted to spawner abundance. Spawner abundance (N) after t years is calculated as:

$$N_t = N_0 e^{rt}$$

where N_0 is the initial spawner abundance (e.g. immediately prior to supplementation), and r is the instantaneous (yearly) rate of growth or decline. Cramer and Neeley (1993) recommend a natural log transformation:

$$\ln (N_t) = \ln (N_0) + rt$$

Estimates of N_0 and r are obtained by performing a simple linear regression of In (N_t) on t. Either analysis of variance or the t test can be employed to test the one-tailed hypothesis $N_0 > 0$. In effect, we are asking the question "Is the population increasing at an exponential rate?"

If the null model of exponential growth is accepted, the mean spawner abundance for a discrete time interval should be calculated as a geometric mean rather than as an arithmetic mean. The geometric mean is estimated by calculating the mean of the In (N_t)'s, and then transforming back to the original scale. However, it will not be possible to test for differences in mean spawner abundance between time periods since replication is not possible in the Clearwater River.

Sampling Units and Schedule

During the pre-operational period, NPT biologists should compile existing information on parr densities, smolt yield, adult escapement, and redd counts..

Effective immediately, parameters required to estimate mean parr density should be measured once each year under late summer (August through mid-September) flow conditions in all treatment and control streams. Parr counts should be completed before nighttime water temperatures drop below 3 C.

Lolo Creek and Meadow Creek screw traps should be operated in the fall from mid-August until cold weather shuts down operations or until no further movement of emigrants is detected. Sampling in the spring should commence as soon after 1 March as weather permits. The traps should be operated continuously unless safety concerns and repairs warrant its temporary removal.

Weirs should be installed on all NPTH streams at the earliest date possible after 1 June, and operated until mid-August. Fall chinook redd counts should begin in late October and end in the second week of December. Surveys should include all sections of the Clearwater River containing fall chinook spawning habitat.

5. I. 3.3.2 Survival

Recommended performance variables:

1. Egg-to-parr survival
2. Parr overwinter survival
3. Smolt-to-smolt survival
4. Spawner-to-smolt survival
5. Smolt-to-adult survival

Application

If the NPTH is to succeed, relatively high survival rates need to be maintained, since stock productivity is a direct function of survival. Increases in survival can be gained by reducing mortality occurring within and outside of the hatchery. With regard to the former, the Master Plan calls for facilities to be designed and a variety of broodstock management and rearing practices implemented that will minimize selective mortality, maintain genetic and phenotypic variability among individuals, and provide for consistently high survival across life stages Hatchery survival rates will be routinely monitored to ensure that this is the case.

The combination of genetic conservation and environmental management practices that will be employed to maintain high survival and viability within the hatchery should also confer high fitness in post-release environments If hatchery fish are qualitatively similar to wild fish in size, morphology. behavior. physiological status. health and other ecological attributes at the time of their release, and if they are released in areas and at times that are generally conducive to their survival, then there should be negligible difference in their respective survival rates. Levels of post-release survival that permit stock rebuilding and eventual harvest represent one of the key uncertainties in the NPTH; it will be collectively addressed by all of the survival performance variables.

Natural and man-caused disturbances in the Clearwater drainage have reduced the quantity of area available for spawning and rearing. and have also led to a reduction in habitat quality. Both the causes and the effects of habitat degradation can lower the survival of different chinook life stages. Spawning substrates, water temperatures, and riparian and instream cover are oft-cited habitat components that have changed for the worse in the project streams. We plan to monitor egg-to-parr, parr-to-smolt (overwinter), and smolt survival in selected NPTH streams and mainstem reaches to identify bottlenecks in freshwater production. Spawner-to-parr survival estimates will be based on changes in abundance in experimental streams. Overwinter and smolt migration mortality will rely on PIT tag mark-recapture data. Under certain conditions, smolt survival will be partitioned into tributary, mainstem, and dam passage components.

Chinook salmon smolt-to-adult survival rates - lower today than they were historically - will also be monitored through the application and retrieval of coded wire tags. Data do not exist for Clearwater River salmon under pristine conditions, but between 1964-1968, when only 4 dams were in place on the Columbia and Snake River, 4.2% of the spring chinook smolts tagged and released from Rapid River Hatchery on the lower Salmon River returned. on average, as adults (Raymond 1988). Today. fewer than 0 5% of the smolts from the same hatchery survive to adult stage Survival rates for fish released as smolts from Dworshak NFH in recent years have ranged between 0. 1 and 0.3% (Giorgi 1992). In determining spring chinook natural production goals for NPTH streams, Larson and Mobrand (1992, p. 34) assumed that smolt-to-adult survival would average 0.44 % for both hatchery and wild spring chinook. The recovery of Clearwater chinook salmon, as well as other stocks of Snake River salmon, rides on the assumption that mortality accruing during smolt migration, estuary and marine residency. and returning adult life stages can be collectively reduced.

Measurements

Egg-to-parr

Temporary weirs and adult traps will be installed in the lower reaches of NPTH streams each year to intercept returning spring chinook spawners (Section 5.1.3.3.1, Abundance). Adult salmon will be counted (not estimated), sampled for life history data (Section 5.1.2.3, Life History performance variables), and released above the traps to continue their upstream spawning migration. The number of spawners will be estimated by applying an appropriate pre-spawning survival rate (approximately 0.95) to the number of adults passed above the weirs. The number of eggs deposited (N_1) will be estimated as the product of the number of spawning females and the number of eggs per female (approximately 5,000), determined from length-fecundity relationships applied to measured female lengths. Length-fecundity relationships will be calculated from data collected from hatchery-spawned fish. Potential egg deposition will be adjusted for mean egg retention if it is found to be significant among hatchery spawners.

The total number of chinook parr (N_2) present in late summer in NPTH streams will be determined by stratified sampling; empirical estimates of parr densities will be extrapolated to unmeasured channel units and associated stream reaches (see Abundance performance variables). Sampling will be stratified by micro- and mesohabitat (i.e., habitat and reach) types using census methods similar to those described by Kiefer and Lockhart (1993).

Egg-to-parr survival rates will be calculated as N_2 / N_1

Parr-to-smolt

Smolt production will be estimated for those streams in which emigrant traps are installed, notably Lolo Creek and Meadow Creek. The traps will be operated continuously during the fall (late August through November), spring (early March through May), and at other times dictated by outplanting schedules.

Some of the chinook parr residing in NPTH streams are expected to drop down into mainstem reaches in the fall. The rest of the fish will overwinter within the streams and will emigrate the following spring. A complete census of fall and spring emigrants in any of the NPTH streams is cost-prohibitive, therefore, smolt production will be indirectly estimated either by estimating total parr abundance in the preceding fall, and then reducing this number by the number of fish expected to die before spring, or by trapping a portion of fish as they emigrate and dividing the number caught by the sampling efficiency of the trap.

Daily trap counts of fall and spring emigrants will be expanded to estimate the total number of emigrants by applying estimates of daily trap efficiency. On at least 10 days and 10 nights during each outmigration period. subsamples of 25-50 fish caught in the juvenile trap will be marked (either fin-clipped or PIT-tagged or both) and released upstream. The proportion of marked fish recaptured at the trap will be used as an estimate of trap efficiency Alternative methods for estimating trap efficiency may be possible for spring emigrants. Flow-efficiency regression relationships should be established and used to calibrate trap efficiency to streamflow on days when empirical estimates are unavailable. Daily trap counts will be divided by estimated daily trap efficiency to estimate the total number of emigrants passing the trap each day Daily emigration estimates will be summed to calculate the total number of fish emigrating either in the fall or in the spring The total number of fall emigrants will be multiplied by an appropriate overwinter survival rate to estimate the number of fish surviving to smolt stage the following spring. Overwinter survival rates will be estimated from the literature. Total smolt production (N_3) will calculated as the number of fall emigrants. adjusted downward to account for overwinter mortality, added to the number of spring emigrants

Parr-to-smolt survival rate will be calculated as N_3 / N_2

Smolt-to-smolt

By smolt-to-smolt survival we mean the rate at which fish die from the time they begin to actively migrate from overwintering areas to detection points passed downstream There are three general methods available to estimate smolt-to-smolt survival within NPTH tributaries and mainstem river reaches. All require marking or tagging of fish and a means of recapturing at least a portion of those marked fish. The methods are 1) measure or estimate the collection efficiency of the sampler (e.g., emigrant trap), then adjust mark recoveries from upstream areas by collection efficiency, 2) assume constant collection efficiency of fish and then directly compare recovery rates of different groups of fish, and 3) use direct release methods. The first two methods will be used only in the event that the third method is untenable. A direct release method that will enable estimates of smolt survival within NPTH tributaries and mainstem reaches of the Clearwater and Snake Rivers has been proposed by Steward (1994)

Regardless of the method used to estimate smolt numbers, survival between two points is calculated as N_4 / N_3

The spawner-to-smolt ratio (N_3 / N_1) is generally useful as a measure of survival over the entire non-migratory freshwater period. However, under the recommended monitoring and evaluation framework, spawner-to-smolt survival estimates will in most cases be less reliable than spawner-to-parr estimates. This is because smolt production will be derived indirectly from parr abundances in most NPTH streams. Emigrant trapping will permit less biased estimates of smolt production in Lolo and Meadow Creeks. Thus, spawner-to-smolt ratios will be calculated for Lolo Creek and Meadow Creek chinook for comparison with non-NPTH populations.

The absolute abundance of adult chinook returning to NPTH experimental streams will be directly measured as the number of fish ascending weirs sited at the mouth of those streams. Spawner abundance estimates will be corrected for pre-spawning mortality.

Smolt-to-adult

We will estimate annually the number of chinook salmon smolts either produced naturally or resulting from hatchery outplants in all NPTH streams. Direct measures of adult escapement will be obtained by operating weir traps in lower reaches of treatment and control streams at the time adults are ascending those streams to spawn. Key assumptions are that the weirs are 100% effective, and that the traps do not affect the upstream movement, survival, or spawning distribution of returning adults. In estimating potential egg deposition, it is not necessary to assume that all fish passing the weir spawn successfully, only that adjustments for pre-spawning mortality are reasonably accurate.

Sampling Units and Schedule

The key to estimating survival (as well as stock composition, fishery contribution, and straying) will be our ability to differentially mark, recapture, and accurately count or estimate numbers of marked and unmarked fish. Fin (adipose and rayed) clips, coded wire tags, and PIT tags will serve as the primary means of identification, with otolith and external marks (fluorescent sprays, thermal brands, and tags) used under special circumstances. All marks and mark-recovery procedures and data will be compatible with regional (e.g., IDFG, PSMFC, IHOT) guidelines and databases. The number of fish to be tagged will be determined from a statistical treatment of data obtained from earlier or related studies. Random sampling should be used when estimates of population parameters are desired.

Hatchery-reared fish will be identifiable to individual release groups by unique binary codes etched on coded wire tags. Subsamples of hatchery fish in each release group will be tagged prior to release. Subsamples of wild and hatchery chinook captured by electrofishing will be PIT-tagged during late summer population surveys (all NPTH streams) and in emigrant traps in the fall and spring (selected streams). PIT tags will enable researchers to track the movements and fate of individual fish. They may also be used to generate mark-recapture estimates of population abundance at individual study sites. Variability in parr densities in treatment and control streams will be used to evaluate supplementation effects.

Emigrant traps, mainstem dams, adult traps, hatcheries, and field study sites will serve as survival evaluation points. Pre-operational studies should be directed at testing field techniques, determining logistical constraints and, most importantly, establishing sample sizes and variances that can be used to design future studies. Emphasis should be placed on measuring survival over a range of conditions and to perfecting sampling, tagging, and release techniques. Added costs may be less of a factor than logistical constraints.

5.1.3.3.3 Reproductive Success

Recommended performance variables:

1 Adult-to-redd ratios

2 Productivity (Recruit Spawner ratios)

Application

The reproductive success criteria can be broken down along two general lines. The first concerns the proportion of returning adult salmon that actually spawn. as indexed by the number of fish per redd. Ideally, there should be one pair of spawners for each redd observed, assuming that all fish and redds are accounted for. Ratios of less than two fish/redd would suggest that males are mating with more than one female, and/or females are digging more than one redd. Far more likely. however, are ratios greater than 2: 1. As can be seen in Table 18, ratios ranging up 3 fish per redd are common among Columbia River chinook populations. High fish/redd counts result from pre-spawning mortality or unbalanced sex ratios (i.e., a surfeit of males). Exceedingly high ratios (greater than, say, 4 fish/redd) would indicate serious problems, most likely related to factors causing pre-spawning mortality such as disease, elevated water temperatures, or a lack of adult holding habitat. Thus, we have identified fish/redd ratios as a reproductive success performance variable.

Another measure of reproductive success is the number of surviving progeny (recruits) produced by an average spawner. Termed the productivity ratio, it is simply the product of mean survival rates and fecundities averaged across age classes for a given broodyear.

Table 18. Fish per redd estimates for selected Columbia River chinook salmon populations [from Howell et al. (1985) as reported in Lichatowich (1992)].

Population	Fish/redd
Cowlitz	2.8
Klikitat	2.1
Grande Ronde	2.75
Imnaha	2.75
Wenatchee	3.1
Entiat	3.1
Methow	3.1

For a population of salmon to remain stable or to increase in size, it must at least replace itself from one generation to the next. That is, the productivity ratio must equal or exceed 1. When it is less than 1, the population will decrease. Clearly, the productivity of a population is influenced by biological and environmental factors affecting its vital rates (birth, death, and growth). Density-dependent feedback mechanisms tend to promote accelerated population growth (i.e., many recruits per spawner) at low population sizes and a decreased rate of growth when numbers are high. Each population will have a uniquely shaped spawner-recruit curve that reflects its particular circumstances. Hypothetical spawner-recruit relationships are shown in Figure 1 1

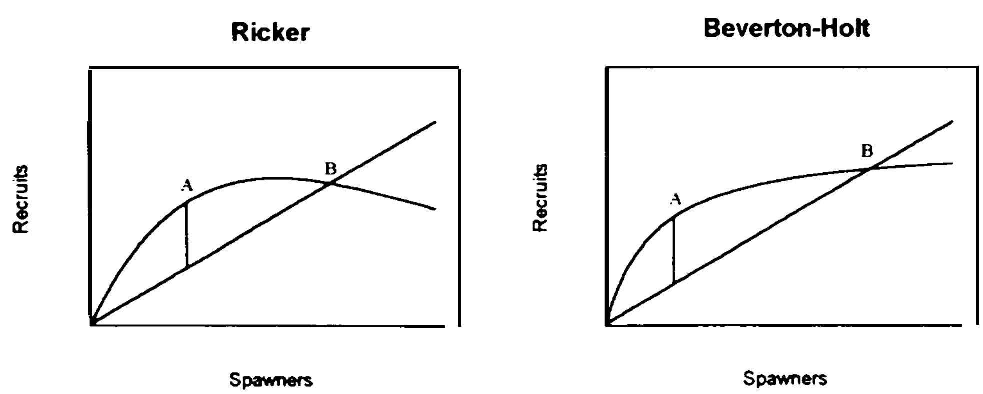

Figure 1 1. Ricker and Beverton-Holt spawner-recruit curves. A represents the number of spawners and recruits at maximum sustained yield; B is the replacement point.

At present, chinook populations are either absent in NPTH streams or they exist at levels well-below historical and current carrying capacities In theory, the NPTH will boost natural production in streams targeted for supplementation to their full potential, as determined by density-dependent factors that constrain local populations below some theoretical maxima. We assume that populations are constrained by freshwater rather than marine carrying capacity, although evidence suggests that this may not always be the case. If we assume further that freshwater carrying capacity is determined by factors regulating the number of chinook fry, parr, or smolts, and that conditions can be managed to maximize the survival of those life stages, then continued infusions of hatchery fish will be unnecessary once carrying capacity is reached However, if natural production is constrained by factors influencing pre-spawning, spawning, incubation, and early rearing life stages. then supplementation can be used to increase total system capacity. The natural system will still impose upper limits on population size, but they will occur at a higher carrying capacity, most likely one determined by the quality and quantity of juvenile rearing habitat present. Under this scenario. supplementation will need to continue to fully utilize the rearing potential of NPTH streams year in and year out.

A long-term NPTH goal is to collect enough data to derive spawner-recruit relationships that can be used to calculate optimal spawning escapements and to set harvest quotas.[16] Once healthy populations of naturally-spawning chinook have been established, they will be managed to create harvest opportunities for tribal members. For each population. this will require maintaining the spawning escapement at a level that permits surplus fish to be caught without impairing the population's ability to maintain itself. The point on a spawner-recruit curve at which maximum harvest is theoretically attainable is known as the point of "maximum sustained yield" (Point A in Figure 1 1). Since optimum levels of escapement and harvest are key project uncertainties, preliminary (theoretical) spawner-recruit curves will be developed during the pre-operational period using the best available information. The curves will be continually upgraded with empirical data once the project begins.

Measurements

Due to the practical limitations of conducting basinwide spring chinook redd surveys, the fish/redd performance variable will only be measured on an *ad* hoc basis in selected experimental streams Adult count and spawner survey data will be collected on Newsome Creek and Lolo Creek - both spring chinook streams - and compared

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[16] Long-term cyclic or systematic changes in environmental conditions such as ocean productivity, freshwater habitat quality. and mainstem flows as affected by hydrosystem operations have altered historical stock-recruitment relationships. Unfortunately, non-random environmental change will continue into the foreseeable future. so productivity and capacity can be expected to change as well.

with similar data from other streams included in Idaho Supplementation Studies (e.g., Upper White Sands Creek). More NPTH streams may be added later. Fish/redd ratios will not be measured for fall chinook since it will not be possible to directly enumerate returning adults.

Productivity ratios will be calculated annually for all spring chinook populations as soon as adult weirs are in place and a complete spawner-recruit cycle occurs. Factors affecting productivity will be discerned through monitoring of survival and other performance variables. Capacity will be estimated from Natural Environment monitoring and a consideration of density-dependent mechanisms.

Sampling Units and Schedule

Fish/redd data will be collected each year from selected treatment streams. The primary unit of measurement for productivity will be individual populations associated with treatment and control streams. in the case of spring chinook. and the population *in toto* from the entire Clearwater River system, in the case of fall chinook. Note that productivity as a measure of reproductive success will span a single generation. By contrast, trends in stock productivity over longer time periods will be used to index long-term fitness. discussed next.

5. I. 3.3.4 *Long-term Fitness*

Recommended performance variables:

1. Key genetic and life history traits
2. Stock productivity

Application

NPTH managers intend to minimize the length of time that fish are exposed to the hatchery environment, both within and across generations. A key assumption is that differential reproductive success and genetic exchange among hatchery and wild fish will not impair the long-term fitness of the aggregate population. The potential for genetic harm is particularly acute in Lolo Creek, Newsome Creek, and Meadow Creek (Selway), which currently support small populations of spring chinook salmon. It is the stated intent of the project that supplementation will not harm these populations, regardless of their ancestry

Long-term fitness does not imply genetic stasis but refers to the ability of a population to evolutionarily track changes in the local environment. Briefly, the effect of natural selection is to maximize the mean fitness of the population by ridding the population of less fit alleles. Although an allele's rate of change can be calculated, we cannot describe with certainty either its adaptive function or the selective forces acting upon it Sot only are allele frequencies subject to random variation, but their relative fitness can be expected to fluctuate in a constantly changing environment. For this reason, there exist no direct or readily interpreted genetic measures of fitness for natural populations. Our approach will be to compile information from several sources, and to deduce from these data whether the long-term fitness of the population has been impaired. We assume that reductions in fitness can be inferred from changes in genotype. phenotype. life history. and stock productivity (spawner-recruit ratios) over time These parameters will be measured under Genetic Resources. Life History Types. and Population Viability subcategories

Measurements

Performance variables associated with genetic. life history. and other performance criteria will be used as a surrogate measures for Long-term Fitness In particular. we will attempt to identify and assess the relative contribution to fitness of life stages whose component phenotypes experience significant differential mortality

Sampling Units and Schedule

All populations will be sampled on an ongoing. multi-generational basis

5 1 3 4 Summary of M&E Activities

Population Viability monitoring and evaluation tasks designed to measure stock abundance and survival criteria are summarized in Figures 12 and 13 Summaries for reproductive success and long-term fitness are combined in Figure 14

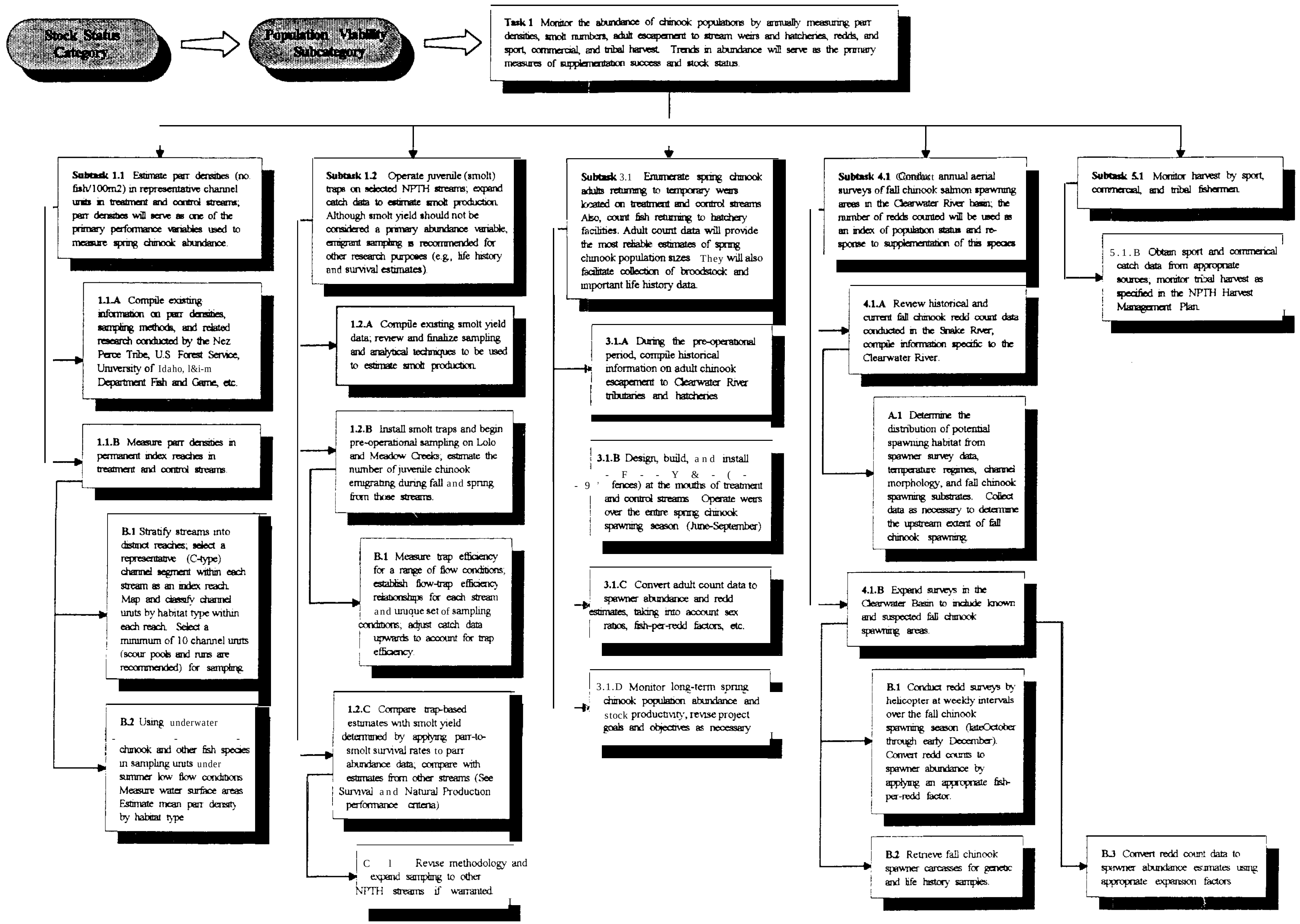

Figure 12. Tasks and subtasks associated with the monitoring and evaluation of stock abundance (Population Viability, Stock Status)

