CSMEP

Collaborative Systemwide Monitoring
and Evaluation Project (CSMEP)

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Project No. 2003-036-00

Snake River Basin Pilot Study

Volume 2

COLUMBIA BASIN
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AUTHORITY

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Executive Summary

The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) was created for the shared, multi-agency development of a regional monitoring and evaluation (M&E) program for fish populations. It is a bottom-up effort to build consensus to ensure technically and consistently sound programmatic decisions on M&E. Specific goals for CSMEP are to: 1) document, integrate, and make available existing monitoring data on listed salmon, steelhead and other fish species of concern, 2) critically assess strengths and weaknesses of these data for answering high priority monitoring questions, and 3) collaboratively design and help agencies implement improved monitoring and evaluation methods related to key decisions in the Columbia Basin.

CSMEP adopted the Environment Protection Agency's (EPA) Data Quality Objectives process (DQO) to guide development and evaluation of alternative designs within the five M&E domains (Status & Trends, Harvest, Hydrosystem, Habitat and Hatcheries). The DQO process helped CSMEP to clarify program objectives, define the appropriate types of data to collect/analyze and specify tolerable limits on potential decision errors. This provided a basis for establishing the quality and quantity of data needed to support management decisions. For habitat action effectiveness M&E, CSMEP additionally developed a 'Question Clarification' process that provided some greater flexibility in identifying information needs. In conjunction with the DQO, CSMEP has been using a structured decision analysis approach to help evaluate trade-offs across the M&E design alternatives. CSMEP's evolving quantitative tools and analyses allow assessment of a variety of M&E design alternatives, in terms of both qualitative and quantitative evaluative criteria.

Systematically developing and evaluating alternative M&E designs is complex. CSMEP, therefore, initially focused on spring/summer Chinook in the Snake River Basin ESU, as a test case to refine design methods and analytical tools. The Snake River Basin was considered large enough to present many of the M&E challenges typical of the entire Columbia River Basin, including consideration of tradeoffs among monitoring objectives, and forced CSMEP scientists to use relevant data from other regions, particularly for hydro, hatchery and harvest questions that are Columbia River Basin-scale in nature. CSMEP's design evaluations within the Snake River Basin pilot study are described for each of the five M&E domains.

Status and trends

Status Quo monitoring for Snake Basin Spring Summer Chinook contains weaknesses for assessing viability at the population level as per IC-TRT viability criteria. The current monitoring does not assess spatial structure information in many populations and lacks abundance estimates in non-index areas for populations without weirs or spatially representative redd counts. CSMEP's recommended 'Medium' design would cost considerably less than the Status Quo monitoring, yet should perform better in answering the question: is the ESU viable? It must be recognized that Status Quo monitoring has not been developed to address only this single viability question, but is rather a consolidation of weirs, redd counts, and other monitoring that is being done to address a variety of questions. However, it appears that a simple reallocation of resources to Status Quo monitoring in the Snake River Basin could address current weaknesses and improve viability assessments. This would require; (1) changing the redd survey program to CSMEP's 'Medium' design where all populations have multiple redd counts and spatial structure assessed, and (2) installing a weir in the Middle Fork Salmon River MPG.

The IC-TRT rule set is conservative, so high uncertainty generally results in underestimating viability. The most likely error from CSMEP simulation models was in depicting a population as 'Not Viable', when the population is in fact ‘Viable’. This common result must be considered when evaluating the tradeoffs among designs. While simpler designs for monitoring viability may be less costly in the short term, inferior data resulting from such designs may incur higher costs over the long term due to the inability to make a correct assessment of the ESU.

Harvest

Status Quo harvest monitoring generally does not provide precision estimates around harvest impacts. Such estimates, however, would improve the ability of managers to quantify risks of harvest management decisions. Uncertainty around harvest impact estimates can result in overharvest of listed stocks or conversely in lost harvest opportunities. It can also contribute to uncertainty around evaluation of status, trends and viability. New analytical techniques are required for preseason and in-season abundance forecasts, although improvements to run size estimates and inseason forecasts may be possible at modest cost with available data and methods. There is a need to evaluate new technologies/techniques for improved stock identification and composition estimates (e.g., PIT tags, GSI). These techniques may be suitable to improve stock identification resolution. Ultimately, there is a considerable need to further improve coordination between entities collecting fisheries harvest monitoring and evaluation information.

Hydro

Status Quo monitoring has allowed a good estimate of annual compliance with the SAR target for wild spring-summer Chinook, but this is partly because SARs have historically been so far below the target. If SARs get closer to the 2-6% target range, higher precision estimates may be required to definitively assess compliance. CSMEP’s ‘High’ design improves the precision of estimates of SARs and in-river survival for wild spring-summer Chinook, allowing more definitive evaluations of annual compliance with targets than is possible with Status Quo monitoring. CSMEP’s ‘Medium’ design enables more *representative* estimates of hatchery survival than is possible with Status Quo monitoring, but has little effect on statistical reliability. CSMEP’s ‘Low’ design, which drops CSS tagging of hatchery fish, would substantially reduce the current ability of managers to assess annual compliance of in-river survival targets (wild plus hatchery fish), and the ability to assess transportation effectiveness for hatchery fish.

Multiple-year estimates should be used for assessing compliance, in addition to annual estimates. Multiple-year estimates can provide insights on compliance with only a relatively small number of PIT-tags (e.g., 5,000 tags), which permits analyses on smaller spatial scales (e.g., MPGs, some large populations) and smaller temporal scales (in-season patterns). Increasing the number of tags per year will improve the precision of annual and seasonal estimates, but for transportation evaluations a very large increase in tags would be required to make substantive improvements over the Status Quo, and is likely not cost-effective. For multiple-year estimates, statistical precision increases with increasing tag numbers up to 5,000 tags, but beyond this level little further benefit is seen. Adding more years to those averages can significantly improve statistical precision. But there is a tradeoff however, in that longer durations of monitoring (e.g., beyond 5-10 years) may be beyond the time scales of interest for some decisions.

Habitat

Various issues must be resolved in creating designs for habitat action effectiveness monitoring. Practical action effectiveness monitoring designs must first incorporate sufficient analytical flexibility to compensate for less than complete control over action implementation. Also it is likely that long term Status Quo designs (generally intended for status and trends monitoring), cannot provide adequate information at the temporal and spatial scales required for efficient implementation of action effectiveness evaluations. Thus, it is likely that implementation of action effectiveness evaluations will necessitate both a new sampling effort and the modification of existing sampling efforts. Further targeted research on the mechanistic linkages between habitat restoration actions and fish population responses is also still needed.

CSMEP's designs for monitoring the effectiveness of habitat actions in the Lemhi River watershed (their pilot area for developing designs) would all provide better information than the current and ongoing Status Quo monitoring in the watershed. Although each CSMEP design alternative would allow quantitative evaluations of the effects of reconnection projects on fish populations to varying degrees of accuracy and precision, CSMEP's more intensive and costly 'Medium' or 'High' designs would likely be required for discerning the mechanistic connections between restorative actions and fish response (i.e., why actions worked or did not). While simpler designs for monitoring effectiveness may appear less expensive in the short term, they are likely to be ultimately more costly as monitoring will need to be continued longer to detect effects. Simpler designs will also lack the added benefit of providing transferable mechanistic information on the benefits of specific projects or project types that can inform cost savings in other watersheds.

As one moves to other subbasins where habitat management issues are diverse, there are likely to be potentially large differences in design elements; in particular, where and when to deploy monitoring resources. It will be impossible to predict this ahead of consideration of the mature scientific questions specific to those locations. Consideration of those questions will in turn require a unique rather than template process that is informed by the management history and management plans in those new locations.

Hatcheries

Columbia River Basin status quo hatchery RME is primarily focused at the scale of individual projects. At that scale, the existing RME is likely to provide adequate information to evaluate hatchery mitigation goals and to address the impacts of hatchery supplementation on abundance and productivity of targeted populations. Alternatively, little existing research is focused on the aggregate impact of hatcheries at larger spatial scales (drainage or basin level), particularly in regard to the impact of hatchery straying and relative reproductive success (RRS) in non-target populations. The current non-random distribution of straying and RRS monitoring precludes statistically valid inference from sampled to un-sampled populations. As a result, under the Status Quo, monitoring effort must be deployed wherever we want an answer. Methods for collecting, analyzing, and reporting data also vary significantly among agencies. Thus, even if effort were representatively distributed, it is unclear whether the resulting information could currently be aggregated and analyzed to enable statistically valid inference to un-sampled populations.