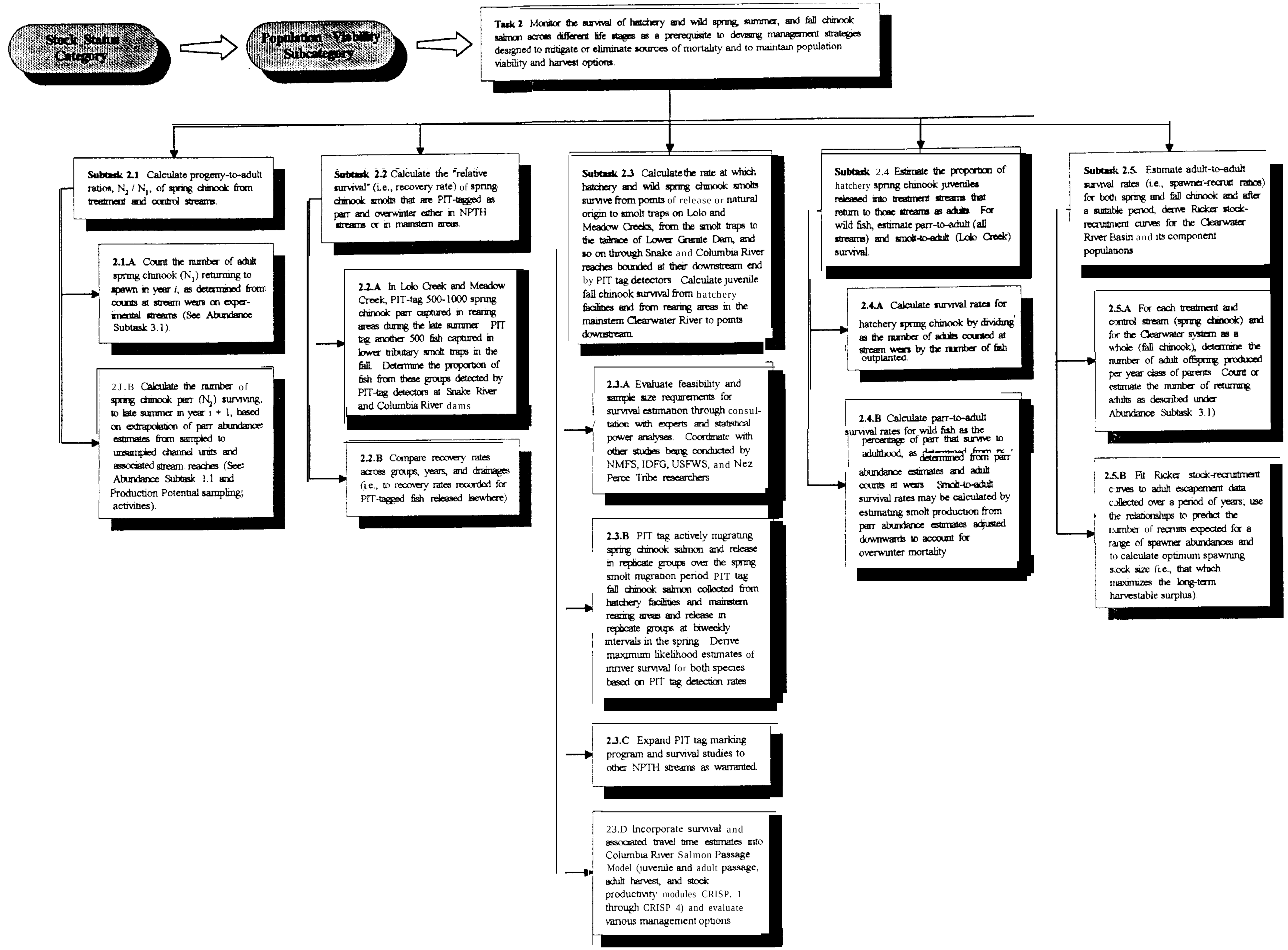

Figure 13. Tasks and subtasks associated with the monitoring and evaluation of chinook survival (Population Viability, Stock Status).

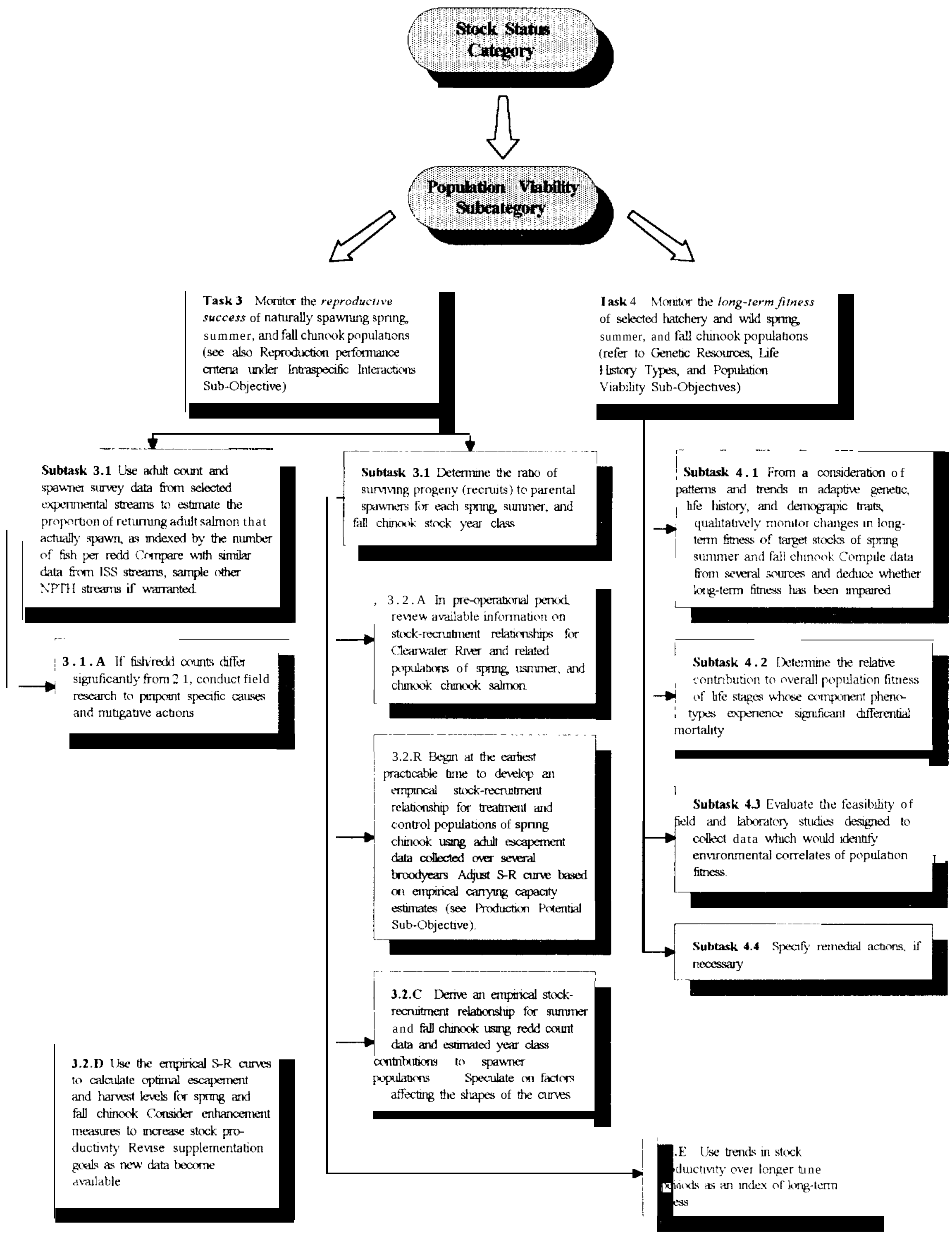

Figure 14. Reproductive success and long-term fitness monitoring and evaluation activities (Population Viability Subcategory Stock Status Category).

Ecological Interactions

Chinook salmon compete with other fish species for food and space, they eat a variety of organisms and are eaten, in turn, by other species, and they serve as hosts or vectors for disease and parasites. Collectively, the organisms and processes which comprise these relationships represent biological interactions in which chinook salmon play a direct role. The interactions may have little or no effect on the outcome of supplementation, either because they are benign, can be manipulated, or primarily affect the other species involved. Programmatic changes may be necessary if these impacts are deleterious. In particular, we desire that no harm comes to wild chinook salmon or to ecologically sensitive species as a consequence of our actions. The performance criteria and variables described below are designed to address the more important critical uncertainties associated with intraspecific and interspecific interactions.

In our evaluation of intraspecific interactions, we focus on short-term shifts in resource use, behavior, growth, survival, and fitness caused by the superimposition of hatchery chinook on wild chinook populations. We also emphasize the need to monitor the potential for genetic exchange with other chinook populations, as measured by the number of fish that stray into other drainages.

Interspecific competition can be evaluated in similar fashion, but we opted instead to evaluate its effects by measuring long-term changes in species distribution and abundance. The advantages of this approach - long term trend data at low cost - are somewhat offset by the difficulty of making strong inferences regarding the link between supplementation and species abundance. The effects of supplementation on resident biota may be difficult to discern since they may take years to become manifest, and even then they may be weak or indirectly expressed. Many biological processes - especially those that involve long-lived organisms with long generation times- take years to be completed and understood. Indeed, our basic understanding of how competitors, predators, and disease organisms respond to changes in abundance is poorly developed in general. For this reason, we recommend a monitoring and evaluation strategy that is geared primarily towards containing easily recognizable risks such as declines in bull trout abundance, and secondarily towards collecting information that would improve our understanding of basic aspects of biology, such as long-term variability in resource availability and population abundance.

5.2.1 *Intraspecific Interactions*

5.2.1.1 Background

By intraspecific interactions we mean activities or processes affecting competition, reproduction, (i.e., within-species), and disease transmission between hatchery and wild fish. Interactions may occur between fish of the same population or may between NPTH fish and individuals from unrelated populations. A primary objective of monitoring and evaluation under this performance criteria is to minimize competition for food, space, mates, or other factors which may displace or result in the death of wild chinook, or interfere with normal foraging, predator avoidance, migratory, reproductive, or other adaptive behaviors.

5.2.1.2 Critical Uncertainties

The results of the risk assessment process applied to assumptions relating to Intraspecific Interactions are summarized in Table 19.

5.2.1.3 Performance Variables

5.2.1.3.1 *Intraspecific Competition*

Recommended performance variables:

1. Relative abundance
2. Growth rates, mean size, condition factors
3. Food habits (feeding behaviors, diet composition and overlap)
4. Stomach fullness and state of digestion

Application

Since NPTH facilities and management practices have been designed to produce "wild-type" hatchery chinook, it is inevitable that intraspecific competition for key resources will occur where hatchery and wild chinook coexist. It is only when competition significantly reduces the survival among one or the other groups of fish that there is reason for concern, especially at times when resources are not limiting elsewhere in the system. The effects of intraspecific competition will be investigated by comparing the survival, growth, diet, and habitat utilization of sympatric and allopatric populations of hatchery and wild chinook. This performance criteria deals primarily with food utilization and interactive behaviors (e.g., aggression) displayed under certain conditions, notably those present at the time of release. Measurements of survival and habitat utilization are described elsewhere.

Table 19. Intraspecific Interactions assumptions and associated levels of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Competition	1	Hatchery and wild chinook of the same size will have identical ecological needs, will possess similar behavioral repertoires, and will compete on an equal footing for limited resources	4
	2	Hatchery and wild chinook eat similar types and quantities of food	2
	3	Supplementation fish will not competitively displace wild chinook but will disperse into vacant habitats	4
	4	Resource shortages caused by competitive interactions will affect hatchery and natural chinook equally'	3
	5	Hatchery chinook will not alter predator avoidance or migratory behaviors of wild chinook	3
Reproduction	6	Hatchery chinook compose no more than 50% of the spawning population	3
	7	Hatchery chinook will spawn successfully with wild chinook and other hatchery chinook	3
	8	Hatchery and wild spawners will compete equally well for mates; there will be no difference in reproductive behavior or fitness	3
	9	Mate choice will be unaffected by hatchery experience	3
	10	The potential for straying and hybridization with non-target populations will be low	4
Disease transmission	11	Supplementation will not increase the incidence of disease or parasites among wild stocks, and vice versa	4
Other Interactions	12	Supplementation will not adversely impact non-target chinook populations, either through competition, increased fishing pressure, or other forms of interaction	3

The primary goals will be to determine whether hatchery and wild chinook compete equally well for limited resources, and whether intraspecific competition appears to be an important factor regulating chinook production within NPTH streams. Answers to these questions will help managers devise appropriate supplementation strategies that take full advantage of the production potential of the streams.

Hatchery fish will have little opportunity to feed on natural prey prior to release. Their post-release survival will depend on their ability to switch to and secure a natural diet. Adequate survival will require that sufficient food be available and consumed to sustain growth. The amount of food available to individual hatchery and wild fish is expected to decrease with supplementation since a larger number of fish will vie for finite resources, If the diets of hatchery and wild fish are similar, yet growth rates decline, competition for limited resources may be inferred. Competition may also be implicated by dissimilar diets and unequal growth rates. Evidence for dietary overlap and competition will be obscured by differences in habitat use and size-dependent differences in prey selection. The sampling regime described below will partially control for dietary differences caused by habitat use and fish size.

The expense of monitoring chinook diets at levels necessary to detect density-dependent effects and environmental correlations may be prohibitive. For this reason, we advocate:

- A baseline study in which hatchery and wild parr stomach contents and co-occurring benthic fauna will be sampled in Lolo Creek and Meadow Creek (Selway). These streams will be periodically outplanted with hatchery chinook over the next few years, and so will provide sampling opportunities prior to project implementation.
- A post-operational study if preliminary findings indicate differences in diets or feeding behaviors among hatchery and wild chinook. Study objectives and performance variables may be revised to include more frequent measurements, controlled laboratory tests, and estimates of food consumption and demand expanded over number and time.

The objectives of pre-operational and post-operational studies of competition are to:

1. Determine whether hatchery and wild fish eat similar types and quantities of food,
2. Determine the relative importance of different food items, and
3. Compare feeding demand and growth with aquatic insect abundance in control and treatment streams to determine whether food might be limiting

Chinook feeding behavior

Dietary differences may be a function of inappropriate or maladaptive feeding behaviors expressed by hatchery fish following release. Frequency of occurrence of feeding bouts and other qualitative observations relating to feeding among hatchery chinook will be made in conjunction with routine surveys of population abundance and distribution (see Abundance and Species Composition performance criteria).

Measurements

Chinook diets

Stomach samples will be collected initially from hatchery- and naturally-reared chinook fry, parr, and smolts in Lolo Creek and Meadow Creek (Selway). Samples will be taken from anaesthetized chinook by the lavage technique, i.e., using a blunt needle syringe filled with water to flush stomach contents into a container. Samples will be coarse filtered and preserved in 70% ethanol in the field. In the laboratory, individual gut contents will be identified to genus, if practicable. In addition to counts of the prey items within each stomach, some indices of stomach fullness and digestion rate should also be estimated (see Cailliet et al. 1986). These data will be compared to chinook food preferences and consumption rates reported in the literature. When combined with observations of feeding behavior, it should be possible to determine whether hatchery-reared chinook are successful in securing prey items that are typical of wild chinook diets. If reasonable doubt exists concerning the quantity and quality of hatchery fish diets, or if growth rates appear to differ between hatchery and wild fish, then sampling will be expanded to include wild fish in both control and treatment streams.

Diets will be described for samples of 20-30 hatchery-reared fish collected from presmolt and smolt release groups in the summer and/or spring, as appropriate. Only hatchery and wild chinook parr and smolts in Lolo Creek and Meadow Creek will be sampled initially. Based on preliminary findings, a decision will be made to continue or drop food habits studies during the post-operational phase.

The “importance” of different food items collected from chinook stomachs will be represented and compared in terms of

1. Frequency of occurrence (F_c) - the proportion of fish that contained one or more individuals of prey taxa *i*.
2. Percent composition by number (P_c) - the number of individuals of prey taxa *i* expressed as a percentage of the total number of individuals counted.
3. Electivity index - relates the extent to which the observed diet differs from the composition of the co-occurring benthic fauna. If the relative abundances of

potential prey in the environment is known, a Forage Ratio (FR) can be calculated for each prey taxa *i:*

$$FR = P_c / P_e$$

where Pe = the number of individuals of prey taxa i in benthic macroinvertebrate samples, expressed as a percentage of the total number of individuals counted.

4. Overlap index - a measure of the similarity in composition of the diet of two groups. One measure is the Percent Similarity Index (Odum 1971), which is the smaller of the P_c values obtained for the two groups. Several other measures of diet overlap have been used by fisheries investigators (e.g., the Jacard and Sorenson indices described in Section 5.3.2.3.1, Species Composition and Diversity). Final selection of electivity and overlap indices should be deferred until further assessment is made of their mathematical properties, statistical reliability, and biological relevance (Bowen 1983).

<u>Chinook feeding behavior</u>

The frequency of occurrence of daytime feeding among recently released hatchery chinook fry, parr, and smolts will be determined by direct underwater observation. In conjunction with periodic snorkel surveys of habitat use and abundance, twenty juvenile chinook will be observed without disturbance for up to 5 minutes each. The percentage of fish observed feeding within this time period will be recorded. Other questions, such as time to first feeding, and differences in behavior, feeding efficiency, and consumption rates, will be examined later in more detail if warranted by the data.

Sampling Units and Schedule

<u>Chinook diets</u>

Samples of 20-30 hatchery- and naturally-reared fry, presmolts, and smolts will be collected annually in the summer and/or spring, as appropriate. Only Lolo Creek and Meadow Creek will be sampled during the pre-operational period. If obvious differences in diet composition are noted, sampling will be expanded in the post-operational period to include more fish, if necessary, and experimental streams supporting hatchery and/or wild chinook populations.

<u>Chinook feeding behavior</u>

Qualitative data on feeding by hatchery chinook will be collected during population abundance surveys; i.e., at least once each summer (parr) and spring (smolts).

5.2.1.3.2 Reproduction

Recommended performance variables:

1. Interbreeding among hatchery and wild fish (spring/summer chinook)
2. Straying

Application

Very little is known about the fate and reproductive success of naturally spawning hatchery fish, their interactions with natural stocks, and the relative fitness of their offspring. Previous studies suggest that although hatchery fish are able to spawn successfully (Lura and Saegrov 1991), they are less likely to survive and reproduce in the wild than naturally spawned fish, they are more likely to mate with each other than with wild fish (Leider et al. 1984, 1990), and they are competitively inferior to wild fish (Fleming and Gross 1993). Knowledge of the relative breeding success of hatchery fish is important since current supplementation policy dictates that hatchery fish compose no more than 50% of the fish spawning naturally (Larson and Mobrand 1992). Since this rule of thumb has no empirical basis, it should be evaluated further.

One of the arguments in favor of conducting spawner surveys under the NPTH is to gather evidence of interbreeding and reproductive exchange among hatchery and wild fish. If actively spawning chinook can be identified to origin, then reproductive overlap can be monitored by determining the proportion of spawning chinook pairs falling within four classes:

1. Hatchery x hatchery fish
2. Wild x wild fish
3. Hatchery female x wild male
4. Hatchery male x wild female

The null hypothesis is that mating is random; i.e., observed mating proportions are determined by the relative abundance and sex ratios of hatchery and wild fish. If sex ratios are 1:1, the expected proportions conform to the square law:

$$h^2 + 2hw + w^2$$

where h and w are the proportions of hatchery and wild chinook, respectively, among spawners. For example, if 60% of the returning adults are hatchery fish and 40% are wild, then the following mating proportions are expected under the null hypothesis:

	H_M (p = 0.6)	H_F (p = 0.6)	W_M (q = 0.4)	W_F (q = 0.4)
H_M (p = 0.6)	-	0.18		0.12
H_F (p = 0.6)	0.18		0.12	
W_M (q = 0.4)	-	0.12		0.08
W_F (q = 0.4)	0.12		0.08	

Correspondence among expected and observed mating proportions can be evaluated using Fisher's exact probability test. Note that both assortative mating and differential pre-spawning mortality may cause proportions to vary. It would also be useful to know whether spawning proportions varied among streams and over time, but these comparisons may be precluded by lack of adequate sample sizes.

Straying of returning adult wild salmon to non-natal streams is relatively rare (Quinn 1993) but nonetheless represents an important mechanism for reproductive exchange and the introduction of new and possibly adaptive genetic material into disjunct populations. It is also the primary means by which salmonids colonize new habitats (Milner 1987) and avoid unfavorable local conditions (Leider 1989). However, straying can also have negative impacts related to the disruption of adaptive gene complexes (outbreeding depression) and adverse ecological interactions. The prevalence of straying varies among species, populations, years, and hatcheries. Within conventional hatchery settings, the source of broodstock seems to be more important than rearing and release procedures in influencing the tendency of salmon to stray (Mundy et al. 1994).

Three assumptions that are fundamental to the NPTH are that some straying of hatchery-produced fish is inevitable (and may even be beneficial), that straying will not exceed natural levels, and that the observed levels of straying and gene flow will not harm recipient populations, Because the implications of straying are not fully understood, it is critically important that it be monitored under the NPTH. If possible, we would like to pinpoint the causes of straying; i.e., whether it is influenced more by genetic or environmental factors, and if the latter, whether they stem from hatchery practices or from conditions existing at the time of return (e.g., flow, temperature, etc.).

Measurements

Spring chinook salmon redd surveys will continue on selected NPTH streams, notably Lolo, Yoosa, Eldorado, Brushy Fork, Meadow, Mill and Newsome Creeks. We recommend that a pilot study be conducted, perhaps by a graduate student from the University of Idaho, of the spawning characteristics and interbreeding of hatchery and wild spring chinook in one or more of these streams. The study should include a comparison of escapement estimates based on adult counts at weirs and redd surveys, estimates of pre-spawning mortality, and an assessment of spawner distributions and pairings within the drainages. A combination of external body tags and fin marks will be used to distinguish hatchery fish from wild fish on the spawning grounds.

If hatchery fish appear to differ from wild fish, we recommend that additional field and laboratory experiments of hatchery and wild chinook interbreeding be conducted to identify the mechanisms responsible.

The prevalence of straying will be indexed by PIT tag and coded wire tag recoveries in adjacent streams, watersheds, and hatcheries.

Sampling Units and Schedule

NPTH biologists will assess the feasibility of a field study to investigate the spawning characteristics and reproductive success of hatchery and wild spring chinook salmon during the pre-operational period. If such a study appears warranted and sufficient funds are available, it will be conducted during the post-operational period. Straying will be monitored at hatchery and adult sampling facilities within and outside the Clearwater Basin. Tags will also be retrieved from the carcasses of fish collected on the spawning grounds of NPTH streams,

5.2.1.3.3 Disease Transmission

<u>Recommended performance variables:</u>

1. Ambient monitoring: Prevalence of infectious and non-infectious diseases among free-living chinook parr.
2. Event-triggered monitoring: Disease diagnosis, prevalence, and mortality effects among free-living chinook during disease outbreaks.

Application

The purpose of disease monitoring is to collect data which allow assessment of changes in wild and hatchery population status that can be attributed to viral, bacterial, and parasitic diseases. Major concerns are the progression of disease among recently released hatchery fish, the horizontal transmission of disease from hatchery to wild fish, and the extent of mortality attributable to disease agents (Hastein and Lindstad 1991). Note that other elements of fish health monitoring, notably physical and physiological status are addressed through Stock Status Subcategories.

Disease monitoring will include routine sampling ("ambient monitoring") to establish background levels of important disease agents known to affect chinook populations, and extemporaneous ("event-triggered") sampling of disease outbreaks among free-living fish to determine the cause and extent of mortality.

Hatchery fish are exposed to novel and potentially stressful conditions during and following release. The resultant physiological stress may activate latent bacterial or viral infections formerly held in check by the protective mechanisms of the fish. Periodic sampling for disease and measurements of survival among post-release life stages of hatchery fish may help explain the effects of one on the other.

Monitoring of disease prevalence among free-living populations presents many obstacles, Many potential pathogens can exist in a population without causing disease. Or they may be present at such low levels as to be unmeasurable. Significant levels of disease are typically difficult to detect in the field, either because the fish are disease free, they are not dying from pathogens at the time of sampling, or they have already died and are therefore unavailable for sampling. Because wild fish may not show clinical signs of disease, it will be more difficult and costly to examine them for the presence of disease agents. It will be doubly hard to relate measured levels of disease to observed patterns of mortality (Anderson and Barney 1991).

Monitoring under this performance criteria should be carefully coordinated with and draw upon resources and expertise available through other fish health and hatchery effluent monitoring activities. Sampling guidelines and policies developed by the Integrated Hatchery Operations Team and the Pacific Northwest Fish Health Protection Committee should be heeded if possible.

Measurements

Ambient monitoring - References to disease monitoring of wild chinook populations presume that they are sufficiently abundant to justify sacrificing the number required for disease sampling. Sampling will be restricted to populations from which genetic samples are taken. If possible, whole fish samples collected for electrophoretic analysis should be preserved in a condition that also permits disease sampling and diagnosis. Focus should be on disease agents known to cause significant mortality among chinook, most importantly *Renibacterium salmoninarum*, causative agent of bacterial kidney disease.

Disease samples will be taken using proper techniques and media to ensure that they arrive at the diagnostic lab in good condition. We recommend that sampling be conducted under the supervision of a certified fish health specialist, and that samples be processed at a qualified fish disease laboratory. Analysis of samples should follow standard protocols, as defined in the latest published edition of the AFS "Fish Health Blue Book" (Procedures for the Detection and Identification of Certain Fish Pathogens). The Tribe should consult further with fish health experts at research facilities such as the Idaho Department of Fish and Game's Eagle Fish Health Laboratory for help in identifying and treating disease.

Sampling of returning wild adults should be considered if high pathogen levels are detected among hatchery spawners. Samples should be obtained using non-lethal methods unless internal organ tissues are needed, in which case they should be obtained from spawner carcasses.

Event-triggered monitoring - Localized and intensive disease monitoring should be implemented whenever significant disease outbreaks occur among wild populations. In this case, samples would include apparently healthy fish, moribund fish showing signs of the disease, and dead fish, if locatable. Standard necropsy, pathogen sampling, and data reporting procedures should be followed. If the disease appears to be stress-mediated, environmental parameters such as temperature and dissolved oxygen should be measured as well. This information should be combined with laboratory diagnosis and other disease monitoring data to give a more complete picture of the problem.

Sampling Units and Schedule

Only one treatment-control stream pair need be sampled each year. From these streams, random samples of 50 free-living hatchery and wild chinook parr will be collected in late summer. Sample sizes were determined as the minimum size required to detect a pathogen in 2% of the fish at the 95% confidence level (Amos 1985). Smaller sample sizes would be required if the pathogen were present in a higher percentage of fish.

Event-triggered sampling will be conducted on an *ad hoc* basis.

5.2.1.4 Summary of M&E Activities

A flow chart summarizing Intraspecific Interaction performance criteria monitoring activities is presented as Figure 15.

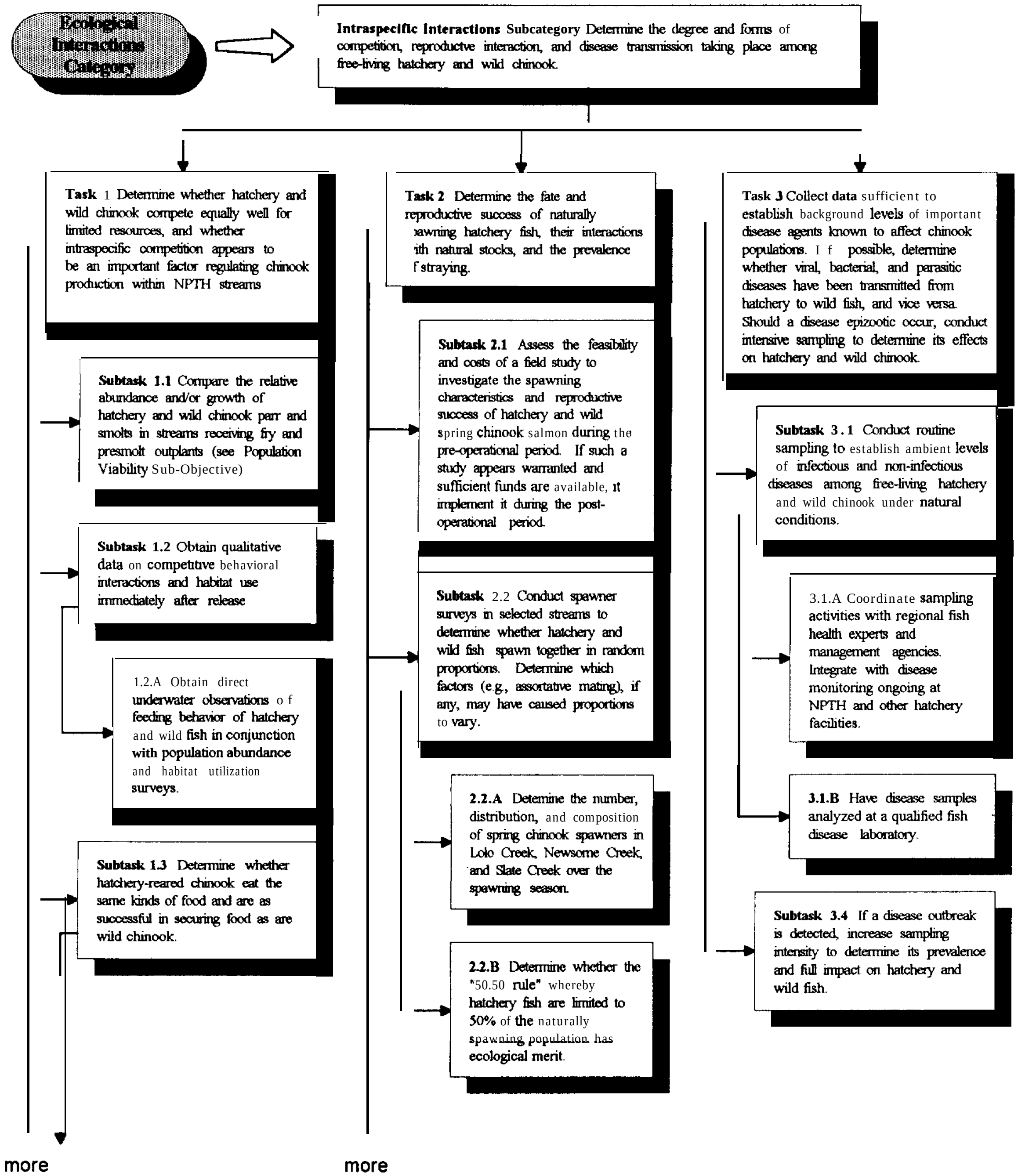

Figure 15. Monitoring and evaluation tasks and subtasks identified for the Intraspecific Interactions Subcategory (Ecological Interactions Category).

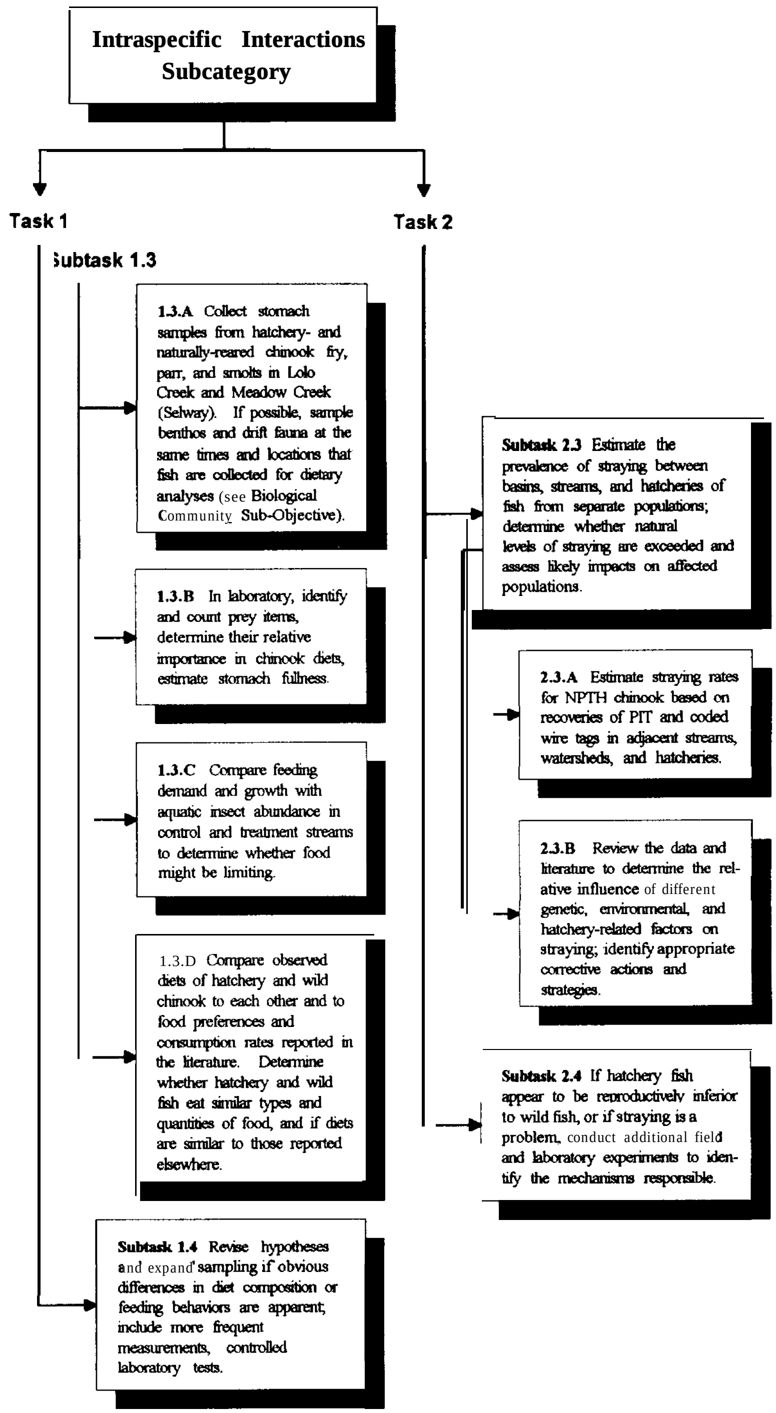

Figure 15 (continued). Intraspecific Interactions tasks and subtasks.

5.2.2 *Interspecific Interactions*

5.2.2.1 Background

This sub-objective is addressed by several performance criteria relating to competition, predator-prey dynamics, disease, and other potentially significant ecological interactions between resident fish and chinook salmon (both hatchery and wild individuals). Because steelhead trout, cutthroat, and bull trout are important competitors and/or predators of chinook, they will receive the greatest attention of the fish species present. Uncertainties relating to ‘the quantity and types of food available to chinook are dealt with Intraspecific Competition (Section 5.2.1.3.1) and Biological Community (Section 5.3.2.3.1) subcategories.

We are concerned that interspecific interactions will prevent the restoration of chinook populations to sustainable levels. If the existing fish communities are highly structured and one or more competitor species have exploited the ecological niche formerly occupied by chinook salmon, then re-establishment of chinook populations may be difficult. Furthermore, there is reason to believe that predation may be an important factor (Patten 197 1), especially in mainstem reaches. However, even if this is the situation, as long as there are no compelling reasons to maintain the other species at their current levels of abundance, it should be possible to reduce their numbers and to increase the number of chinook outplanted to the point that the “invasion resistance” (*sensu* Baltz and Moyle 1993) of the established community is overcome.

Another form of interspecific interaction, this one involving humans, that may thwart progress towards rebuilding goals is tribal, sport, or commercial fishing. A major risk associated with hatchery fish is the potential for overharvest of less abundant, commingled stocks. This issue will be addressed under the Harvest Category.

5.2.2.2 Critical Uncertainties

Interspecific Interaction critical uncertainties and attendant risks are summarized in Table 20.

Table 20. Interspecific Interactions assumptions and associated level of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Competition	1	Interspecific competition will not prevent chinook populations from becoming reestablished	3
	2	Interspecific competition will not cause unacceptable impacts to non-target species or populations	3
Trophic Dynamics	3	Predators will not kill chinook nor modify their behavior to the point that chinook populations cannot persist	3
	4	Supplementation will not cause further declines in threatened or endangered species within the ecosystem	4
	5	Predation risk and mortality will not increase among other species as a consequence of supplementation	3
	6	Supplementation will not alter trophic relationships or community structure within the ecosystem	3
Pathogen Interactions	7	Disease and parasites will not prevent chinook populations from becoming established	3
Other	8	The potential for interspecific hybridization is low	2
	9	Biotic interactions taking place in mainstem, estuary, and marine environments will not thwart supplementation	3
	10	Supplementation will not promote the overharvest or management neglect of other species	3
	11	Biotic interactions between supplementation fish and non-target species will not obscure treatment effects	4

5.2.2.3 Performance Variables

5.2.2.3.1 Competition

Recommended performance variables:

1. Competitor abundance
2. Resource use, interactive behaviors

Application

We will attempt to monitor the effects of competition between juvenile chinook and their principle competitors through direct underwater observations of interactive behaviors at the time of release, through overlap in utilization of food and habitat, and through changes in relative abundance. Emphasis will be on the latter performance variable since it clearly reflects the outcome of interspecific competition, and can be directly applied to performance standards and management goals developed for other species.

There is a strong likelihood that supplementation will cause a change in the long-term abundance of other economically or ecologically important species within the Clearwater drainage. In general, the abundance of competitor and predator species is expected to go down and up, respectively. Unfortunately, the natural variability in abundance in most populations is so great that it will be difficult to establish a baseline against which supplementation effects can be measured. Nevertheless, it is important that long-term monitoring of selected species commence immediately, and that an acceptable balance be struck between supplementation production targets and the abundance of resident fish species. NPTH managers must commit to incorporating monitoring results into future decisions involving hatchery operations.

Measurements

The late-summer abundance of all non-target competitor species (steelhead, cutthroat trout, bull trout, brook trout, etc.) will be measured in conjunction with ongoing chinook parr monitoring studies (see Abundance performance criteria, Section 5.1.3.3.1). Direct underwater observation will be used to quantify mean densities of resident fish by year class in representative channel units in low gradient ("C") reach types of all NPTH experimental streams. Standard habitat surveying techniques will be used to estimate stream surface areas, so that count data may be converted to density estimates.

Observations of competitive interactions (e.g., aggression) and habitat use at the time of release or shortly thereafter will be made in conjunction with intraspecific interaction studies. The types of data and method of collection are described in the preceding section.

Sampling Units and Schedule

Fish abundance in at least 5 units of each habitat type will be sampled once each year in mid-to-late summer in permanently established index reaches in NPTH streams.

5.2.2.3.2 Trophic Dynamics

Recommended performance variables:

1. Predator abundance index (cutthroat, bull trout, squawfish, avian predators)
2. Prey abundance index (see Intraspecific Competition and Biological Community performance criteria)
3. Direct measurement of instantaneous mortality due to predation at time of release
4. Estimated losses to predators during freshwater residency and smolt outmigration

Application

Our approach to evaluating the effects of supplementation on predator populations and vice versa will include monitoring the distribution and relative abundance of key predators and deriving estimates of the number of chinook consumed by them. Direct estimates of consumption by predators are time-intensive, requiring extensive field sampling programs which may be difficult to accommodate on a management budget. For this reason, we propose to limit direct measurements of predation to estimates of the number of hatchery chinook lost to predation immediately following release. First-order approximations of the total number of chinook that might potentially be lost to predation during freshwater residency and smolt outmigration periods will be obtained by applying indirect methods, including freshwater production-based and smolt migration simulation models.

Measurements

To assess predation impacts on hatchery chinook, we recommend approaches that range from direct measurements of consumption by predators to the application of production-based and smolt survival models.

Immediate post-release losses to predation: The number of hatchery chinook lost to predation at a release site within 24 hours of release will be determined from by examining the stomach contents of selected individual predators, and multiplying the average number of chinook eaten by the total number of predators present. Stomach samples will be taken from individuals whose distribution overlaps that of the released chinook. Initially, steelhead, cutthroat, and bull trout will be targeted; brook trout, whitefish, and sculpins may be added to this list at a later time. Predation by squawfish and smallmouth bass is expected to be negligible in release areas due to small population sizes. However, the potential for significant predation by these species is high in mainstem reaches of the Clearwater, Snake, and Columbia rivers. A variety of marine vertebrate species, notably pinnipeds, prey upon chinook in estuarine and marine areas. It would be extremely difficult to measure predation effects in these areas so we do not recommend attempting to do so.

Total chinook production lost to predation: As a first-order approximation of release-to-smolt mortality attributable to predation by a particular species, we recommend one of the production-based approaches described by Ney (1990). P-B models offer a simple and rapid procedure to estimate chinook consumption from predator population data. The simplest approach requires estimates of annual production for different age classes (cohort) of the predator population. Production (P = GB) is the product of the instantaneous rate of growth (G) and mean biomass (B) over the year, A range of production estimates can be found in the literature for most salmonid species. These can be applied to NPTH streams, with adjustments made for observed predator standing crops.

According to Ney (1990), theoretical total annual consumption (C_T) by each predator age class can be estimated by the assumed relationship:

$$C_T = 2P + 3B$$

The multipliers were derived from measurements of gross food conversion efficiency and annual maintenance rations for adult piscivorous fish in temperate freshwater systems. It may be possible to derive multipliers specific to resident salmonids using bioenergetic models. C_T will overestimate actual consumption to the extent that chinook are unavailable to the predator and other prey items are represented in the predator's diet. Availability is determined by the overlap of predator and chinook populations in space and time, and by the fraction of the chinook that is usable (catchable, ingestible) by the predator of interest. Values generated for C_T (scaled to the time interval between release and smoltification) can be compared with production estimates for hatchery and wild chinook (P_H and P_W). The ratios C_T/P_H and C_T/P_W provide an index of potential predation by species.

Insights into potential losses of chinook smolts to predation can be gained by applying the Columbia River Salmon Passage Model developed by Jim Anderson and colleagues at the University of Washington. The model simulates the downstream migration and survival of smolts through the mainstem portion of the Snake and Columbia Rivers. The effects on chinook survival of varying predator densities and activity levels in different river segments can be evaluated under various combinations of biological and environmental parameters.

5.2.2.3.3 Pathogen Interactions

The development of disease in chinook salmon is a complex interaction between the fish, the environment, and the disease agent involved. We do not propose to characterize this interaction, but do recommend that microfauna having potential to exert significant infectious pressure on hatchery and wild fish populations be routinely assayed under a disease monitoring program. See Section 5.2.1.3.3 (Disease, Intraspecific Interactions) for further details.

5.2.2.4 Summary of M&E Activities

A condensed summary of monitoring tasks and activities proposed for Interspecific Interactions is given in Figure 16.