CSMEP's recommended 'Medium' stray ratio design provides stray ratio estimates at the population scale and enables estimates of precision and bias in carcass recovery methods, while the recommended 'Medium' RRS design ensures that RRS can be calculated over the entire life-cycle, although it will not give comparable productivity estimates in un-supplemented populations. Implementation of any of CSMEP's designs for stray ratio and relative reproductive success (RRS) offers substantial improvement over the Status Quo. While RME costs would increase over the short-term, in the longer-term the inferential ability afforded by even the low designs will significantly reduce RME expenditures within the Columbia River Basin. Under the Status Quo, RME is required for every program/population for which information is desired. While the CSMEP designs do not supplant the need for all program specific RME, they do significantly reduce the breadth of RME that would otherwise be required to accompany all programs. In addition, the CSMEP designs enable an evaluation of the aggregate impacts of hatcheries, which cannot be achieved given existing RME. Perhaps most importantly, the CSMEP designs enable informed decisions with regard to the use of hatcheries, and achieve this goal by building on existing RME effort, thus affording substantial cost-efficiency.

Integration

Monitoring and evaluation involves systematic long-term data collection and analysis to measure the state of the resource, detect changes over time and test action effectiveness. Currently, fish populations in the Columbia River Basin are monitored by a number of separate programs established by different agencies. Most of the fish monitoring programs were designed to answer specific management questions at small spatial and temporal scales, and utilize different measurement protocols and sampling designs. This has resulted in an inability to efficiently integrate monitoring at larger spatial scales required for ESU or regional fish population assessment. There is a need for consistent, long-term integrated monitoring of Columbia River Basin fish populations.

Developing a workable plan for efficiently integrating Columbia Basin-wide M&E (spatially, temporally, ecologically and programmatically) will likely involve multiple, simultaneous strategies, which CSMEP has been pursuing in their Snake River Basin pilot. These strategies include:

1. *Building on a Status & Trends foundation.* Layering of action effectiveness M&E alternatives on a consistent foundation of spatially representative Status and Trends monitoring
2. *Integration within domains*. Evaluating how alternative designs could best address multiple questions within a particular M&E domain (i.e., Hydrosystem, Hatchery, Harvest, Habitat, or Status & Trends specific)
3. *Integration across domains*. Evaluating how alternative designs could best address multiple questions across M&E domains (e.g., what elements of each subgroup’s designs can serve multiple functions)
4. *Maximizing benefits of monitoring techniques*. Evaluating how any particular monitoring technique can help address multiple questions across M&E domains (e.g., PIT tagging to address a suite of questions)
5. *Maximizing sampling efficiencies and minimizing redundancies in designs*. Evaluating shared costs and data gathering opportunities across overlapping designs.

General CSMEP recommendations

Regional M&E for fish populations should be developed through a long-term, systematic process that involves dialogue with Columbia River Basin fish managers and decision makers to identify the key management decisions, spatial and temporal scales of decisions, information needs, time frame for actions, and the level of acceptable risks when making the decisions. It should be recognized that monitoring and evaluation are absolutely critical to the region’s adaptive management cycle.

Decisions on regional M&E designs need to be based on a quantitative evaluation of the costs and benefits of the Status Quo and alternative designs to answer management questions. It will likely be much more cost-effective to build on the strengths of the region’s existing monitoring infrastructure, rather than applying a uniform “cookie-cutter” approach throughout the Columbia River Basin. Each region in the Columbia River Basin has invested considerable resources to develop a monitoring infrastructure that is primarily adapted to address local needs. Improved designs that can overcome weakness in the existing M&E programs should allow assessments at larger spatial and longer temporal scales.

The development and implementation of sound M&E designs must be accompanied by strong data management systems which facilitate the sharing, analysis and synthesis of data across agencies, spatial and temporal scales, and disciplines. Without a strong investment in data management, even the best monitoring designs will falter.

Status and trends monitoring of fish populations must satisfy the needs of population and ESU level assessments (for both listed and unlisted species) of viability, as well as assessments of overall trends in population abundance and productivity at larger spatial and longer temporal scales. It must also meet the needs of multiple agencies with different objectives, questions, and scales of interest.