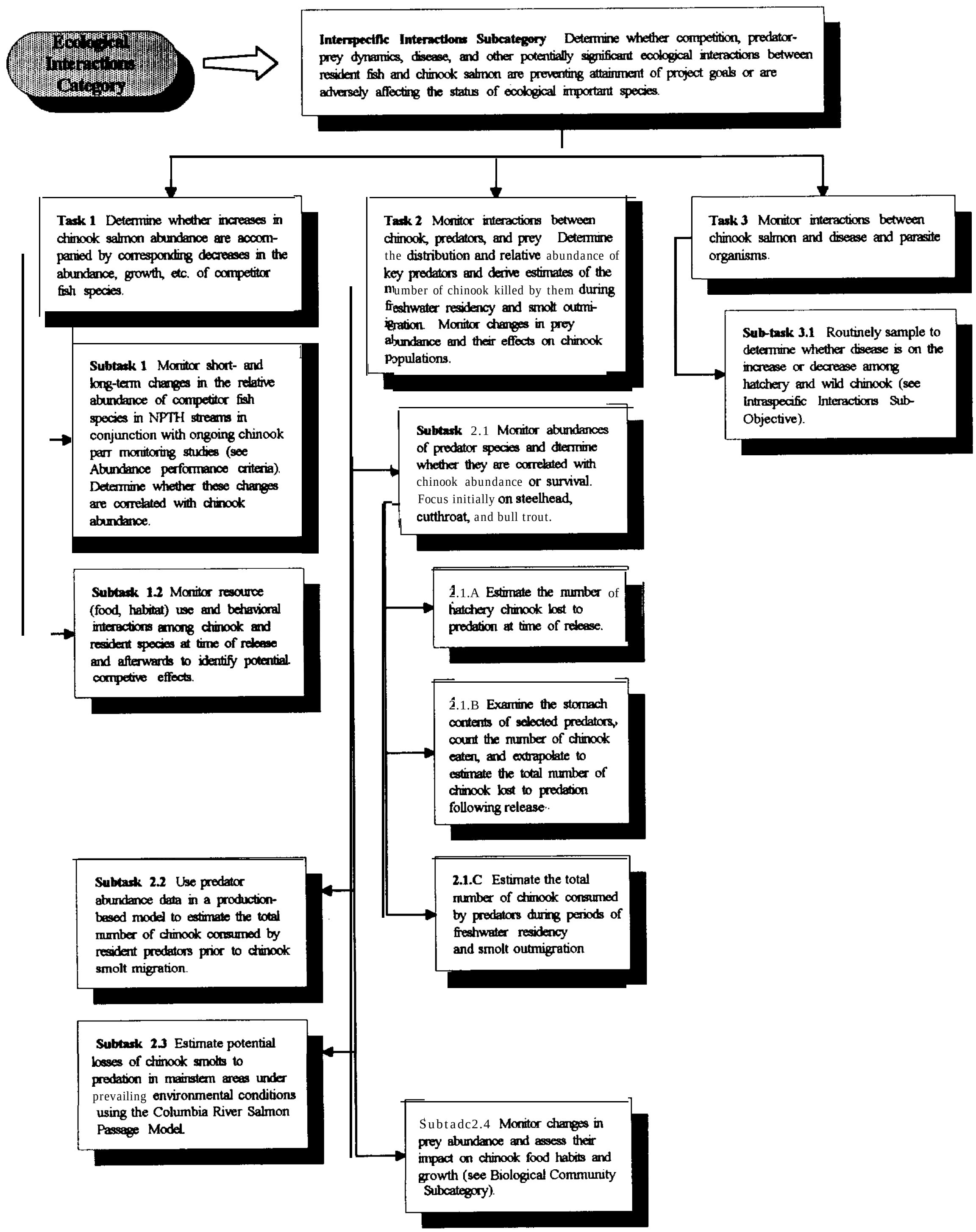

Figure 16. Monitoring and evaluation tasks and **subtasks** identified for the Interspecific Interactions Subcategory (Ecological Interactions Category).

Natural Environment

Much is known of the habitat requirements and preferences of salmonids along with the environmental conditions under which they exist. A discussion of the myriad interactions between salmonids and environmental factors which regulate their numbers and production is beyond the scope of this document. The reader should consult Fausch et al. (1988), Marcus et al. (1990), Bjornn and Reiser (1991), and references therein as a useful starting point for information on salmonids and their habitat.

The purpose of this section of the report is to identify high-risk uncertainties under the Natural Environment Category and to devise monitoring and evaluation activities that enable Nez Perce Tribe fisheries managers to refine project goals and objectives. We identity elements of the natural environment that are critical to implementation of the NPTH and to the long-term maintenance of re-established chinook populations. Monitoring strategies and techniques are developed within the usual framework of performance criteria and variables.

We have organized Natural Environment critical uncertainties and performance variables under three Subcategories: Production Potential, Biological Community and Extrinsic Factors. Performance criteria and variables associated with the Production Potential subcategory are delineated in the first part (Section 5.3.1) of this section of the report. The criteria, variables, and tasks are designed to monitor the availability of resources and the ecological processes expected to influence the natural production and viability of chinook populations within NPTH streams. Specifically, sampling and modeling approaches are described by which existing and new data can be used to estimate the production potential of NPTH streams under historical, current, and projected future conditions. This information will be useful in identifying constraints, devising supplementation strategies, setting hatchery and natural production goals, and determining whether goals are met.

Under *Biological Community* and *Extrinsic Factors* subcategories (Sections 5.3.2 and 5.3.3) are grouped monitoring and evaluation criteria, variables, and tasks that seek to describe critical ecosystem attributes and human activities that may be influenced by the project or are likely to influence its success. For the project to be successful, the Nez Perce Tribe must actively monitor watershed conditions and a wide array of federal and state management activities. As necessary, the Tribe should intervene or take other steps to ensure the restoration and protection of biological diversity and watershed -integrity within the Clearwater River drainage. It is also essential that the Tribe monitor and, if possible, ameliorate external impacts such as hydrosystem operations, ocean conditions, harvest, and special management regulations which might affect the productivity of NPTH chinook populations. Even if the NPTH were to realize the full freshwater production potential of Clearwater streams, poor survival in mainstem and ocean areas could result in poor adult returns and reproductive failure.

5.3.1 *Production Potential*

5.3.1.1 Background

We propose to classify, inventory, and assess the biophysical resources that are essential for chinook population growth, stability, and persistence. In particular, we would like to know how many chinook can be produced, on average, by individual NPTH streams. This information will be used to refine hatchery and stream production goals and to identify alternative mitigation and enhancement measures.

After an initial determination of resource status is made, periodic reassessments will occur during the post-operational phase of the NPTH. Monitoring activities will combine proven sampling methods with new statistical and modeling techniques to assess the quality, quantity, distribution, and pattern of chinook habitat within NPTH streams. Salmonid habitat will be classified and measured at three spatially nested hierarchical levels - the reach (macrohabitat), the channel unit (mesohabitat), and the location of individual fish (microhabitat). All levels must be considered if we are to accurately assess production potential within NPTH streams. We will also monitor the status and trend of critical water quality parameters and of riparian areas adjacent to NPTH streams in order to assess the effects of out-of-channel variables and processes on instream chinook habitat. All monitoring activities will be carefully coordinated with those conducted under Stock Status and Biotic Interactions Categories.

5.3.1.2 Critical Uncertainties

Production Potential uncertainties and associated levels of risk are identified in Table 21.

Table 2 1. Production Potential assumptions and associated levels of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Hydrology	1	Chinook production will be strongly affected in both the short- and long-term by the hydrologic regimes of project streams	2
	2	Flow conditions are presently adequate to support natural production of chinook salmon; neither floods nor low flows will diminish food supplies or space to the point that population viability is threatened	3
	3	Regulated and unregulated streamflows will be suitable for up- and downstream passage	4
Water quality	4	The distribution and production of chinook will be controlled in part by water temperatures	1
	5	Water temperatures do not reach levels which disrupt normal life history functions and thereby limit freshwater production	3
	6	Sediment and flow will interact to maintain suitable spawning, food production, overwinter residency, and other characteristics associated with high quality chinook habitat	4
	7	Suspended sediment concentrations will not reach levels that are deleterious to chinook	2
	8	Natural concentrations of chemical water quality parameters (e.g., dissolved oxygen, ammonia) will not impair the normal function or activities of resident biota, especially downstream of hatchery facilities	3
Riparian areas	9	Riparian areas and associated vegetation will adequately provide or moderate water temperatures, streambank stability, nutrient inputs, cover elements, and terrestrial food organisms	3
Habitat	10	NPTH streams are capable of supporting viable natural populations	3
	11	Habitat exists or is accessible over a large enough area to permit self-sustaining populations to persist within the metapopulation matrix	3
	12	Historical, existing, and potential carrying capacities can be estimated for density-dependent life stages and life history types	3
	13	Sources and effects of density-dependent and density-independent mortality can be distinguished	4
	14	The key factors and life history types/life stages that regulate chinook production can be identified	4
	15	NPTH streams are capable of supporting significant increases in natural production	3
	16	Habitat conditions will not degrade in the future to the point that carrying capacity is reduced	4

Table 2 1 (continued).

Performance Criteria	Assumption Number	Assumption, Description	Level of Risk
Habitat (continued)	17	At full seeding, supplementation can be used to circumvent habitat limitations or other bottlenecks (natural or otherwise) that occur within the Clearwater River basin	2
	18	The Rosgen stream classification system will accurately reflect the variability in large-scale habitat conditions that influence chinook production	2
	19	Stratification and evaluation (quality ranking) of stream reaches will permit a rapid, coarse-level assessment of stream carrying capacity; enough information exists or will be obtained to enable reasonably accurate production potential estimates of different stream reaches	2
	20	Variation in the distribution and local abundance of juvenile spring chinook can explained by differences in the frequency and type of habitats (channel units within a reach) present	2
	21	The carrying capacity and production potential of mainstem reaches for fall chinook can be accurately determined by applying hydraulic and microhabitat (velocity, depth, and substrate) models to existing data	3
	22	Carrying capacity will be a function of food availability and suitable habitat relative to the ecological requirements of the species life stage	2
	23	Spawning habitat in target streams will not limit chinook populations at proposed seeding or rebuilding levels	3
	24	Spring chinook smolt production is influenced more by summer carrying capacity than by winter carrying capacity; winter habitat is sufficient to support the number of parr surviving at the end of the growing season	4
	25	The primary constraints on adult production are factors affecting smolt survival; ocean rearing conditions will not limit natural production	4
	26	The quantity and quality of instream cover will be sufficient to enable chinook to coexist with other species at self-sustaining levels	2
	27	The quality and quantity of habitat in the migration corridor, estuary, and ocean is sufficient to support target life history types and life stages at projected levels of supplementation	4
	28	Freshwater carrying capacities and production potential can be estimated for non-target species	3
	29	Supplementation will reduce the production of some, but not all, resident species	2

5.3.1.3 Performance Variables

5.3.1.3. 1 Hydrology

Recommended performance variables:

1. Snowpack
2. Discharge
   a. Summary flow statistics
   b. Duration curves
   c. Flood and drought recurrence intervals

Application

The amount and timing of water entering a stream influences the structure and texture of the channel, the physical and chemical characteristics of the fluid medium, and therefore the biological forms and processes occurring within the stream. To index variability in the production potential of NPTH streams, we propose to monitor hydrological inputs in the form of snow and rainfall, and hydrological outputs in the form of stream discharge.

NPT biologists will compile historical and recent hydrological data to identify both short- and long-term, seasonal and interannual, variations in precipitation and discharge. Hydrological monitoring should commence immediately and after a sufficient database has been secured, the models should be used to forecast and explain variability in potential production in project streams as it relates to precipitation and discharge. Possible correlations between snowpack, streamflow patterns, and stock status performance variables should be sought.

Measurements

Pre-operational: Download historical precipitation and stream gaging records from appropriate sources (e.g., the National Water Information System of the U.S. Geological Survey). Statistically summarize both datasets; the discharge data should be expressed as mean daily, monthly, and annual flows. For each stream or reach, identify the shape and dimensions of the normal annual hydrograph and its extremes (e.g., floods, spring run-off, summer baseflow, etc.) Identify low, normal, and high flows, corresponding to flows that are exceeded 90%, SO%, and 10% of the time, as determined from flow duration curves. Compute flood and drought recurrence intervals, in years. Examine data for long-term trends, particularly those attributable to human activities.

Post-operational: Continue to monitor and evaluate snowpack and streamflow data from established USGS gages and compare with historical record. Continue to measure discharge and water elevation (gage height) at streamflow monitoring locations on treatment and control streams. Establish a stage-discharge relationship for each stream. Correlate flow measurements at these sites with streamflows measured simultaneously at nearby USGS gaging sites. Correlate flow variables with chinook movements, survival, etc. Identify the potential for changes in flow regime resulting from land use activities.

Sampling Units and Schedule

We recommend a historical analysis and continued monitoring of snowpack measured at 2 sites, one each in the upper and lower portion of the Clearwater drainage. Streamflow records should also be similarly analyzed for established gaging sites on NPTH tributaries and mainstem rivers. A single permanent discharge measurement transect should be established on each treatment and control stream. When measuring discharge, no more than 5% of the total flow should be measured at each vertical along a transect. A wide range of flows and gage heights should be sampled. Measure discharge on at least 20 different occasions prior to project startup; and at least five times each year thereafter. Sample gage heights on an opportunistic basis. Modify sampling regime as necessary to achieve monitoring objectives.

5.3.1.3.2 Water Temperature

Recommended performance variables:

1. Summary temperature statistics
2. Annual heat budgets

Note:. Water temperature is one of three performance variables identified as appropriate indicators of water quality. Sediment and the Water Quality Index are the other variables of interest; they are discussed under separate performance criteria.

Application

Water temperature effects on salmon physiology, growth, and survival are well-documented and are deserving of long-term monitoring and evaluation. Temperature effects are most critical during summer when juveniles are rearing and during winter when embryos are incubation. Temperature preferenda and tolerance levels for spring chinook life stages are compiled in Table 22. Prolonged temperatures outside the tolerance range of salmonids

Table 22. Recommended temperatures for spring chinook salmon life stages (Source: Armour 1992).

Life Stage	Temperature	Range
Adult migration	3.3-13.3° C 2.0-16.0° C	Recommended” Tolerance[b]
Spawning	5.6-13.9° C 5.0-14.0° C	Recommended[a] Tolerance[b]
Incubation	5.0-14.0° C 0.0-16.0° C	Recommended[a,c] Tolerance[b]
Juvenile rearing	7.9-13.8° C 2.0-16.0° C	Recommended” Tolerance[b]
Other	• Adult spawning migrations are blocked at temperatures exceeding 21 .0° C (Major and Mighell 1 967)[d] • Spawning adults become susceptible to lethal diseases when temperatures exceed 16.0° C (Snyder and Blahm 1968) • 850 daily temperature units required for hatching[e] • 700 daily temperature units required beyond hatching for emergence from gravel[e] • Juvenile fish cannot tolerate temperatures exceeding 25.1° C for a l-week period (Brett 1952)	

[a] Reiser and Bjornn (1979)
[b] Wilson et al. (1987)
[c] 4.5-12.8° C required from the outset of incubation for a period of > 2 weeks but < 3.5 weeks for good embryo survival (Brett 1952).
[d] Reported for sockeye salmon but assumed to apply.
[e] T. Levendofske, personal communication

result in death. Suboptimal temperatures can impair competitive, predator avoidance, and migratory abilities; they can also reduce the scope for activity, retard or halt development and growth, and lower resistance to pathogens and toxic substances.

The production potential of NPTH streams is directly related to prevailing thermal regimes. In natural environments, the effects of temperature are conditioned by other physical, chemical, and biological processes. As part of a larger ecosystems analysis, the effects of land use on water temperature, and water temperature on trophic interactions within freshwater habitats should be investigated. Potential causes of excessive temperatures and effects on important ecological processes should be identified, and their probable contributions to chinook survival evaluated, weighted, and if possible generalized to other situations. From this information, causes should be identified and sites prioritized for rehabilitation.

Measurements

Historical water temperature records from the USFS, USGS, and other sources should be compiled and analyzed for significant spatial and temporal trends. Temperature data collected to date on NPTH streams should be analyzed without further delay. The Nez Perce Tribe currently monitors water temperatures in several NPTH streams using automatic temperature recorders (e.g., Omni Datapods or Ryan Tempmentors). We recommend a review of these data to determine whether monitoring should continue at the same locations and if new permanent monitoring sites need to be established. Temperatures should be measured year-round at a minimum of one site in each NPTH stream. The Tribe should consider establishing other monitoring sites in stream reaches where temperatures are suspected of exceeding tolerance limits for chinook spawning, incubation, or rearing.

Summary temperature statistics (e.g., daily means, monthly and annual 1- and 7-day minima and maxima) and annual heat budgets should be calculated for each stream and reach of interest. Habitat suitability based on water temperatures and temperature units should be determined for each species/life stage for all production areas (including downstream mainstem reaches).

Sampling Units and Schedule

Available temperature data should be compiled during the pre-operational period. Data collection and analysis should be coordinated with temperature monitoring activities currently underway in the subbasin. For example, water temperatures will be measured in mainstem areas of the Clearwater River as part of ongoing fall chinook research. In NPTH streams, water temperature should be measured at hourly intervals on a continuous basis at a minimum of one permanent monitoring station per stream. Candidate monitoring stations include. permanent acclimation and weir sites. Temporary monitoring sites should be established at experimental release sites and in reaches where temperatures approach or exceed thermal tolerance limits for chinook. Additional ambient temperature data should be obtained from federal and state agencies.

Products:

1. A map of water temperature monitoring sites and measured temperatures, categorized according to their suitability for chinook and potential for degradation/restoration.
2. A comparison of pristine and existing temperature regimes; identification of discontinuities that may limit natural production.
3. Prioritized list of potential restoration sites and recommended remedial actions.
4. Reassessment of long-term temperature monitoring needs and sites.

5.3. I. 3.3 Sediment

Recommended performance variables:

1. Sediment yield
2. Turbidity

Note:. Substrate composition and quality will be monitored in chinook spawning and rearing habitats. They are considered Microhabitat performance variables and are therefore described under the Microhabitat performance criterion. This performance criterion discusses the need to monitor sediment production - one of three variables selected to index water quality within NPTH watersheds. The other water quality variables - water temperature and the Water Quality Index - are discussed under separate performance criteria.

Application

If sediment is delivered to a stream in quantities exceeding that stream's capacity to transport it downstream, then deposition and aggradation occurs. The potential for deleterious impacts on chinook spawning and rearing habitats is high in NPTH streams, since many of them drain the highly erodible parent material of the Idaho Batholith. NPTH planners should attempt to quantify this potential as a function of the topography, geology, soils, vegetation, land use, etc. within NPTH watersheds. This information can then be used to predict the effects of proposed human activities.

Turbidity levels in streams generally correlate positively with suspended sediment concentrations. High levels of suspended sediment can be deleterious to salmonids. Although suspended sediment concentrations in the Clearwater River are unlikely to reach levels known to adversely affect the feeding, growth, and survival of salmonids, turbidity should nevertheless be monitored as an index of sediment loading and deposition.

The procedures selected for monitoring the effects of sediment on chinook salmon and their habitat is based on a method developed by the USFS for the Idaho Batholith, which would include all of the NPTH drainages. The USFS method is described in detail by Stowell et al. (1983). We recommend that sufficient data be gathered to detect reasonable (>10%) changes in habitat quality.

Measurements

Sediment yields and in some cases, turbidity data, may be obtained from the USFS. The USFS R1-R4 model predicts sediment yield from land disturbances. These data and predictions should be examined to estimate existing sediment delivery rates to NPTH streams and their sensitivity to future disturbances and sediment inputs. USFS and other knowledgeable personnel should be consulted. The USFS should be encouraged to regularly update its database and to continue to implement best management practices to reduce the amount of sediment delivered to the streams. If existing data are insufficient to describe sediment delivery to the NPTH streams, we recommend that resources be located to conduct an analysis before project startup.

Turbidity should be measured with a field meter so a large number of samples can be taken in a short time.

Sampling Units and Schedule

Databases and sediment model outputs should be updated annually. Tribal and USFS geomorphologists and hydrologists should meet on a regular basis to discuss sediment production, sources, and impacts on NPTH streams and chinook populations. Turbidity should be monitored during the spring runoff period since the majority of sediment is delivered to the stream at this time.

5.3.1.3.4 Water Quality

Recommended performance variables:

1. Water temperature
2. Sediment yield
3. Turbidity
4. Water Quality Index

Note:. Water temperature, sediment yield, and turbidity are discussed in separate performance criteria. Substrate quality is addressed as a Microhabitat performance variable.

Application

This category of information includes water temperature and sediment - parameters considered important barometers of water and habitat quality. The primary NPTH objective is to conduct ambient or trend monitoring with the ultimate goal of maintaining or restoring to NPTH full habitat function as it relates to water quality. Monitoring activities are designed to take advantage of ongoing tribal, state, and federal water quality sampling and management programs, most notably the State of Idaho Nonpoint Source Management Program (Clark 1990).

Measurements

State of Idaho Nonpoint Source Management Program recommends ambient monitoring of the following water quality parameters:

Temperature	Solids
Oxygen	. Bacteria
pH	Ammonia Toxicity
Trophic Status	Metal Toxicity
Aesthetics	

A standardized Water Quality Index may be calculated for each of these parameters by referencing measured values to a "severity scale" ranging from 0 to 100. The severity scale reflects water pollution criteria of EPA and the State of Idaho, including sensitivity of aquatic life to the parameter in question. The lower the WQI the better the water quality.

Water Quality Index	Rating	Definition[1]
0-20	Good	Water quality is generally high and beneficial uses are fully supported
21-60	Fair	Water quality is periodically marginal and uses are partially supported
61-100	Poor	Water quality is poor and does not support beneficial uses

[1] Beneficial use is defined as "the reasonable and appropriate use of water for a purpose consistent with Idaho state laws and the best interest of the people."

In addition to the aforementioned parameters, consideration should be given to measuring electrical conductivity (a surrogate for total dissolved matter) since it may possibly be related to stream carrying capacity for salmon (R. Reisenbichler, USFWS, pers. communication). No WQI scale has been developed for conductivity.

If funds are available, each of the parameters identified above should be sampled on a regular basis. The NPT should seek assistance from the State DEQ on sampling protocols, laboratory analyses, and data storage, interpretation, and reporting. Quantitative databases of interest are maintained by the U.S. Environmental Protection Agency (National Water Quality Data Storage and Retrieval System) and the State of Idaho, Division of Environmental Quality.

Sampling Units and Schedule

The U.S. Geological Survey currently maintains a water quality monitoring station on the lower Clear-water River at Spaulding; the State Division of Environmental Quality (DEQ) maintains a similar station near Orofino. Provided that a cooperative agreement can be struck with DEQ, the Nez Perce Tribal Fisheries Department should arrange to collect water quality data at permanent monitoring stations on NPTH streams at no less than quarterly time intervals. Sampling sites should correspond to streamflow measuring sites established on each NPTH stream.

5.3. I. 3.5 Riparian Area

Recommended performance variables:

1. Distribution and acreage of riparian area
2. Vegetation composition and condition

Application

Riparian areas are the vegetative zones that occur between the upland or terrestrial zone and the aquatic or deep water zone. They are diverse, dynamic, complex, and absolutely essential to the maintenance of stream health (Naiman et al. 1993). Alteration of riparian areas, including removal of vegetation and streambank destabilization, occurs in association with timber harvest, agricultural, mining, and construction activities. Riparian vegetation intercepts runoff, shades streams, and acts as a source of terrestrial food items and nutrients. Roots and larger organic debris help stabilize banks and provide overhead and instream cover. The maintenance of an intact riparian zone will be essential to meeting NPTH natural production goals.

The Tribe should adopt a uniform system of defining and classifying riparian areas, and identifying their status and trend. A method based on aerial photo interpretation, ground truthing, and mapping was proposed and partially implemented on the Nez Perce National Forest (Harrison and Kellogg 1986).[17] The State of Idaho DEQ has adopted a standardized method of riparian vegetation inventory and classification (Burton et al. 1991). With some modification, we recommend use of their method for NPTH monitoring purposes. The ultimate goal is to identify the location, area1 extent, and composition of riparian vegetation on computer-generated maps. Status and trend data will help identify where special management may be required. Monitoring and assessment of riparian areas should be closely coordinated with the State of Idaho, U.S. Fish and Wildlife Service (National Wetlands Inventory), U.S. Forest Service and other agencies as appropriate.

Measurements

Contact the above-mentioned agencies for information on existing riparian databases, aerial photographs, maps, and sampling procedures. Obtain recent aerial photographs (preferably true color, 1: 10,000 to 1:24,000 scale stereo coverage) of NPTH stream courses. Query databases and examine photographs to determine how much is known of riparian vegetative community composition (type) and condition in NPTH stream watersheds. Evaluate the relative importance (ecological potential) of riparian areas within each stream reach with respect to chinook production. Describe how the riparian zone has been altered by human activities. Identify potential climax vegetation, future trends in human and natural disturbances, and their likely impact on chinook populations.

Aerial Photography

Air photos will be used for riparian vegetation analysis, pre-typing of stream reaches, and field mapping of habitat units and other significant channel features. Large-scale aerial photography will also be useful for experimental or specific design applications such as acclimation site development or habitat improvement projects. Riparian areas adjacent to NPTH streams should be delineated on aerial photos and classified based on vegetative characteristics (e.g., physiognomy and dominant/subdominant plant species), visible hydrology, and local geography. Ground truthing should be used to corroborate aerial photo interpretation. The photo delineations should be transferred by means of zoom transfer scopes to USGS 1:24,000 scale base maps. The resulting maps should meet National Wetland Inventory map formatting and quality standards.

As time permits, vegetation composition and regenerative status of selected riparian areas will be described by community type and by woody shrub age class, as

[17] Consideration should also be given to the classification and inventory methods recently developed by Hansen et al. (1989) for riparian systems in Montana.

determined by inventories conducted in reference reaches. Consult Hansen et al. (1989) and Burton et al. (1991) for further details.

Sampling Units and Schedule

Resource agencies will be contacted and existing information will be compiled during the pre-operational period. The endpoint of this activity will be aerial photos and maps with riparian areas delimited and classified by riparian type. An assessment of the status and trend in riparian areas and management practices in the Clearwater River subbasin in general and NPTH drainages in particular will be provided in annual progress reports. As time permits, the total acreage of riparian area will be estimated for NPTH streams.

5.3.1.3.6 *Macrohabitat*

Recommended performance variables:

1. Stream reaches: classification, geographical location, dimensions (length, width)
2. Reach quality ranking
3. Carrying capacity
4. Production potential

Note: The method described below to estimate chinook freshwater carrying capacity and potential production is one of three approaches recommended under the Monitoring and Evaluation Plan. The other two methods are detailed under Mesohabitat and Microhabitat performance variables (Sections 5.3.1.3.7 and 5.3.1.3.8). The Macrohabitat approach makes use of readily available data and will provide a rapid, pre-project assessment of stream carrying capacity and potential production.

Application

Classification and measurement of stream reaches is a prerequisite to meso- and microhabitat inventory, study site selection, and chinook abundance/production estimation. Stratification of stream sections by reach type is recommended because variation in the distribution and local abundance of juvenile chinook cannot be fully accounted for by differences in habitat type (e.g., pool frequency). Basic differences in the hydrophysical features associated with different reach types are responsible for unique biological structures and processes. Several stream and habitat classification schemes have been developed; however, the one most commonly used in the Pacific Northwest was first proposed by Rosgen (1985). The Rosgen system differentiates stream reaches on the basis of their morphological characteristics (Table 23).

Table 23. Rosgen stream (reach) type classification based on channel geomorphology and adjacent landform features.

STREAM TYPE	GRADIENT	SINUOSITY	W/D RATIO	DOMINANT PARTICLE SIZE Of CHANNEL MATERIALS	CHANNEL ENTRENCHMENT-VALLEY CONFINEMENT	LANDFORM FEATURE SOILS/STABILITY
Al	4-10	1.0-1.1	10 or less	Bedrock.	Very deep/very well confined.	Deeply incised bedrock drainageway w/ steep side slopes and/or vertical mck walls.
Al-a	10 +	(Criteria	same as	Al)		
A2	4-10	1.1-1.2	10 or less	Large & small boulders w/mixed cobble.	Same	Steep side slopes w/predominantly stable materials.
A2-a	10 +	(Criteria	same as	A2)		
A3	4-10	1.1-1.3	10 or less	bull boulders, cobble, coarse gravel.	Same	Steep, depositional features w/predominantly coarse textured soils. Debris avalanche is the predominant erosional process. Stream adjacent slopes are rejuvenated with extensive exposed mineral soil.
A3-a	10+	(Criteria	same as	A3)		
A4	4-10	1.2-1.4	10 or less	Predominantly gravel, sand, and some silts.	Same	Steep side slopes w/mixture of either depositional landforms with fine textured soils such as glaciofluvial or glaciolacustrine deposits or highly erodable residual soils such as grussic granite. etc. Slump-earthflow and debris avalanche are dominant erosional processes. Stream adjacent slopes arc rejuvenated.
M-a	10+	(Criteria	same as	A4)		
A5	4-10	1.2-1.4	10 or less	Silt and/or clay bed and bank materials.	Same	Moderate to steep side slopes. fine textured cohesive soils, slump-earthflow erosional processes dominate.
A5-a	10+	(Criteria	same as	A5)		

STREAM TYPE	GRADIENT %	SINUOSITY	W/D RATIO	DOMINANT PARTICLE SIZE OF CHANNEL MATERIALS	CHANNEL ENTRENCHMENT-VALLEY CONFINEMENT	LANDFORM FEATURE - SOILS/STABILITY
B1-1	1.5-4.0	1.3-1.9	10 or greater (X̄:15)	Bedrock bed, banks, cobble, gravel, some sand.	Shallow entrenchment. Moderate confinement.	Bedrock controlled channel with coarse textured depositional bank materials.
B1	2.5-4.0 (X̄:3.5)	1.2-1.3	5-15 (X̄:10)	Predominantly small boulders, very large cobble.	Moderately entrenched/ well confined.	Moderately stable, coarse textured resistant soil materials. Some coarse river terraces.
B2	1.5-2.5 (X̄:2.0)	1.3-1.5	8-20 (X̄:14)	Large cobble mixed w/ small boulders & coarse gravel.	Mod. entrenched/ Mod. confined.	Coarse textured, alluvial terraces with stable, moderately steep, side slopes.
B3	1.5-4.0 (X̄:2.5)	1.3-1.7	8-20 (X̄:12)	Cobble bed w/ mixture of gravel & sand - some small boulders.	Mod. entrenched/ well confined.	Glacial outwash terraces and/or rejuvenated slopes. Unstable, moderate to steep slopes. Unconsolidated, coarse textured unstable banks. Depositional landforms.
B4	1.5-4.0 (X̄:2.0)	1.5-1.7	8-20 (X̄:10)	Very coarse gravel w/ cobble mixed sand and finer material.	Deeply entrenched/ well confined.	Relatively fine river terraces. Unconsolidated coarse to fine depositional material. Steep side slopes. Highly unstable banks.
B5	1.5-4.0 (X̄:2.5)	1.5-2.0	8-25 (X̄:15)	Silt/clay.	Same	Cohesive fine textured soils. Slump-earthflow erosional processes.
C1-1	1.5 or less (X̄:1.0)	1.5-2.5	10 or greater (X̄:30)	Bedrock bed, gravel, sand, or finer banks.	Shallow entrenchment, poorly confined.	Bedrock controlled channel with depositional fine grained bank material.
C1	1.2-1.5 (X̄:1.3)	1.5-2.0	10 or greater (X̄:18)	Cobble bed with mixture of small boulders and coarse gravel.	Mod. entrenched/ Mod. confined.	Predominantly coarse textured, stable high alluvial terraces.
C2	0.3-1.0 (X̄:0.6)	1.3-1.5	15-30 (X̄:20)	Large cobble bed w/ mixture of small boulders & coarse gravel.	Mod. entrenched/ well confined.	Overfit channel, deeply incised in coarse alluvial terraces and/or depositional features.
C3	0.5-1.0 (X̄:0.8)	1.8-2.4	10 or greater (X̄:22)	Gravel bed w/mixture of small cobble & sand.	Mod. entrenched/ slight confined.	Predominantly moderate to fine textured multiple low river terraces. Unstable banks, unconsolidated, noncohesive soils.
C4	0.1-0.5 (X̄:0.3)	2.5 +	5 or greater (X̄:25)	Sand bed w/mixtures of gravel & silt (no bed armor).	Mod. entrenched/ slight confined.	Predominantly fine textured, alluvium with low flood terraces.
C5	0.1 or less (X̄:.05)	2.5 +	5 or greater (X̄:10)	Silt/clay w/mixtures of medium to fine sands (no bed armor).	Mod. entrenched/ slight confined.	Low, fine textured alluvial terraces. delta deposits, lacustrine, loess or other fine textured soils. Predominantly cohesive soils.
C6	0.1 or less (X̄:.05)	2.5 +	3 or greater (X̄:5)	Sand bed w/mixture of silt & some gravel.	Deep entrenched/ slight confined.	Same as C4 except has more resistant banks.
D1	1.5 or greater (X̄:2.5)	N/A Braided	N/A	Cobble Bed w/mixture of coarse gravel & sand & small boulders.	Slight entrenched/ no confinement.	Glacial outwash, coarse depositional material, highly erodable. Excess sediment supply of coarse size material.
D2	1.5 or less (X̄:1.0)	N/A Braided	N/A	Sand bed w/mixture of small to medium gravel & silts.	Slight entrenched/ no confinement.	Fine textured depositional soils, very erodable - excess of fine textured sediment.

Table 23 (continued). Rosgen classification criteria.

Classification criteria include stream gradient, sinuosity, width/depth ratio, channel material, entrenchment, confinement, and soil/landform features. The Rosgen system is currently used by the IDFG to stratify streams sampled for parr density estimates. IDFG researchers observed late-summer chinook parr densities that were several times higher in low gradient, alluvial "C" channels than in high gradient, high energy "B" channels. Because of this demonstrable difference in habitat use, and to maintain consistency across inventory databases, we recommend application of the Rosgen system in NPTH monitoring and evaluation. Reach classification will be used to identify and compartmentalize biological variability and to reduce sampling effort through resulting gains in precision.

Chinook juveniles favor pool habitats in Type C channels, defined by Rosgen (1985) as low-gradient, meandering reaches of stream. High gradient reaches often have an abundance of deepwater habitats, but these typically are populated less by juvenile chinook than by steelhead and cutthroat trout. That chinook and trout densities differ between the two reach types probably reflects evolutionary adaptations based in part on past competitive interactions.

Carrying capacity: We will estimate carrying capacity at the macrohabitat level by using the Smolt Density Model (SDM) of the Northwest Power Planning Council (NPPC) (MEG 1989).[18] The data used to parameterize the model, however, will be modified using information obtained during the pre-operational sampling period.

The method used by the NPPC to assess the potential for a stream to produce smolts is to divide the stream into discrete reaches, multiply the surface area of each reach by a parr density that is indexed to the quality of physical habitat present, and then sum across reaches. Stream reaches are classified as either B or C channels. Reach surface area is the product of reach length and mean width. Because mid-channel areas in mainstem rivers are considered unsuitable for juvenile chinook, reaches greater than 60 feet wide were treated as though they were in fact 60 feet wide.

Habitat within each reach is rated as poor, fair, good, or excellent habitat based on available information and the judgment of knowledgeable fisheries biologists (Table 24).

[18] Other approaches to estimating carrying capacity and potential production are described in the Mesohabitat and Microhabitat performance criteria.

Table 24. Habitat quality criteria and parr capacity ratings used by IDFG and NPPC to estimate the chinook smolt production potential of Idaho streams (Source: Rich et al. 1992).

Habitat Quality Rating	Criteria	Density (parr/100m²) NPPC[1]	IDFG
Excellent	Undisturbed C channel	180	108
Good	Moderate gradient, undisturbed B channel	128	77
Fair	High gradient B channel, low disturbance	74	44
Poor	High gradient B channel, high disturbance	20	12

[1] Originally reported as smolt capacities; 50% parr-to-smolt survival assumed.

Habitat quality ratings and parr capacities associated with degraded C channels were not provided. The parr capacity of "excellent" quality habitats (108 parr/100m²) were based on empirical data collected from fully seeded C channels in several Idaho streams (Petrosky and Holubetz 1988). IDFG assumed that parr capacities of the other habitat classes were proportional to those used in the NPPC Smolt Density Model.

Measurements

Reaches will be cross-referenced to NPPC species presence/absence files and to all relevant fisheries/habitat databases. The IDFG and other agencies will be contacted for existing information, resources, and sampling procedures. NPTH stream reaches will be delineated and classified using recent aerial photographs, topographic maps, and databases (see Riparian Area, Section 5.3.1.3.5). Reaches will be typed using Rosgen criteria (Table 23) and sampling procedures. Reach lengths and widths will be verified during the pre-operational period. The reach type database will be updated as additional information is gained through on-site visits.

<u>Carrying capacity</u>: The SDM developed by the NPPC will be used in conjunction with IDFG parr densities to assess the carrying capacity and production potential of NPTH streams until alternative models based on mesohabitat and microhabitat data are available. The species presence/absence database will be reviewed to determine whether reach identification, length, width, and habitat quality information is correct. Any new data relating to these variables will be incorporated into the database prior to project startup.

<u>Production potential</u>: The Smolt Density Model will be used to estimate the potential of NPTH streams to produce parr and smolts under historical, current, and future conditions. Parr carrying capacities predicted by the model will be considered valid estimates of potential production under existing conditions. Smolt carrying capacities will be derived by applying an appropriate parr-to-smolt survival rate, as determined from NPTH monitoring studies and from the literature (Lindsay et. al. 1989; Kiefer and Forster 1991, 1992; Fast et al. 1991). To estimate historical or future production potential, reach quality ratings and associated parr densities will be modified to reflect pristine or anticipated habitat conditions.

Sampling Units and Schedule

Existing maps and databases should be checked for accuracy and preliminary production potential estimates made before the project begins. Reach data, habitat quality, and parr densities should be updated as information becomes available. Chinook parr densities and parr-to-smolt survival rates will be measured in NPTH treatment streams once the project is underway (see Abundance and Survival performance criteria). Until such time, NPTH biologists will apply values obtained from reliable sources.

5.3.1.3.7 Mesohabitat

<u>Recommended performance variables:</u>

1. Channel units: type, frequency, surface area
2. Mesohabitat diversity

Application

Several methods and sources of data will be used to estimate chinook abundance, carrying capacity, production potential, and appropriate seeding levels for NPTH streams. We recommend a variety of approaches because ecological factors regulating chinook populations operate at different scales and because more than one computational method can be used to estimate carrying capacity. This performance criterion describes procedures for estimating abundance, carrying capacity, etc. using mesohabitat data." For our purposes, mesohabitat is considered synonymous with channel unit classified by habitat type, following the system first proposed by Bisson et al. (1982) and later refined by others, notably Helm (1985) and Hawkins et al. (1993). Mesohabitat is intermediate in scale between stream reach (macrohabitat) and the stations or territories occupied by individual chinook salmon (microhabitat).

Habitat types are the various classes of pools, riffles, and their derivatives that comprise running water ecosystems. Each habitat type is characterized by morphologic and hydraulic properties that influence the associated biological community (Huryn and Wallace 1987; Bisson et al. 1988; Nickelson et al. 1992). The basic premise of the approach described here is that the potential of a NPTH stream to produce smolts (or any other freshwater life stage) is determined by the number and quality of channel units comprising the stream. We also hypothesize that chinook carrying capacity and production are directly related to the diversity of mesohabitats present.

In 1993, NPTH biologists delineated channel units within four 500 m sections of Meadow Creek (Selway) and classified them by habitat type (Table 25). Significant differences were found in the mean densities of steelhead, resident trout, and recently stocked chinook parr within channel units representing different habitat types (Steward and Johnson, in preparation). Earlier surveys of Clear-water tributaries by Shepherd and Bjornn (1981) recorded differences in fish abundance among pools, runs, riffles, and pocket water habitats. Although a less complex habitat classification system was used, the evidence supports our contention that existing and potential chinook production will vary in proportion to the availability and suitability of different habitat types within a stream.

We propose to stratify sampling by habitat type and reach in all NPTH streams to enable more precise estimates of chinook abundance and chinook fry, parr, and smolt carrying capacities (Hankin and Reeves 1988). Chinook abundance is the instantaneous number, density, or standing crop of chinook by life stage either measured or estimated for a channel unit, reach, or stream. It may reflect initial seeding levels (e.g., escapement), carrying capacity limitations, or both. When a stream is underseeded by natural spawners, as the Clearwater system is at present,

[19] **Separate carrying capacity estimates will be generated from models based on mesohabitat (channel unit) and macrohabitat (reach) typing.**

Table 25. **NPTH** stream habitat types and the characteristics by which they are identified in the field.

Fast Water Habitat Types:

(C) Cascade - High energy zone characterized by rapid, turbulent flow; large bed elements tend to protrude above the surface, constrict flow, and create "pocket water" habitats.

(RA) Rapid - **Swiftly** flowing water of shallow to moderate depth usually caused by a channel constriction in a high gradient section of stream; large, usually submerged substrates may create standing waves but not whitewater.

(R) Riffle - Au area of shallow, uniformly fast-flowing water with a steep water surface slope and a turbulent but unbroken water surface, commonly flowing at a diagonal over gravel/cobble bars.

Slow Water Habitat Types:

(DP) Dammed Pool - Upstream of obstruction, flow rapidly decelerates within the unit, negligible water surface slope and a smooth to wavy water surface; the size of a dammed pool depends on the degree to which flow is obstructed.

(EP) Eddy Pool - Downstream of obstruction, eddy pools are separated from high velocity flow by a strong shear zone, **and** exhibit weak to moderate flow reversals.

(PP) Plunge Pool - Flow is rapid, turbulent, and subducting where it enters the pool, generally over au elevated bed element or through a constriction that spans > 80% of the channel; plunge pools tend to be short, deep, and hydraulically complex.

(SP) Scour Pool - Fast-flowing water enters at the upstream end, but scour pools are deeper, on average, with slow to moderate velocities and a smooth to wavy water surface.

(CP) Confluence pool - Usually scour pools or glide units that are influenced by flows and sediments delivered by tributaries.

Transitional Habitat Types:

(R/G) Run/Glide - Slower, smoothly flowing section of channel with velocities, depths, and water surface slope close to the average for the reach as a whole, commonly straight, often forming a transition from elongate pool to downstream riffle.

(LH) Lateral Habitats - Stream margin areas that are separated from the adjoining main channel by partial obstructions or topographic breaks that cause sharp hydraulic discontinuities; lateral habitats are depositional zones of shallow, predominantly slow water.

abundance will be influenced more by density-independent factors than by density-dependent factors. Once chinook populations begin to rebuild, density-dependent factors will play a greater role.

Armed with abundance and habitat data, NPTH biologists will describe the seasonal distribution and abundance of different life history types and life stages of chinook in relation to stream and basin-wide habitat availability. The questions "Is available habitat not being used?, What habitat types appear to be limiting? and Which life history types/stages are affected?" should be answered with reference to historical, current, and future carrying capacities and production potentials. In particular, the relation between historical habitat and life history diversity should be explored.

Carrying capacity is the *maximum* abundance of a particular chinook life stage that a habitat unit, reach, or stream can theoretically support under a range of environmental conditions. Carrying capacity is determined by the complex interaction of myriad ecological factors that influence the amount and quality of food and space available for chinook salmon.

We define production potential as the number of chinook produced at carrying capacity, taking into consideration the number of fish that survive earlier life stages. Production potential is a function of density-dependent recruitment, growth, and mortality operating across one or more freshwater life stages under temporally varying environmental conditions. The conditions of interest are those that exist now, those that existed historically, and those that might be attained under a modified biophysical regime, such as might arise through supplementation or habitat alteration. The number of smolts and returning adults are the preferred index of production potential since they reflect cumulative mortality and survivorship within and outside of the Clearwater subbasin, respectively. However, to better understand the causal mechanisms involved, to identify opportunities for habitat enhancement, and to estimate realistic stocking densities, production potential should be determined for each life stage.

Drawing upon Moussalli and Hillborn (1986), Lestelle et al. (1993) developed a multistage life history simulation model that can estimate salmonid production potential under existing, historical, or other user-defined conditions. The model simulates how production responds to changes in the quality or quantity of habitat associated with any of three freshwater life stages: egg deposition to fry emergence, fry emergence to late summer parr (or presmolt), and presmolt to smolt. Given initial seeding levels, habitat capacities, and life stage-specific stock-recruitment relationships, the model tracks the number of fish surviving to each life stage over one or more life cycles.