Status and trends monitoring can provide the foundation of a regional M&E program but it must be integrated with action effectiveness monitoring. An integrated M&E program provides economy of scale, prevents duplicative efforts, and is cost effective. Action effectiveness monitoring is more focused on specific questions that influence fish populations hence, it is typically of fixed duration and usually provides more precision. It can respond to adaptive management needs by focusing its efforts to address the mechanistic causes of uncertainty in the relationship between management actions and fish population responses. Action effectiveness monitoring designs must respond to highly varied M&E needs. M&E designs under development must also be integrated across species.

Agencies should evaluate hybrid sampling designs to improve fish population monitoring that is based on fixed index sites. A hybrid sampling design would supplement the existing non-random, index monitoring sites with spatially representative sites. This approach would allow agencies to assess the bias in index sites, get reliable estimates of population abundance for viability assessments, permit aggregation to a variety of larger spatial scales (e.g., MPG, sub-basin), support the sharing of data collected by different agencies with different interests, and facilitate data analyses.

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Glossary

BONN	Bonneville Dam
CSMEP	Collaborative Systemwide Monitoring and Evaluation Project
CSS	Comparative Survival Study
CWT	coded wire tags
BiOp	Biological opinion for operation of the Federal Columbia river Power system.
DIT	double index tagging
DQO	Data Quality Objectives
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCRPS	Federal Columbia River Power System
GSI	genetic stock identification
IC-TRT	Interior Columbia Technical Recovery Team
IDFG	Idaho Department of Fish and Game
ISS	Idaho Supplementation Studies
LCR	Lower Columbia River
LGR	Lower Granite Dam
LOM	looking outward matrix
M&E	monitoring and evaluation
MaSA	major spawning area
MiSA	minor spawning area
MR	mark-recapture
MPG	major population group
NPCC	Northwest Power and Conservation Council
ODFW	Oregon Department of Fish and Wildlife
PIT tags	Passive Integrated Transponder tags
PNI	proportionate natural influence
PTAGIS	PIT Tag Information System
RME	research, monitoring, and evaluation
RRS	relative reproductive success
SAR	smolt-to-adult return rate
SR	Snake River
TIR	transport to in-river ratio
TRT	Technical Recovery Team
WDFW	Washington Department of Fish and Wildlife
VSI	visual stock identification

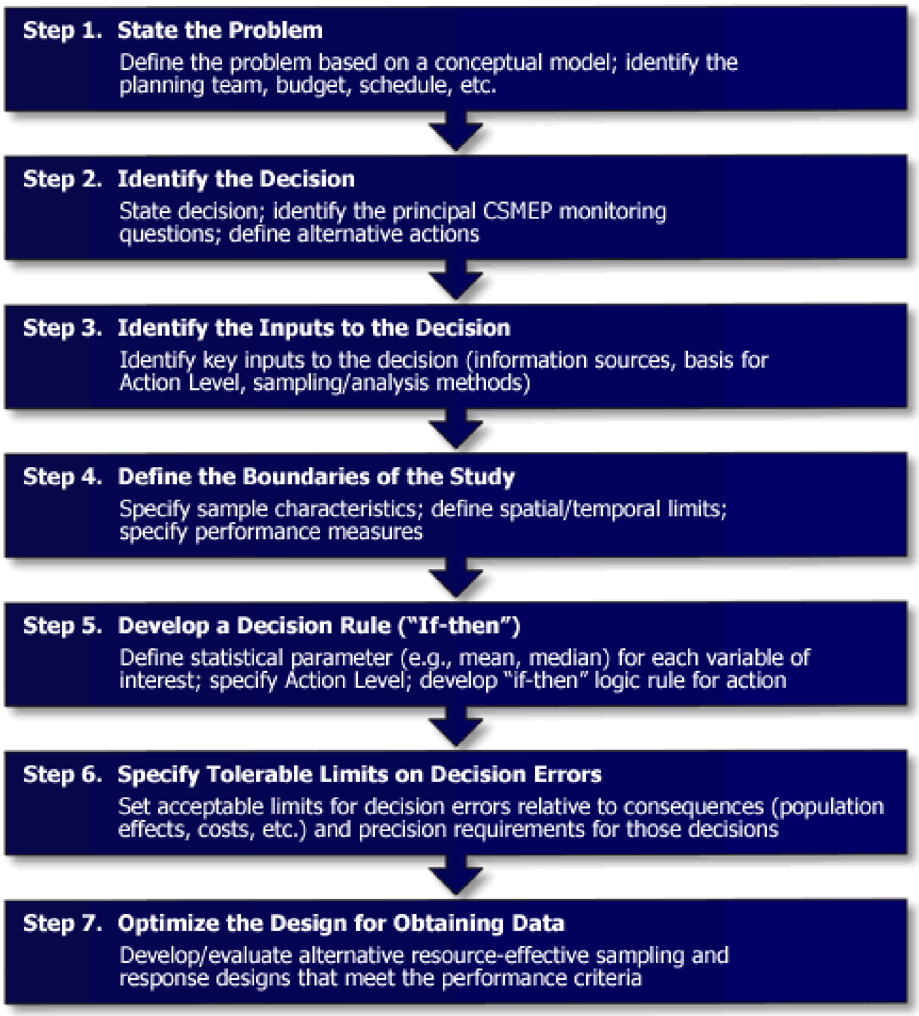
1. Overview of the CSMEP Snake Basin Pilot