Lestelle et al. (1993) divided the period from spawning to recruitment into several life stages, and used stage-specific stock-recruitment functions to describe mortality and survivorship across life stages. The Beverton-Holt model was chosen because it explicitly considers the effects of density-dependent and density-independent factors on production. Using this model, the number of fish produced of a given life stage is calculated as:

$$R = \frac{pS}{1 + \frac{p}{c}S}$$

where S = number of fish in the preceding life stage, p = productivity parameter, and c = capacity parameter. Life stage productivities are estimated from density-independent survival rates (i.e., survival at very low densities), determined either empirically or from the literature. They are affected primarily by habitat quality (Moussalli and Hillborn 1986). Although the model is not currently configured to do so, it can be modified to link habitat quality to the availability of suitable water temperatures, food, cover, and clean substrate (L. Lestelle, personal communication).

The capacity parameter provides an estimate of production potential (i.e., abundance) at full seeding. Lestelle et al. (1993) suggested different ways of estimating stage capacities; the one favored here is based on direct observations of fry, late summer parr, and late winter presmolt densities by habitat type in areas that are fully seeded *at the beginning* of *each life stage.* Unfortunately, data of this kind are scarce and will have to wait until the Meadow Creek studies have been completed. Preliminary fry stage capacity estimates can be obtained from Scully and Petrosky (1991), who compared redd densities to subsequent age-0 chinook densities in several Salmon River tributaries. The data were not summarized by habitat type, however, and included only a few observations that approached carrying capacity.

Even without fine-scaled carrying capacity estimates, the model can be used to examine the effects of altering habitat quality or quantity for one or more life stages. For example, if the number, surface area, or proportion by habitat type of channel units is changed to simulate pristine or some other conditions, the model recomputes the corresponding stage-specific capacity and productivity. The model also allows incorporation of factors such as streamflow directly in the stock-recruitment function.

The carrying capacity and production potential of mainstem reaches will be estimated by applying hydraulic and microhabitat (velocity, depth, and substrate) models that were developed specifically for these areas by NPTH biologists (Arnsberg et al. 1992). Procedures for estimating quantities of chinook rearing and spawning Weighted Useable Area (WUA's) in mainstem areas and converting them to estimates of carrying capacity and production potential by life stage are described by Steward (1993).

Measurements

The number of channel units and their surface area within stream reaches needs to be determined so that chinook abundance, carrying capacity, and production potential can be estimated. The mesohabitat approach to estimating chinook *abundance* within NPTH streams is based on the two-stage sampling design recommended by Hankin and Reeves (1992). The ocular method attempts to reduce sampling variability by stratifying samples by habitat type and reach type. The following steps are required:

1. Each stream will be stratified into reaches according to the Rosgen classification system. Individual reaches will be combined into ***r*** strata corresponding to the total number of reach types present, as described in the Macrohabitat performance criterion (see previous section).

2. The total number, ***N***, of channel units within each reach type will be determined from aerial photographs or videotape footage supplemented by direct field observations. Channel units will be classified by habitat type (Table 25).

3. Within each strata, water surface areas will be measured for a systematic sample of ***n*** channel units of each habitat type, then summed to estimate the total surface area of all units by habitat type.

4. Chinook abundance (numbers), will be estimated by snorkelers using underwater observation techniques within the same ***n*** channel units from each habitat type/reach type category. Abundance will be summed across units within each strata, as above.

5. Empirical estimates of abundance will be extrapolated to unsampled units by multiplying by the proportionality factor, N/n. The result is the total number of fish by habitat type within a given reach. Hankin and Reeves (1988) provides a variance formula which takes into account sample sizes, replication, and within- and between-unit variation in abundance estimates. Estimates of the total abundance of chinook salmon within a reach will be calculated by summing across all habitat types. Total abundance will be estimated for each stream as the sum of ***r*** reach-specific abundances.

Numerical abundances will be divided by surface areas calculated in Step 3 above to estimate fish densities (fish per unit area), which is recommended for purposes of comparison. Note also that chinook abundance will be determined for conditions which prevailed at the time that samples were collected. As time permits, these steps will be repeated to estimate seasonal abundances based on observations of habitat availability and use at different times of the year.

Estimates of channel unit surface areas and within-strata variability in abundance will be calculated from baseline samples collected from Meadow Creek during the pre-operational period. This information will be used to optimally allocate sampling effort on other NPTH streams so that total abundance can be more precisely estimated.

Mesohabitat diversity (ϕ) will be computed for each reach as the coefficient of variation of the number of channel units, m_i, or the mean surface area, $\bar{a}_i$, of channel units by habitat type (i = 1, 2, . . ., n) within that reach, expressed as a percentage of the mean of the n habitat types ($\overline{M}, \overline{A}$):

$$\phi_1 = (s_1^2 / \overline{M}) \times 100$$

and

$$\phi_2 = 1 - (s_2^2 / \overline{A}) \times 100$$

where s_1^2 and s_2^2 are the standard deviations of the number or mean surface area of channel units by habitat types is

$$s_1^2 = \frac{\sum_{i=1}^{n} (m_i - \overline{M})^2}{(n-1)}$$

substituting $\overline{A}$ to calculate s_2^2.

The advantages to using of this measure is that it permits comparison of the relative amounts of variation in habitat composition and size in reaches possessing different physical dimensions and unequal numbers of channel units.[20]

Channel units will be randomly sampled and mapped within each reach. Two observers will walk sections of stream, identifying and marking the boundaries of randomly selected channel units on large scale maps until requisite sample sizes are obtained. Channel unit surface areas will be calculated as the mean unit width times its length. Procedures for measuring chinook abundance (spawners, redds, juveniles) and microhabitat quality (instream cover, Weighted Usable Area) are discussed elsewhere.

To estimate stream carrying capacities under existing conditions, mean chinook densities will be replaced with *maximum* densities in the preceding calculations. We will assume that the meso- and microhabitat present is that which exists under a normal hydrologic cycle. Maximum chinook densities will be derived initially from

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[20] Burton (1991) offers an alternative measure of mesohabitat diversity.

normal hydrologic cycle. Maximum chinook densities will be derived initially from expert opinion and literature reported values. Differences between observed and maximum densities will give some indication of how far NPTH streams are below carrying capacity.

We intend to use the salmonid life cycle model developed by Lestelle et al. (1993) to simulate production potential in NPTH streams under historical, present, and future environmental conditions. Historical production will be estimated without reference to supplementation. In this case, we will assume that spawning habitat was fully seeded and that "pristine" habitat existed for each life stage. Present and future production simulations will consider a variety of supplementation and non-supplementation scenarios.

In the absence of supplementation, these models will assume that spawning habitat is fully seeded and that existing or anticipated habitat conditions prevail. With supplementation, the effects of a range of initial seeding levels, applied at different life stages, will be evaluated.

Simulation of production potential under historical, existing, and future production scenarios will require alteration of habitat quality and quantity values within the life cycle model. We have few quantitative data which would enable us to accurately characterize past or future habitat conditions. Without valid information, estimating production is a matter of chance. Nevertheless, it should be possible to describe changes in habitat relative to what exists now. For example, water temperatures are higher in Lolo Creek now than they were in the past; production potential is therefore expected to have declined from historical levels. In the future, improvements in watershed management may alter the frequency or surface area associated with different habitat types. If these kinds of changes are incorporated into the life cycle model, different production estimates will result. These differences can be examined and inferences made regarding the potential effects of supplementation and environmental perturbation on chinook production.

Sampling Units and Schedule

USFS, IDFG and UI habitat type databases will be interrogated before undertaking field studies. The feasibility of using low altitude aerial photography or videotape to identify, classify, and quantify (surface areas) channel units will be determined.

Each NPTH stream will be stratified into reaches using Rosgen classification criteria. Within each reach, channel units will be randomly selected, mapped, and classified by type. A maximum of 20 channel units of each type will be selected for measurement of surface area, chinook abundance, and microhabitat quality. No fewer than 10 and no more than 20 channel units of each type will be sampled per stream, unless the habitat type is poorly represented. These are tentative sample sizes; the final number of channel units selected will reflect a balance between statistical requirements and logistical constraints.

Channel units and juvenile chinook abundance will be measured under late summer and winter baseflow conditions. Spawner densities and habitat use will be determined from annual spawner/redd surveys.

5.3.1.3.8 Microhabitat

Recommended performance variables:

1. Interstitial Space Index (ISI)
2. Percent fines
3. Large woody debris

Application

Cover, herein defined as those instream areas that provides refuge from high velocity and protection from predators, is an important component of chinook microhabitat. Cover results from the interplay between streamflow, streambed and bank form, and large bed elements. Its use by juvenile chinook depends on the time of year, and factors affecting predator abundance and the availability of food.

Five primary types of instream cover are available in NPTH streams:

1. Cobble-boulder substrates
2. Large woody debris
3. Overhanging bank and vegetation cover.
4. Air bubbles entrained by turbulent flow
5. Ice and snow cover

We recommend periodic monitoring of substrate quality and the quantity of large woody debris in NPTH streams. Substrate quality will be indexed by the Interstitial Space Index **(ISI)**[21] and percent surface fines in run channel units. Both give some indication of the number of nooks and crannies in the streambed that juvenile chinook use for concealment and refuge from high velocities, The spaces between and underneath large substrates are especially important during the winter months when cold water temperatures force juvenile salmon to seek cover. Excess sedimentation

[21] The IS1 is preferred over cobble embeddedness because it is less variable over space and time.

can fill in the interstitial spaces and reduce the amount of food and overwinter habitat available. It can also smother eggs and block emergence of newly hatched fry.

Early efforts to quantify sedimentation impacts on salmonid streams in Idaho resulted in the development of quantitative protocols for visually determining the availability of interstitial space and the percentage of fine sediments (Bjornn et al. 1977, Burns 1984). The State of Idaho DEQ has recommended that these performance variables be incorporated into the State's nonpoint source water quality monitoring program (Burton and Harvey 1990). The methods advocated by DEQ are essentially those of Burns and Edwards (1985), as modified by the sampling design and analytical procedures of Skille and King (1989). We recommend that the equipment, sampling design, and statistical methods reviewed by Burton and Harvey (1990) be used to monitor trends in substrate quality in NPTH streams.

LWD has a positive effect on the quality of rearing and spawning habitats. Large pieces of debris provide resting areas and concealment cover for chinook juveniles and adults. They are important channel forming features in NPTH streams, creating local areas of scour and deposition. We recommend that LWD be monitored by recording the number and volume of pieces present in representative reaches of NPTH streams once each year. Sampling should be conducted in channel segments that are contiguous with riparian vegetation sampling reaches.

Measurements

Both ISI and percent fines are measured for surface substrates encircled by a hoop 60 cm in diameter (0.28 m^2). The ISI is a measure of the amount of cobble substrate (4.5 cm to 30 cm in diameter) that projects above the surrounding streambed matrix. It is calculated as the sum of the difference between the embedded depth and vertical height of exposed cobbles, divided by the area of the hoop. Percent fines is the percentage of the streambed covered by fine substrates less than 6.35 mm (1/4 inch) in diameter. Visual estimates are satisfactory.

The ISI and percent fines will be measured at permanent sampling transects established in run/glide channel units of each NPTH stream. The lower ends of C reach types are preferred sampling areas. Three runs should be randomly selected and permanent transects established at 1/4, 1/2, and 3/4 the distance along the length of each run. The transects should sample cross-sectional areas possessing relatively uniform depths, velocities, and substrates. Transect endpoints should be permanently marked with metal stakes (rebar). ISI and percent fines should be sampled by the hoop method at points equal 1/4, 1/2, and 3/4 the distance along the wetted cross-section. The exact sampling locations should be recorded so that measurements can be repeated in subsequent trips. The sampling design suggested here is less intensive than the one proposed by Burton and Harvey (1990) but should be adequate for status and trend monitoring in NPTH streams.

All pieces of organic debris (>10 cm in diameter and > 1 m long) within the wetted perimeter of the channel will be counted within 500 m subreaches of treatment and control streams. Only pieces that contact the water will be inventoried. Each piece will be identified by type (root wad, trunk, and brush), size (volume), and cover utility (low, medium, high).

Sampling Units and Schedule

Substrate quality will be measured in three run channel units in each stream under late summer baseflow conditions. Three substrate measurements will be made at three permanently established transects within each channel unit, for a total of 27 samples. Sample sizes may need to be adjusted depending on within-site variability.

Measurements of LWD will be made once each year during the late summer.

5.3.1.4 Summary of M&E Activities

The step-down chart portrayed in Figure 17 summarizes monitoring tasks and activities proposed for Production Potential performance criteria.

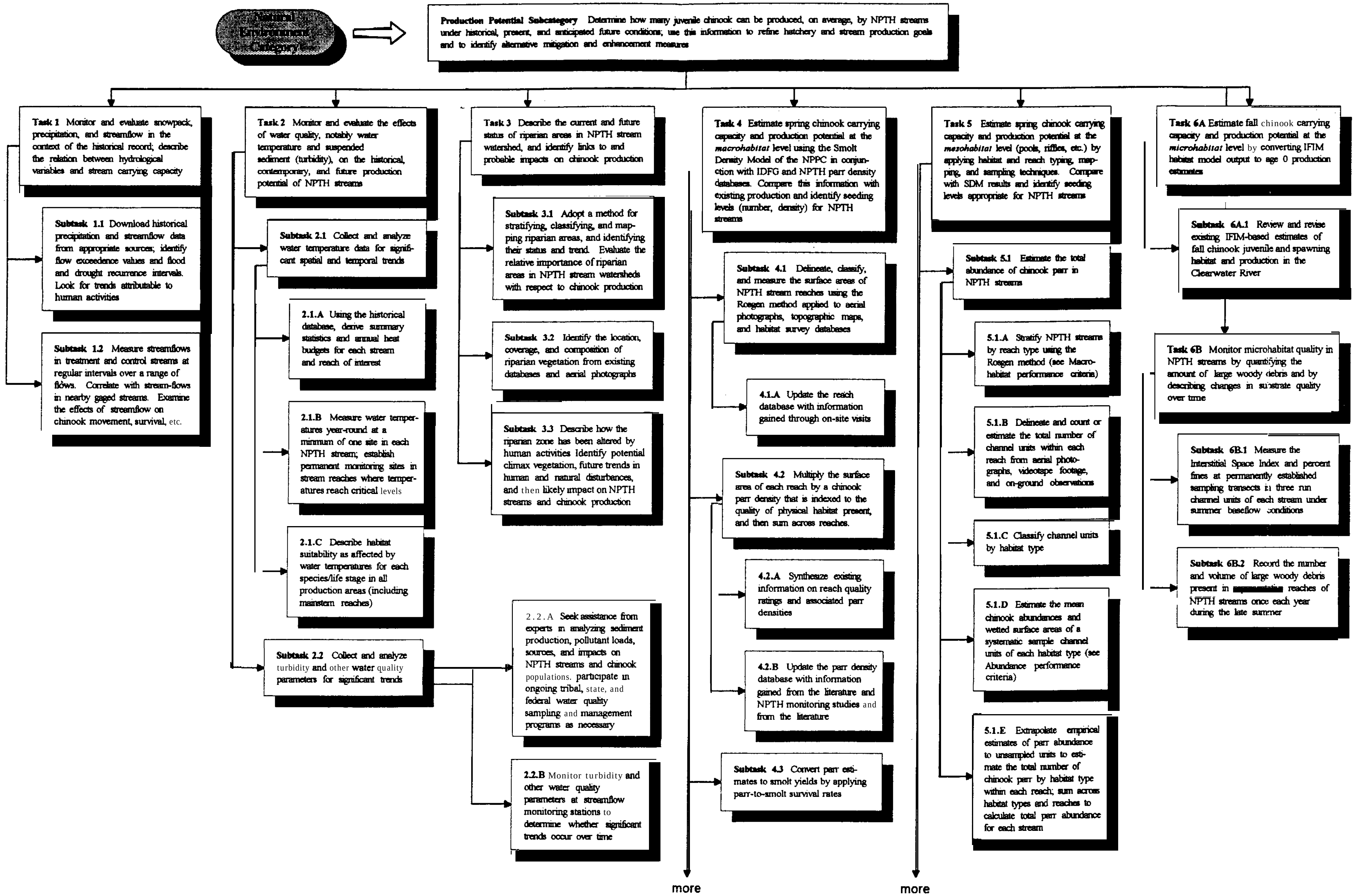

Figure 17. Monitoring and evaluation tasks and subtasks identified for the Production Potential Subcategory (Natural Environment).

5.3.2 Biological Community

5.3.2.1 Background

A fundamental requirement of NPTH is that healthy and productive biological communities are maintained within areas affected by supplementation. Biological Community was identified as an essential performance criterion so that background levels of environmental quality would be monitored within the Clearwater River. The performance variables developed for this criteria include commonly used indices of ecosystem health as well as specific measures of the status of sensitive, threatened, and endangered species. Diversity indices are preferred since they are sensitive to changes in species richness (the total number of species in the community) and equitability (the evenness with which the individuals in the community are distributed among the species). Risk containment monitoring is recommended so that reductions in species diversity, ecological resiliency, and community stability and productivity can be detected and averted.

5.3.2.2 Critical Uncertainties

Biological Community critical uncertainties and associated levels of risk are identified in Table 26.

5.3.2.3 Performance Variables

5.3.2.3. 1 Species Composition and Diversity

Recommended performance variables:

1. Species composition (fish and macroinvertebrate taxa)
2. Species richness (counts and Log Series Index)
3. Species similarity (Sorenson-Jacard indices)
4. Stress index (Hilsenhoff Biotic Index)

Table 26. Biological Community assumptions and associated levels of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Species composition and diversity	1	The Clearwater, Snake, and Columbia rivers and their biota will undergo further change as the human population within the basin grows and public values and patterns of resource use change	2
	2	The biological community likely to result from supplementation can be deduced from historical data and theoretical principles of community ecology	2
	3	Maintenance of biodiversity and ecological resiliency is important to the long-term sustainability of natural chinook populations	3
	4	Supplementation will increase biodiversity, ecological stability, resilience, and productivity	4
Sensitive species	5	Supplementation will not significantly increase the risk of extinction of non-target species, especially those currently identified as sensitive, threatened, or endangered	4
	6	The health of the aquatic community can be indexed by diversity and species richness indices	2

Application

Under this performance criteria are grouped various measures of the variety and abundance of species that can be used to monitor the ecological well-being and effects of supplementation on NPTH streams. The conservation of biological diversity in the Columbia River system is necessary for the long-term health and persistence of her salmon populations (Steward 1993). We recommend monitoring and evaluating the diversity of fish and, if possible, benthic macroinvertebrate taxa found in treatment and control streams, and comparing them under the Before-After Treatment-Control experimental design. Measurement of fish species diversity is given highest priority due to cost constraints.[22] However, species diversity indices based on benthic macroinvertebrates would be more sensitive to environmental stress, and could also be used to quantify food availability in NPTH streams. Macroinvertebrates should be sampled if time and money permit. Significant changes in species diversity or in the abundance of keystone or sensitive species will be taken as evidence for either increased predation or increased environmental perturbation.

Measurements

Data on fish and macroinvertebrate species composition, richness, and similarity will initially be compiled from existing sources. This information will be reviewed and summarized before field work commences.

The first of the four performance variables selected, species composition, is a prerequisite to measuring the other three. Species composition is simply a list of the fish and macroinvertebrate taxa sampled in NPTH streams. These lists can be checked against presence/absence lists compiled by others, such as a list of fish species known to occur in Idaho.

The second and third performance variables are species diversity and similarity indices. A large number of indices have been proposed by and debated among ecologists. We sought one or two measures whose properties are well-known, easily interpreted, capable of detecting differences between streams or changes over time, and are reasonably straightforward and inexpensive to derive. In reviewing the literature, it became apparent that few indices satisfy all of these criteria (*cf*. Magurran 1988). A summary of the performance and characteristics of several commonly used diversity indices is given in Table 27.

Diversity indices weighted toward species richness are more useful for detecting differences between streams than are indices which emphasize the dominance/evenness component of diversity. One measure of species richness is species density, i.e., the number of species per specified collection area or effort. Species richness can be subdivided further into native and non-native species, salmon species/life stages, trophic guild, or any other logical grouping of organisms. A second measure of species richness is the log series index, α.

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[22] Fisher (1990) modified the Index of Biotic Integrity (IBI; Karr et al. 1986) - a widely accepted tool for describing aquatic health in lotic systems based on fish community structure and other characteristics - to characterize several streams in Idaho. Although not recommended at this time as a monitoring and evaluation performance variable, the utility of the modified IBI as a long-term assessment method should be evaluated further by project biologists.

Table 27. Subjective assessment by Magurran (1988, p. 79) of the effectiveness and frequency of use of a range of diversity indices.

	Discriminant ability	Sensitivity to sample size	Richness or evenness dominance	Calculation	Widely used?
α (log series)	Good	Low	Richness	Simple	Yes
γ (log normal)	Good	Moderate	Richness	Complex	No
Q statistic	Good	Low	Richness	Complex	No
S (species richness)	Good	High	Richness	Simple	Yes
Margalef index	Good	High	Richness	Simple	No
Shannon index	Moderate	Moderate	Richness	Intermediate	Yes
Brillouin index	Moderate	Moderate	Richness	Complex	No
McIntosh U index	Good	Moderate	Richness	Intermediate	No
Simpson index	Moderate	Low	Dominance	Intermediate	Yes
Berger-Parker index	Poor	Low	Dominance	Simple	No
Shannon evenness	Poor	Moderate	Evenness	Simple	No
Brillouin evenness	Poor	Moderate	Evenness	Complex	No
McIntosh D index	Poor	Moderate	Dominance	Simple	No

This index is favored by many ecologists because it describes the pattern of species abundance for a variety of biotic communities, it has good discriminant ability, and because it is relatively insensitive to sample size (see references in Magurran 1988).

Samples can be taken annually from NPTH treatment and control streams, and ANOVA can be used to test for differences among streams and between pre- and post-operational periods.

The third performance variable is essentially a measure of the similarity in species composition among NPTH streams. Since we are interested in differences between paired treatment and control streams, we chose an index which is widely used for that purpose. In its qualitative form, the Sorenson index (and the closely related Jacard index) is calculated as:

$$\text{Sorenson CS} = 2j/(a + b)$$

where j = the number of species common to both stream samples,

a = the number of species in the treatment stream sample, and

b = the number of species in the control stream sample.

The quantitative form of the Sorenson index takes species abundances into account:

Sorenson $C_N = 2jN/(aN + bN)$

where aN = the number of individuals in the treatment stream sample,

bN = the number of individuals in the control stream sample, and

jN = the sum of the lower of the two abundances of species which occur in the two stream samples.