1.1 Introduction

The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) was created to involve federal, state and tribal scientists and managers in the collaborative, multi-agency development of a regional monitoring and evaluation (M&E) program for fish populations. It is a bottom-up effort to build consensus across multiple agencies to ensure technically and consistently sound programmatic decisions on M&E. Specific goals for CSMEP are to: 1) document, integrate, and make easily available existing monitoring data on listed salmon, steelhead and other fish species of concern, 2) critically assess strengths and weaknesses of these data for answering high priority monitoring questions, and 3) collaboratively improve design of M&E related to key decisions in the Columbia Basin.

1.2 Process of developing and evaluating alternative M&E designs

An M&E design is the description of the combination of logical, statistical, logistical, and cost components associated with a particular approach to answering management questions. General design strategies have been prepared for other programs in the Columbia River basin. For example, Hillman (2004) describes an overall monitoring and evaluation strategy for the Upper Columbia Basin using four components: 1) a “statistical” design, which provides the logical structure and identifies the minimum requirements for status/trend and effectiveness monitoring; 2) a “sampling” design which describes the process for selecting sampling sites; 3) a “measurement” design outlining the specific performance measures and how to monitor them; and 4) a “results” design that explains how the monitoring data will be analyzed to make inferences. Consistent with this approach CSMEP has adopted the US Environmental Protection Agency’s DQO (EPA 2000) process to guide the development and evaluation of alternative M&E designs (Figure 1.1).



Step 1. State the Problem
Define the problem based on a conceptual model; identify the planning team, budget, schedule, etc.

Step 2. Identify the Decision
State decision; identify the principal CSMEP monitoring questions; define alternative actions

Step 3. Identify the Inputs to the Decision
Identify key inputs to the decision (information sources, basis for Action Level, sampling/analysis methods)

Step 4. Define the Boundaries of the Study
Specify sample characteristics; define spatial/temporal limits; specify performance measures

Step 5. Develop a Decision Rule ("If-then")
Define statistical parameter (e.g., mean, median) for each variable of interest; specify Action Level; develop "if-then" logic rule for action