Calculation of the log series index requires knowledge of the total number of species (S) and the total number of organisms sampled (N). The log series index a is calculated as:

$$\alpha = \frac{N(1-x)}{x}$$

where x is estimated from the iterative solution of

$$\frac{S}{N} = \frac{I - x}{x[-\ln(1-x)]}$$

If S and N are large enough, differences in control and treatment stream diversities can be compared by calculating the distributions of relative abundance using a goodness of fit test (chi square or G test: Sokal and Rohlf 1981).

Fish species composition will be determined from samples collected by electrofishing reference reaches within NPTH treatment and control streams. The area of stream sampled and the total effort expended will be approximately the same for all streams. Fish will be identified to species using the taxonomic keys of Simpson and Wallace (1982) and Scott and Crossman (1973).

Macroinvertebrate composition, richness, and similarity will be estimated from samples collected in riffle areas of NPTH streams. Field and laboratory techniques are described in Merrit and Cummins (1984).

The final performance variable will be the Hilsenhoff Biotic Index applied to macroinvertebrate data. The HBI is a sensitive indicator of environmental degradation. It can detect organic and nutrient pollution, excessive sedimentation, low dissolved oxygen and thermal impacts (Hilsenhoff 1987). To calculate the index, each taxa is assigned a tolerance value of 0 to 10, ranging from intolerant to highly tolerant of stress. The HBI is the average of the tolerance values for all individuals within a standard sample. Clark and Maret (1993) identified tolerance values for aquatic insect taxa common to Idaho streams and rivers.

Sampling Units and Schedule

Fish and invertebrate samples will be collected once each year during the summer low flow period (July 15-October 1).

5.3.2.3.2 Sensitive Species

Recommended performance variables:

1. Relative abundance

Application

We propose to identify sensitive species that occur within NPTH streams and to monitor their relative abundance in species diversity samples. By sensitive species we mean aquatic taxa listed as rare, threatened, and endangered in Mosely and Groves (1992) and other appropriate sources (e.g., the Idaho Natural Heritage Program). We will monitor their status in conjunction with biological diversity to evaluate project impacts and environmental degradation.

Measurements

The historical and current distribution and relative abundance of sensitive aquatic species in the Clear-water River subbasin will be determined through literature review and agency contacts (e.g., IDFG Fisheries Management Plan [1991], Mosely and Groves [1992]). The frequency of occurrence of sensitive species in fish and macroinvertebrate samples will be documented and reported separately from species diversity measures. All information will be incorporated into the NPTH GIS.

Sampling Units and Schedule

A list of sensitive species will be compiled and current status and distributional maps will be prepared during the pre-operational sampling period. The status of sensitive fish and macroinvertebrate species will be reassessed annually on the basis of species diversity surveys and other sources of data collected in NPTH treatment and control streams. Sampling protocols are described in the Species Composition and Diversity performance criterion.

5.3.2.4 Summary of M&E Activities

Figure 18 summarizes monitoring tasks and activities developed for Biological Community performance criteria.

5.3.3 *Extrinsic Factors*

5.3.3.1 Background

Human activities not directly involved with the NPTH will nevertheless strongly influence the outcome of the project. This section addresses two general questions:

1. What effects do large-scale natural and human-related disturbances have on NPTH? and
2. What effects do other management policies and practices have on NPTH?

The general steps to be followed in monitoring significant natural and human-caused environmental variability would be to:

1. Identify the magnitude, location, and cause of significant threats or disturbances,
2. Evaluate management alternatives,
3. Evaluate their potential impacts on NPTH goals and objectives,
4. Communicate concerns and recommend alternatives to appropriate agencies,
5. Adjust NPTH goals and objectives or, if necessary, take corrective actions,
6. Continue to monitor management actions and environmental impacts, and
7. Repeat Steps 4 through 7, as necessary.

The intensity of monitoring efforts under this performance criteria should be based on the perceived risk to the project or to the natural resource. Monitoring activities conducted under other Natural Environment criteria will provide information on background levels and variability of key environmental variables and processes so that causes of change due to factors other than supplementation can be identified and appropriate actions taken.

5.3.3.2 Critical Uncertainties

Mathematically aggregated risk scores are identified in Table 28 for Extrinsic Factors assumptions.

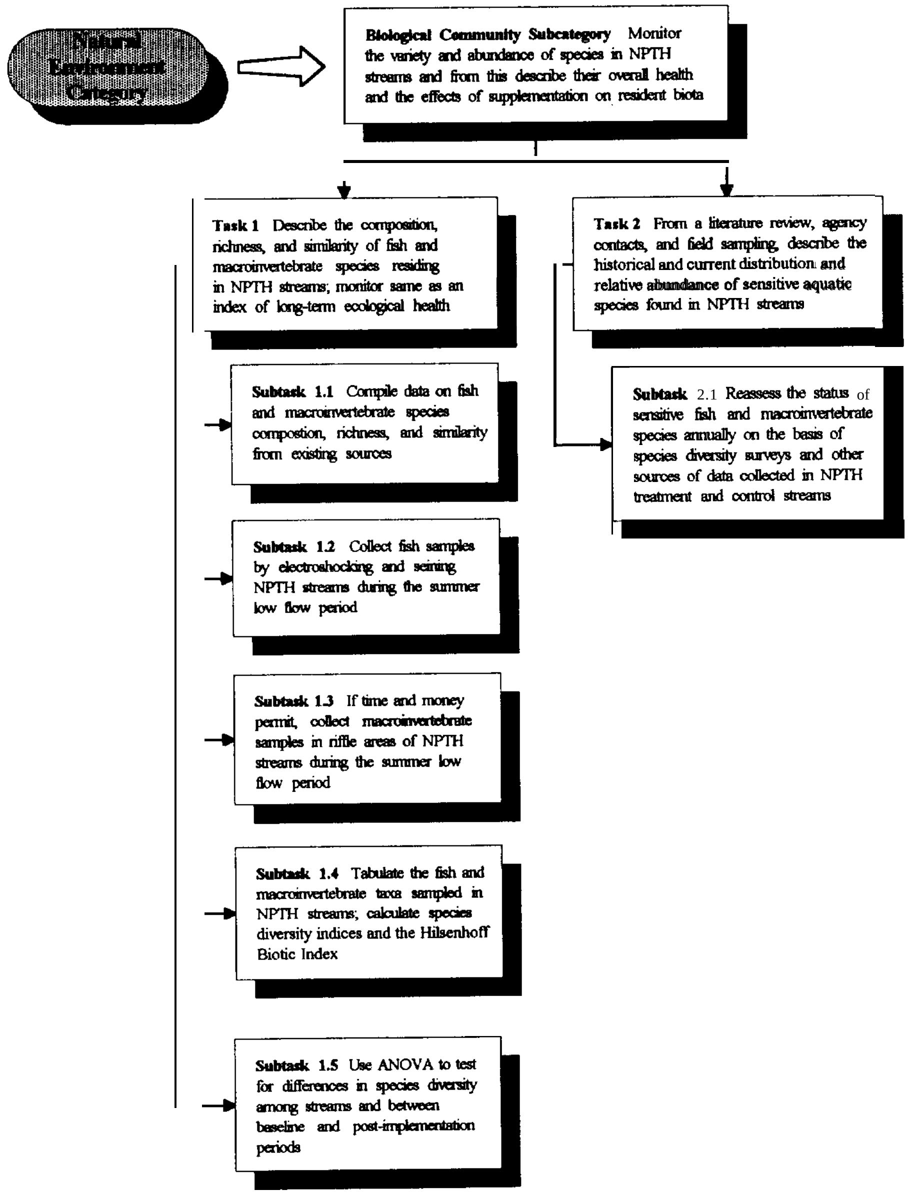

Figure 18. Monitoring and evaluation tasks and subtasks identified for the Biological Community Subcategory (Natural Environment Category).

Table 28. Extrinsic Factors assumptions and associated level of risk.

Performance Criteria	Assumption Number	Assumption Description	Level of Risk
Logging	1	Timber harvest and associated activities will not increase water temperatures, flood magnitudes, bed load movement, or otherwise impair the quality of chinook habitat within NPTH streams	3
Agriculture	2	Agricultural activities and byproducts will not degrade NPTH streams	3
Other land uses	3	Increases in land use and associated human activities will not diminish the future status of chinook populations or the overall quality of aquatic ecosystem	4
Natural stressors	4	The effects of natural disturbances such as fire, floods, and landslides on chinook salmon production will be temporary and inconsequential over the long-term	3
Dams and diversions	5	Future hydroelectric development and water withdrawals or diversions will not reduce chinook populations and their habitat within the Clearwater River	4
Management impacts	6	Policy and regulatory changes affecting the mainstem hydrosystem, ocean and inriver harvest, and downriver ecosystems will not impede progress towards NPTH goals	4
	7	Release of hatchery fish by the Idaho Department of Fish and Game will be coordinated with NPTH managers, and will be compatible with NPTH goals	3
	8	Decisions and the implementation of special provisions to effect the recovery of Snake River spring/summer and fall chinook salmon will not impede progress towards NPTH goals	3
	9	Recovery plans or special regulations affecting other threatened or endangered species will not block NPTH goals	3

5.3.3.3 Performance Variables

5.3.3.3. I Logging

Recommended performance variables:

1. Acreage logged
2. Buffer strips
3. Regulations, policies, and practices

Note: Forest management activities have the potential to modify water temperatures and the amount of sediment and organic material delivered to NPTH streams. Temperature and sediment have been identified as water quality performance criteria and are described under separate performance criteria. Large woody debris, which is an important contributor to instream cover, was identified as a useful indicator of habitat quality. See the Microhabitat performance criteria for details concerning its measurement.

Application

Tree cutting and planting are major sources of impact on water quality and salmonid habitat in the Clearwater River basin. Their effects can be either beneficial or detrimental depending on the extent of changes in habitat and the species or life stage affected. We propose to monitor best management practices (BMPs) - the extent to which they are prescribed and implemented by private and public entities - as indicators of potential impacts of logging and reforestation on NPTH streams. Some of the more important BMP monitoring activities for the NPT to consider were summarized by Everest et al. (1985). BMPs should be identified during the pre-operational period, and reevaluated if they change in the future.

We also recommend monitoring future timber harvests, with emphasis on buffer strips, to ensure that management prescriptions are being followed. The effects of deforestation and aforestation on chinook populations and their habitat will be measured by application of population viability, water quality, and macro-, meso-, and microhabitat performance criteria.

Measurements

NPTH personnel should complete the following tasks:

1. Review recent scientific literature describing the ecological effects of logging and other forest practices;
2. Review agency documents describing forest management activities, regulatory requirements, and policy;
3. Monitor future trends and compliance with best management practices;
4. Communicate project goals and activities to public agencies and private landholders and encourage best management practices;
5. Estimate and report annually the number of acres logged and planted in NPTH watersheds; also estimate the acreage proposed for logging and planting; and
6. Conduct field audits to determine whether buffer strips are intact.

Sampling Units and Schedule

Prior to project startup, NPTH biologists should contact appropriate agencies and private landholders, review documents, and evaluate best management practices with regard to logging and reforestation. Each year the total acreage affected or projected to affected by these activities should be calculated.

5.3.3.3.2 Agriculture

Recommended performance variables:

1. Type and area affected
2. Regulations, policies, practices

Application

This category of extrinsic factors includes human use of land for crop production, pastureland, and rangeland. Agricultural activities have the potential to influence NPTH success through their effect on streamflows, water quality (sediment, nutrients, and bacteria), and ecological structure and function. At present, only streams in the lower portion of the Clearwater drainage appear to be at risk; of the NPTH streams, Lolo Creek and Meadow Creek in particular show signs of anthropogenic stress.

Measurements

NPTH biologists should obtain historical data and future projections of the percentage of land used for the production of food crops and domestic animals.

Grazing impacts, with specific emphasis on riparian areas, should be qualitatively assessed. Other recommended actions are to: review documents describing agricultural practices, regulatory requirements, and policy; monitor future trends and compliance with State Agricultural Water Quality Program on an annual basis for each subdrainage; communicate NPTH goals and activities to public agencies and private landholders; develop cooperative agreements with management agencies to clarify responsibilities and to implement best management practices.

Sampling Units and Schedule

The NPT will contact appropriate agencies, review documents, and qualitatively summarize data on agricultural activities before supplementation begins. Efforts will focus on Lolo Creek, Meadow Creek, and other subdrainages that have been significantly impacted by agricultural development.

5.3.3.3.3 Land Use

Recommended performance variables:

1. Regulations, policies, and practices
2. Road-related impacts

Application

This Extrinsic Factors subcategory includes any human activity, other than logging and agriculture (these activities are monitored separately), that alters the natural landscape with potentially detrimental effects, on chinook salmon populations. Of particular concern are activities such as road design, construction, and maintenance that occur in close proximity to NPTH streams. Monitoring of human settlement (habitation) will become important over the long run as currently uninhabited areas become settled. The purpose of monitoring land uses is to ameliorate potentially adverse impacts through early warning and through the promulgation and enforcement of sound management practices and land use restrictions.

Measurements

Several tasks relate generally to land use monitoring and evaluation:

- Assemble and review documents pertaining to public and private land use and its management within the Clear-water subbasin.
- For each NPTH stream watershed, estimate the percentage of land currently used for timber production, agriculture, mining, and residential and commercial development.

- Identify historic, present, and predicted or planned future land use, and qualitatively describe the likely effects on the hydrology, vegetation, geomorphology, and ecology of the Clearwater subbasin.
- Describe how these activities may affect the future status of chinook populations on a stream-by-stream basis, assuming current NPTH objectives, and convey concerns to the appropriate agencies.

With regard to road-related impacts, the Nez Perce Tribe should request from appropriate agencies all documents pertaining to planned and existing roads within NPTH stream watersheds, and evaluate existing conditions and management practices with respect to their environmental effectiveness and conformity to State and Federal laws. Evans et al. (1980), Hynson et al. (1982), and Everest et al. (1985) should be consulted for road management practices designed to protect salmonid streams. The Tribe should conduct field audits within each of the affected watersheds, document potential and actual road-related impacts on NPTH streams, and identify problem road segments, bridges, culverts, etc. Special attention should be given characteristics affecting erosion rate and sediment delivery to streams, including:

- distance to NPTH streams
- location and type of road drainage into the stream
- erodibility of road surface, cut and fill, etc. material
- number, type, and condition of stream crossings

Potential problems and recommendations for treatment should be conveyed by the Tribe to appropriate agencies.

Sampling Units and Schedule

The Tribe should formally notify State and Federal agencies of project activities, review agency documents, and qualitatively summarize information on past, present, and future land use activities before supplementation begins. Efforts should concentrate on NPTH drainages that appear to be significantly impacted or are at high risk from road construction.

5.3.3.3.4 Natural Stressors

Recommended performance variables:

1. Fire history
2. Land disturbance

Application

Natural stressors are natural disturbances which, should they occur, might have potentially catastrophic effects on chinook salmon populations and their habitat (Barrett and Rosenberg 198 1). Examples include global warming, volcanic eruptions, landslides, blowdowns, debris flows, and wholesale deforestation caused by fire or disease. We propose to monitor large-scale disturbances of this type on an *ad hoc* basis; the primary activities associated with this performance criteria are the development of contingency plans and their implementation should the need arise. Fires and land disturbances were identified as relatively common natural stressors that warrant both contingency planning and event-triggered monitoring.

Measurements

NPTH fisheries biologists, working with their counterparts in Federal and State agencies, will document in narrative and map format past occurrences of fire and large-scale land disturbances (e.g., landslides, slump earthflows, debris torrents) in NPTH watersheds, and will describe in general terms their effects on existing and future stream carrying capacities. Recurrence intervals will be estimated from existing data. Contingency plans will be developed that identify management alternatives under worse case scenarios.

Sampling Units and Schedule

During the pre-operational period, contact State and Federal agencies, review documents, and qualitatively summarize information on the type and frequency of natural stressors in NPTH watersheds before supplementation begins. Also, develop contingency plans and identify performance standards during the pre-operational period.

5.3.3.3.5 Dams and Water Diversions

<u>Recommended performance variables:</u>

1. FERC proceedings
2. NPPC Protected Areas
3. Water diversions - quantity, location, use, impacts

Application

Under this criteria are included proposed and existing small-scale hydroelectric facilities, and water withdrawals or diversions within the Clearwater River system. The associated performance variables focus on licensing and relicensing requirements imposed by the Federal Energy Regulatory Commission and on protection afforded by the Protected Areas amendment of the Northwest Power Planning Council. The NPT Fisheries Department will provide timely feedback to these agencies and potential developers on the adequacy of regulatory constraints, mitigation, monitoring programs, and supporting databases.

The Clearwater River will come under increasing pressure to supply water for consumptive purposes (e.g., agricultural, municipal, and industrial) as more people move into the basin. The amount of water allocated and abstracted for these purposes should be monitored to ensure that instream values, especially in the lower river, are not compromised.

Measurements

The NPT Fisheries staff will compile and maintain a record of proposed and existing small-scale hydroelectric projects. Letters will be sent to developers and appropriate state and federal agencies requesting pertinent information, and stating the Tribe's intent to monitor and intervene, if necessary, in the licensing/relicensing process if the proposed projects are inimical to fish, wildlife, or tribal values. The Protected Areas database on fish species occurrence and distribution will be reviewed and changes recommended, as needed, in the status (i.e., protected or non-protected) of NPTH streams. Monitoring will begin immediately and continue for the duration of the project.

NPT biologists should seek help from the Tribe's legal counsel and appropriate State and Federal entities in monitoring the appropriation and use of surface and subsurface water supplies. The biological consequences of removing water from the channel should be clearly communicated to decision makers.

Sampling Units and Schedule

Contact appropriate agencies and developers, monitor notices in local papers and the Federal Register, review information, and qualitatively summarize data on small hydro development, water rights, and water use and their likely impacts before supplementation begins. Update information and participate in planning as the need arises.

5.3.3.3.6 Management Impacts

Recommended performance variables:

1. Threatened and endangered species policies, regulations, etc.
2. Hydrosystem operation, harvest, and out-of-basin environmental impacts
3. Other management initiatives and regulatory actions

Application

"Management impacts" include effects that originate or are expressed outside of the Clearwater River drainage, yet have a direct bearing on NPTH goals and performance. The development and implementation of special provisions by the National Marine Fisheries Service to effect the recovery of Snake River spring/summer and fall chinook salmon is of primary concern, since they may block or modify NPTH goals and objectives. Recovery plans or special regulations affecting other threatened or endangered species may also require accommodation. NPTH managers will need to coordinate production, release, and monitoring activities with the Idaho Department of Fish and Game and the U.S. Fish and Wildlife Service, both of whom have supplementation and hatchery production programs in the Clearwater River subbasin. Changes in policies, operation, and status of the mainstem hydrosystem, ocean and inriver harvest, and downriver ecosystems will need to be monitored so that NPTH managers can assess their potential impact on the project. Other important developments in the management and regulatory arenas (e.g., NEPA, PacFish) should be evaluated in light of Tribal goals and objectives.

Measurements

The Tribe should participate in forums in which policy issues and decisions that may affect the future of NPTH are debated. The NPT Fisheries staff should communicate the specific goals, objectives, and status of the NPTH so that decision makers may better understand the effects that their decisions will have on the Tribe's welfare.

Sampling Units and Schedule

Broad participation in meetings of statewide, regional, and national scope, and the submission of timely written and oral input to decision makers, should continue on an as-needed basis.

5.3.3.4 Summary of M&E Activities

Tasks and activities that were described under Extrinsic Factors performance criteria are summarized in Figure 19.

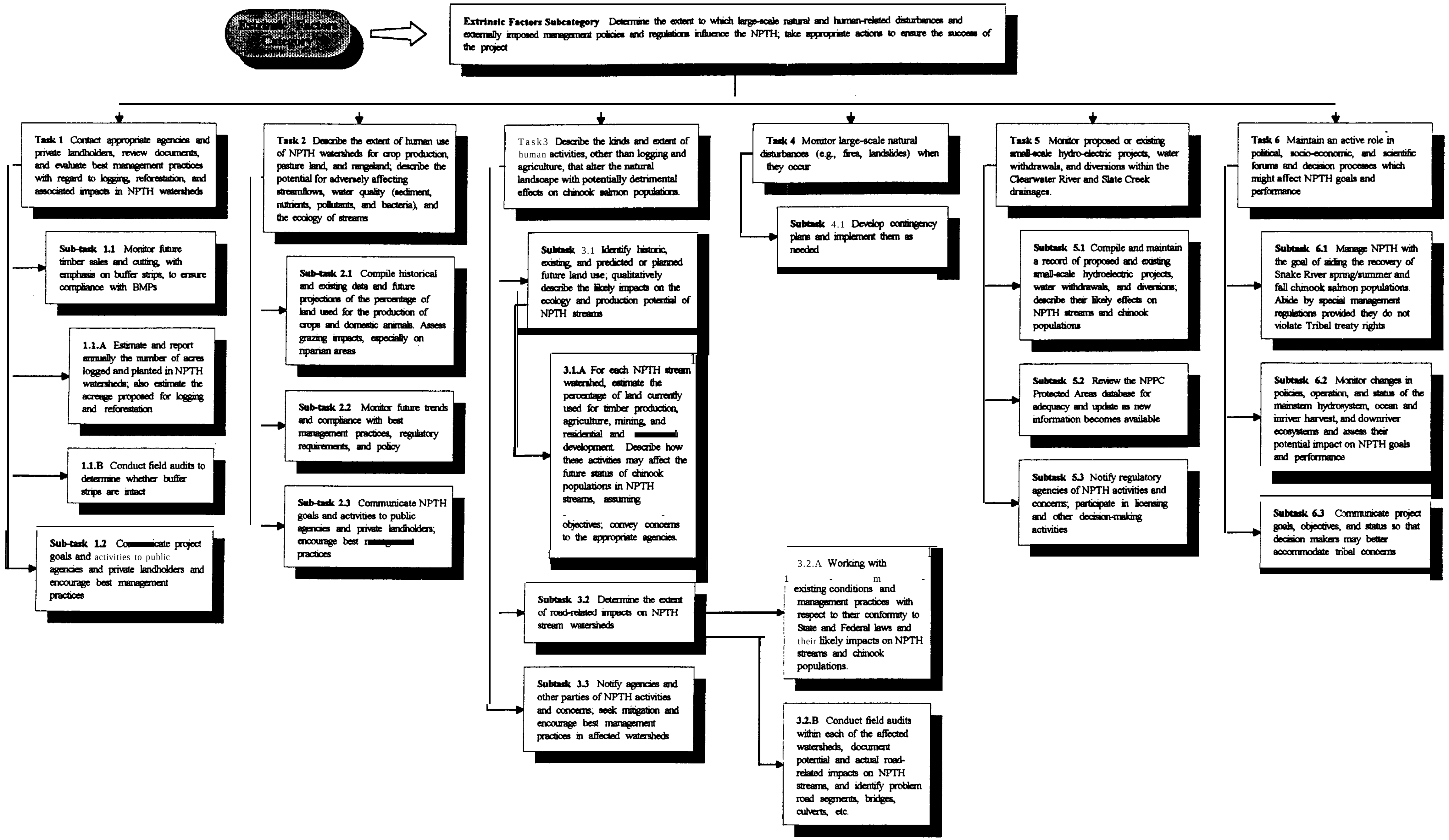

Figure 19. Monitoring and evaluation tasks and subtasks identified for the Extrinsic Factors Subcategory (Natural Environment).

6. IMPLEMENTATION

6.1 Risk Assessment And Monitoring Priorities

This report puts forth a conceptual plan to monitor and evaluate the effects of the Nez Perce Tribal Hatchery on target chinook populations and resident biota of the Clearwater River. The proposed M&E Plan also encompass observations of natural events and human activities that could potentially affect the success of the NPTH Program. The framework and procedures recommended in this report are part of an adaptive learning process whose main goal is to reduce uncertainty so that project goals can be realized.

NPTH managers should evaluate the components of the M&E Plan within the context of Tribal values, risk preferences, and resources when setting future courses of action. Since the range and complexity of managerial actions and possible outcomes is substantial, a number of simplifying strategies were used to prioritize monitoring and evaluation activities.

All monitoring and evaluation activities have been justified by reference to critical uncertainties, defined as project-related assumptions that, if invalid, have the potential to cause undesirable ecological or economic impacts. The risk associated with critical uncertainties was evaluated by explicitly considering our level of understanding of the assumption or process in question, the probability that the assumption or predicted outcome is or will be correct, the likely consequences of being incorrect, and whether the uncertainty and risk could be reduced through research, monitoring, and/or revision of study goals and objectives. Three biologists who are familiar with the project and its environmental setting participated in the risk assessment process.

Information needs identified through the risk assessment process were hierarchically organized by monitoring category, subcategory, and performance criterion. Three categories of information were identified: Stock Status, Biotic Interactions, and Natural Environment. Each of these categories comprises multiple monitoring subcategories that address a common attribute. For example, the category that pertains to targeted chinook populations -- Stock Status -- was partitioned into Genetic Resources, Life History Types, and Population Viability subcategories.

Performance criteria formed the base of the Category - Subcategory - Performance Criteria hierarchy. Performance criteria are attributes or processes that provide useful indicators of project status and impact. The Population Viability subcategory, for example, is composed of four target chinook salmon performance criteria: Abundance, Survival, Reproductive Success, and Long-Term Fitness.

For each performance criterion, one or more performance (monitoring) variables were selected to monitor biological and physical changes. The selection of performance variables involved explicit consideration of their applicability, sensitivity, ease and accuracy of measurement, compatibility with other project monitoring activities, and cost-effectiveness. For example, to monitor changes in spring chinook abundance over time, we recommended that returning adults be enumerated at Lower Granite Dam, several stream weirs, and hatchery facilities. For summer and fall chinook, direct counts at Lower Granite Dam and redd counts are recommended as indices of population abundance. Parr densities, smolt yield, and sport, commercial, and tribal harvest are recommended as auxiliary variables for measuring population abundance for all three races of chinook. Taken together, observations on these variables should provide a reliable record of the size and distribution of chinook populations within the Clearwater subbasin. Some of these variables may be dropped, refined or replaced in the future depending on information gained through their measurement and interpretation.

Once performance variables had been selected, tasks and subtasks were defined to describe the activities and effort required to measure those variables during pre- and post-operation sampling periods. Flow diagrams were used to portray the specific tasks and subtasks for each performance criterion, subcategory, and category. In this way, monitoring activities can be referenced to project critical uncertainties.

6.2 Implementation Priorities

The procedures used to assess risk and define tasks provided a conceptual framework for identifying and prioritizing interrelated monitoring activities whose completion is essential to attaining M&E objectives. Rational implementation of this conceptual plan would involve the deliberate pursuit of some monitoring and evaluation activities, and the deferment or abandonment of others depending on program priorities, budgetary and practical constraints, etc. The NPTH monitoring and evaluation program will need to be flexible enough to adapt to changes in project design, implementation, and funding; to accommodate new information gained through monitoring and evaluation; and to capitalize on opportunities that might arise from the continuous interaction between research, monitoring, and management.

It is unlikely that the Nez Perce Tribe will acquire the resources necessary to implement all of the monitoring activities identified in the conceptual plan. With this in mind, tribal and consulting biologists met to consider alternative implementation strategies. The intent was to devise a method by which the Tribe could justify implementing something less than the full set of monitoring activities should it become necessary to do so. It was decided that greater emphasis should be given to those performance variables and associated monitoring activities that would provide the most useful information per dollar spent.

Two approaches were taken to identifying priorities for monitoring and evaluation. The first was based on a subjective assessment of the relative cost and importance of the different performance criteria. The results are useful for gaining an appreciation of which criteria are more important than others, but they do not indicate the optimal combination of monitoring activities. For this reason, a second approach was devised that involved a subjective assessment of the importance of the performance variables relative to other variables within the same criterion, and to variables within other criteria. Three levels of implementation were identified, corresponding to full, partial, and minimal sets of performance variables.

6.2.1 Prioritization Based on Cost and Importance

To gain a better understanding of the relative importance and cost of different monitoring activities, tribal biologists were asked to group performance criteria into low, medium, and high cost and importance categories.. "Cost" was a subjective estimate of the amount of money needed to fund the monitoring activities identified for that performance criterion. The "importance" of a performance criterion was determined by the number of high risk critical uncertainties associated with it and the opportunity for risk reduction. Both cost and importance were treated as relative measures. The output from this exercise was a two-way matrix in which the 30 performance criteria identified in the conceptual monitoring and evaluation plan were grouped into 6 cost-importance categories, ranging from low cost/low importance to high cost/high importance performance criteria (Figure 20).

Not surprisingly, most (18) of the 3 1 performance criteria were rated high in importance; 11 were rated medium in importance, and 2 were considered to be low in importance. The "high importance" group included eight of the ten performance criteria associated with the Stock Status category. Also thought to be high in importance were criteria that addressed ecological interactions: competition (intra- and interspecific), feeding, and predation (trophic interactions). These interactions are the most likely route by which adverse biological impacts would be expressed. Finally, the need to monitor (non-project) management impacts, principally those that arise from measures taken to protect federally listed species, were considered to be very important.

"High cost" performance criteria - 10 in all -- tend to require labor-intensive, long-term monitoring activities that generate large quantities of data. Most (7) of these

Importance	Low cost	Medium Cost	High Cost
High Importance	Life History Composition Life History Distribution Reproductive Success Hydrology Macrohabitat	Genetic Relatedness Genetic Variability Key Attributes Intraspecific Reproduction Water Quality Status of Listed Species	Abundance survival Intraspecific Competition Interspecific Competition Trophic Dynamics Mesohabitat Management Impacts
Medium Importance	Logging Other Land Uses Dams and Diversions	Genetic Adaptedness Long-Term Fitness Disease Transmission Riparian Areas Natural Stressors	Species Composition Species Diversity Microhabitat
Low Importance	Agriculture	Pathogen Interactions	

Figure 20. Relative importance and cost of monitoring and evaluation activities associated with different NPTH Performance Criteria.

criteria are considered critically important to gauging project success and impact. Examples include stock abundance and survival, different types of competition, habitat carrying capacity, and various indices of ecosystem health. Monitoring and participation by tribal representatives in non-project management activities that might adversely affect the project will also require a considerable investment of time and labor.

Performance criteria considered to be of "medium importance" include most of the criteria grouped under the "Extrinsic Factors" subcategory, such as natural stressors, logging, dams and diversions, and other land uses. These criteria address natural and human processes or activities that are external to the project management, yet nonetheless can influence project success. Most of the remaining performance criteria in this group would provide information that is similar to but of lesser importance than information generated for high importance criteria.

Only two performance variables were considered to be of "low importance" -- agriculture and pathogen interactions. They were ranked lower in importance than other variables because their effects are not expected to have a major impact on the outcome of the project.

6.2.2 Levels of Implementation

The second approach to prioritizing monitoring activities involved assigning the 83 performance variables specified in the conceptual monitoring and evaluation plan to three levels of implementation based on the importance of information they would convey relative to other performance variables. The objective was to identify the most effective combinations of variables under full, partial, and minimal implementation scenarios. "High Importance" performance criteria (see above) were given priority since they were associated with the largest number of high risk critical uncertainties. Within each criteria, however, variables were ranked in terms of their overall reliability and cost effectiveness. If it was determined that two or more performance variables provided equally reliable information, the variable that could be monitored with the lowest economic cost was given highest priority.

The three implementation levels are hierarchical; higher levels include performance variables identified at lower levels. The three implementation levels are defined as follows:

***Minimal** Implementation* (Level I; Table 29) - Monitoring of the 27 performance variables included at this level will provide information considered essential to evaluating project effectiveness and impacts.

***Partial** Implementation* (Level II; Table 30) - Monitoring of the 60 performance variables (including the 27 identified for Level I) grouped at this level will provide a

Table 29. Monitoring activities associated with Level I (Minimal) implementation of the NPTI-I M&E Plan.

Level I - Minimal Implementation				
Subcategory	**Performance Criteria**	**Performance Variable**	**Figure**	**Task**
Genetic Resources	Genetic relatedness	Genetic distance	9	1.1
Genetic Resources	Genetic variability	Effective population size and rate of inbreeding	9	2.1[a]
Genetic Resources	Genetic variability	Heterozygosity, allelic diversity, polymorphism	9	2.1
Genetic Resources	Genetic adaptedness	Changes in adaptive traits	9	3.1
Life History Types	Composition	Life history diversity	10	1.1, 1.2
Life History Types	Distribution	Spatial and temporal distribution	10	2.1-2.3
Life History Types	Key attributes	Key life history attributes	10	3.1-3.3
Population Viability	Abundance	Parr density index	12	1.1
Population Viability	Abundance	Smolt yield	12	1.2[b]
Population Viability	Abundance	Adult escapement	12	1.3
Population Viability	Abundance	Redd counts	12	1.4
Population Viability	Survival	Smolt-to-adult survival	13	2.1, 2.4
Population Viability	Survival	Spawner-to-smolt survival	13	2.1
Population Viability	Survival	Smolt-to-smolt survival	13	2.3
Population Viability	Long-term fitness	Stock productivity	14	3.2[c]
Population Viability	Reproductive success	Stock productivity	14	3.2[c]
Intraspecific	Competition	Relative abundance	15	1.1
Intraspecific	Reproduction	Straying	15	2.3
Interspecific	Competition	Competitor abundance	16	1.1
Interspecific	Trophic dynamics	Predator abundance. index	16	2.1
Production Potential	Hydrology	Summary flow statistics	17	1.1
Production Potential	Water quality	Water temperature	17	2.1
Production Potential	Macrohabitat	Carrying capacity	17	4.2
Production Potential	Mesohabitat	Carrying capacity	17	5.2
Extrinsic Factors	Management impacts	T&E species policies, regulations, etc.	19	6.1
Extrinsic Factors	Management impacts	Hydrosystem operation, etc.	19	6.2
Extrinsic Factors	Management impacts	Other management initiatives, etc.	19	6.3

[a] See also Figure 18, 1.3, 1.4
[b] See also Figure 22, Task 4.3
[c] See also Figure 18, Task 2.5

Table 30. Monitoring activities associated with Level II (Partial) implementation of the NPTH M&E Plan. Performance variables from Level I are not listed, but should be included with those given below.

Level II - Partial Implementation				
Subcategory	**Performance Criteria**	**Performance Variable**	**Figure**	**Task**
Genetic Resources	Genetic adaptedness	Non-random mortality	9	3.2
Genetic Resources	Genetic adaptedness	Shift in allelic frequencies	9	3.2
Genetic Resources	Genetic relatedness	Gene flow	9	1.1
Population Viability	Abundance	Sport, commercial, and tribal harvest	12	1.5
Population Viability	Survival	Egg-to-pair survival	13	2.1
Population Viability	Survival	Parr overwinter survival	13	2.2
Population Viability	Long-term fitness	Genetic resources	14	4.14.3
Population Viability	Reproductive success	Adult-to-redd ratios	14	3.1
Intraspecific	Competition	Growth rates, mean size, condition factors	15	1:1
Intraspecific	Disease transmission	Ambient monitoring	15	3.1
Intraspecific	Disease transmission	Event-triggered monitoring	15	3.4
Intraspecific	Reproduction	Interbreeding among hatchery and wild fish	15	2.2
Interspecific	Competition	Resource use, interactive behaviors	16	1.2
Interspecific	Trophic dynamics	Mortality due to predation at time of release	16	2.1
Interspecific	Trophic dynamics	Estimated losses to predators	16	2.2, 2.3
Production Potential	Hydrology	Discharge	17	1.2
Production Potential	Hydrology	Flood and drought recurrence intervals	17	1.1
Production Potential	Macrohabitat	Production potential	17	4.4
Production Potential	Macrohabitat	Stream reaches: class, location, dimensions	17	4.1
Production Potential	Macrohabitat	Reach quality ranking	17	4.1
Production Potential	Mesohabitat	Channel units: type, frequency, surface area	17	5.1
Production Potential	Mesohabitat	Production potential	17	5.3
Production Potential	Microhabitat	Interstitial Space Index (ISI)	17	6.1
Production Potential	Microhabitat	Large woody debris	17	6.1
Biological Community	Sensitive species	Relative abundance	18	2.1
Biological Community	Species comp. and diversity	Species composition	18	1.1
Extrinsic Factors	Dams and diversions	FERC proceedings	19	5.1, 5.3
Extrinsic Factors	Dams and diversions	NWPPC Protected Areas	19	5.2
Extrinsic Factors	Logging	Regulations, policies, and practices	19	1.2
Extrinsic Factors	Logging	Acreage logged	19	1.1
Extrinsic Factors	Natural stressors	Land disturbance	19	4
Extrinsic Factors	Natural stressors	Fire history	19	4
Extrinsic Factors	Other land uses	Regulations, policies, practices	19	3.3

Table 3 1. Monitoring activities associated with Level III (Full) implementation of the NPTH M&E Plan. Performance variables from Levels I and II are not listed, but should be included with those given below.

Level III - Full Implementation				
Subcategory	Performance Criteria	Performance Variable	Figure	Task
Genetic Resources	Genetic variability	Higher order genetic diversity	9	2.1
Genetic Resources	Genetic variability	· Fluctuating asymmetry	9	2.1
Intraspecific	Competition	Food habits	15	1.2, 1.:
Intraspecific	Competition	Stomach fullness and state of digestion	15	1.3
Interspecific	Trophic dynamics	Prey abundance index	16	2.4
Production Potential	Hydrology	Snowpack	17	1.1
Production Potential	Hydrology	Duration curves	17	1.1
Production Potential	Mesohabitat	Mesohabitat diversity	17	5.4
Production Potential	Microhabitat	Percent fines	17	6.1
Production Potential	Riparianareas	Distribution and acreage of riparian area	17	3.2
Production Potential	Riparian areas	Vegetation composition and condition	17	3.1
Production Potential	Water quality	Water Quality Index	17	2.2
Production Potential	Water quality	Turbidity	17	2.2
Production Potential	Water quality	Sediment yield	17	2.2
Interspecific	Pathogen interactions	Ambient monitoring	18	3.1
Biological Conununity	Species comp. and diversity	Species richness	18	1.1
Biological Community	Species comp. and diversity	Stress index	18	1.1
Biological Conununity	Species comp. and diversity	Species similarity	18	1.1
Extrinsic Factors	Agriculture	Regulations, policies, and practices	19	2.2
Extrinsic Factors	Agriculture	Type and area affected	19	2.1
Extrinsic Factors	Dams and diversions	Water diversions: quantity, location, use, impacts	19	5.1
Extrinsic Factors	Logging	Buffer strips	19	1.1
Extrinsic Factors	Other land uses	Road-related impacts	19	3.1, 3.:

much stronger scientific and empirical basis for evaluating NPTH success and impacts. Partial implementation would substantially reduce the cost and effort associated with monitoring and evaluation without sacrificing significant amounts of information.

Full Implementation (Level III; Table 31) - This level includes the entire 83 performance variables identified in the conceptual monitoring and evaluation plan. Full implementation will provide the greatest assurance that high-risk critical uncertainties will be addressed within an ecosystem management framework.

We assigned highest importance (Level I or Minimal Implementation; Table 29) to performance variables associated with the Population Viability subcategory, in particular those variables specified for the Abundance and Survival performance criteria. We also considered Life History Type variables, including composition, distribution, and key attributes, to be critical to evaluating the success of the project and its impact on targeted wild chinook populations. Other Level I performance variables include those which enable evaluation of chinook salmon genetic resources, stream carrying capacities and basic water quality parameters, ecological interactions with resident fishes, and the effects of certain non-project management activities. With regard to the latter, it is critical that NPTH managers be aware of the impacts of the Endangered Species Act and operation of the Columbia and Snake River hydrosystem on project success.

The 23 variables and associated monitoring activities identified for Level I Implementation would enable NPTH managers to accomplish the following biological objectives with regard to spring, summer, and fall chinook salmon:

1. Develop profiles of genetic, productivity, and life history characteristics of wild and hatchery fish that can be used to differentiate wild from hatchery fish and to detect changes in these characteristics over time;

2. Track the relative abundance and distribution of hatchery and wild fish in the hatchery and the natural environment;

3. Identify natural factors and human influences that have potential to limit the survival and abundance of wild and hatchery fish; and

4. Determine the natural carrying capacity of the mainstem Clear-water River and the streams that are to be supplemented.

Performance variables specified under Level II (Partial Implementation; Table 30) include the 27 Level I variables plus 33 additional variables that would substantially enhance the Tribe's ability to evaluate the effectiveness and impacts of specific actions implemented as part of the NPTH program. A wide array of subcategories and performance criteria are represented by the added variables. Habitat quality and availability variables predominate along with measures of indirect ecological interactions and natural and human-caused disturbances. Armed with this information, the tribe would be better able to refine production goals, identify limiting factors, and identify rearing and release strategies that minimize adverse biological interactions yet take full advantage of the production potential of the natural environment. They would also be better equipped to anticipate and influence fisheries, land and water management actions taken independently of the NPTH program.

The 23 performance variables associated with Level III (Full Implementation; Table 29), when added to Level I and II variables, would provide the most solid footing for evaluating NPTH success and impacts. Added variables include a number of flow and water quality parameters, measures of biological diversity, and the remaining Extrinsic Factors variables. The information gained by monitoring these variables would help resolve the greatest number of critical uncertainties associated with the NPTH program.

We recommend that the Nez Perce Tribe secure the resources necessary to implement Level III monitoring and evaluation. However, in the event that the Tribe's resources do not permit full implementation, we recommend that they monitor the greatest number of performance variables possible with available funding.

In the interest of keeping costs down, NPTH managers should look to existing monitoring programs for useful information and rely on the capabilities and expertise of others, both within and outside the tribe. The Tribe should endeavor to cooperate and develop partnerships with agencies and research institutions that are involved in relevant monitoring activities.

Tradeoffs can be made not only in the number of performance variables monitored, but in the frequency and resolution at which they measured. It may be possible to sample some variables less frequently, thereby keeping costs low enough to include other variables in the sampling regimen. Deficiencies in the monitoring and evaluation program will be revealed following a reasonable test period; these should be addressed, and adjustments made where necessary. The frequency and need for sampling should decrease over time as populations and impacts stabilize. Monitoring should continue no longer than is necessary to demonstrate that natural production has increased and environmental effects are within acceptable limits. When monitoring indicates a project activity is producing an undesirable effect, the activity should be modified or replaced.

6.3 Recommendations Pursuant to Implementation

To facilitate development of the NPTH monitoring and evaluation program, it is recommended that the Tribe:

1. Finalize the list of streams to be supplemented and devise contingency plans to deal with unanticipated deficits and surpluses in hatchery production;

2. Finalize selection of hatchery broodstock, refine production goals, and determine whether enough donor stock can be obtained to meet those goals;

3. Continue to use risk analysis as a tool evaluate management options and to establish monitoring and evaluation priorities;

4. Develop short- and long-term M&E implementation plans consistent with the prioritization schemes outlined earlier; define tasks and subtasks, staffing requirements, responsibilities, schedules, and deliverables;

5. Develop the capacity (e.g., funding, staffing, database QA/QC, software and hardware) for information management (data formatting, entry, storage, retrieval, analysis, and reporting) required for monitoring and evaluation; ensure that project managers obtain accurate and rapid feedback;

6. Improve understanding and increase participation of tribal members in the monitoring and evaluation program;

7. Meet with researchers, consultants, and managers from state and federal agencies, intergovernmental entities, universities, and other research institutions to review NPTH monitoring and evaluation objectives and proposed activities, discuss possibilities for collaboration in data collection and review, and coordinate research and monitoring efforts;

8. Establish (reconvene) an NPTH Advisory Committee composed of tribal and non-tribal scientists, managers, resource users, and interested citizens; the Advisory Committee would meet regularly to review information generated by the M&E program, evaluate proposed actions, coordinate activities of tribal and non-tribal entities, and provide guidance to NPTH managers;

9. Seek better communication and cooperation with state and federal management agencies and others with resource ownership and/or management responsibilities that overlap or directly affect NPTH activities; tribal managers should familiarize themselves with ongoing and proposed management activities so they can protect the tribe's interests. Importantly, tribal personnel should participate in the development of Recovery Plans, Biological Opinions, and other legally mandated

management initiatives designed to protect and restore threatened and endangered species Snake River Basin;

10. With the assistance of the NPTH Advisory Committee, establish more specific performance standards for each performance criterion of interest;

11. Develop a Hatchery Operations Plan that provides detailed information on broodstock maintenance, mating, rearing, transportation, and release protocols consistent with NPTH goals and objectives; specify performance criteria and variables for monitoring and evaluating hatchery operations;

12. Develop a Harvest Management Plan and integrate it with hatchery production and monitoring and evaluation programs;

13. Develop a Habitat Management Plan to ensure that salmon habitat is protected and restored for the benefit of wild and hatchery fish; such restoration activities, to be successful, must be coordinated among tribal and non-tribal interests.

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