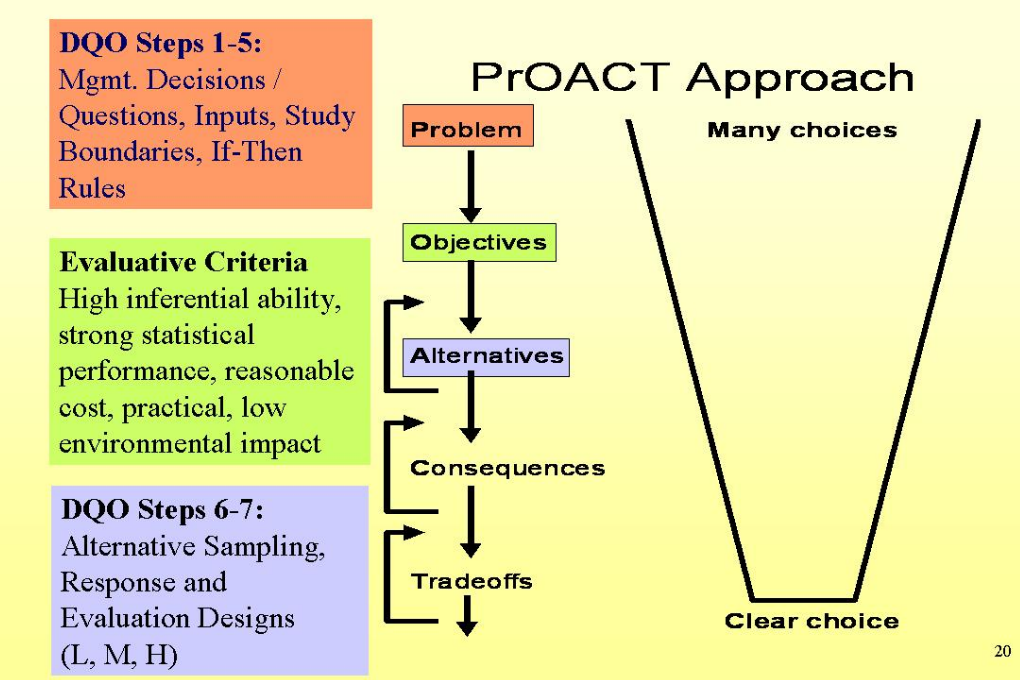
Step 6. Specify Tolerable Limits on Decision Errors
Set acceptable limits for decision errors relative to consequences (population effects, costs, etc.) and precision requirements for those decisions

Step 7. Optimize the Design for Obtaining Data
Develop/evaluate alternative resource-effective sampling and response designs that meet the performance criteria

Figure 1.1. The EPA's Data Quality Objectives process (DQO) (source: EPA 2000). The DQO process is a collection of qualitative and quantitative statements that help to clarify program objectives, define the appropriate types of data to collect/analyze and specify tolerable limits on potential decision errors. This provides a basis for establishing the quality and quantity of data needed to support decisions. The DQO approach has forced CSMEP scientists to consult with program managers on the management decisions to be made, explore alternative analytical/evaluation approaches to those decisions, define the performance measures required to feed those analytical approaches, and design the sampling required to generate the data for the key performance measures. For habitat action effectiveness M&E, we used a 'Question Clarification' process that provided greater flexibility in identifying information needs.

Although development of effective designs within M&E domains is critical it does not of itself provide Columbia River Basin agencies with the information to converge on an 'optimal' M&E program. Ultimately, this involves analyzing the benefits and costs of different designs across multiple client agencies, objectives and M&E domains. It is not an easy problem. CSMEP has been applying the PrOACT approach (Hammond et al 1999) for evaluating cost-effective M&E design alternatives within the five M&E domains, and recommends applying this across domains. ProACT (Figure 1.2) is a simplified approach to multi-objective decision analysis. The acronym stands for ***P***roblem definition, determination of ***O***bjectives, development of ***A***lternatives (M&E designs), calculation or assessment of the ***C***onsequences associated with each alternative across the set of objectives, and evaluation of

Tradeoffs between alternatives for particular objectives, or between objectives within a particular alternative.



DQO Steps 1-5:
Mgmt. Decisions / Questions, Inputs, Study Boundaries, If-Then Rules

Evaluative Criteria
High inferential ability, strong statistical performance, reasonable cost, practical, low environmental impact

DQO Steps 6-7:
Alternative Sampling, Response and Evaluation Designs (L, M, H)

PrOACT Approach

Problem
Objectives
Alternatives
Consequences
Tradeoffs

Many choices
Clear choice

20

Figure 1.2. Flow of the PrOACT decision process recommended by CSMEP to narrow the range of acceptable M&E designs.

PrOACT is an iterative process that involves cycling over the development of alternatives, evaluating them, assessing tradeoffs, then starting again with better alternatives. One begins with a broad set of alternatives that gradually narrows to an acceptable choice or set of choices. Consultation with programmatic levels is critical throughout this process, so that the appropriate objectives and alternatives are considered (Table 1.1). CSMEP has begun to apply this approach as it moves to integrate designs from each domain into a holistic Columbia River basinwide M&E program that addresses multiple management questions.

Table 1.1. Examples of M&E design objectives and evaluative criteria.

CSMEP design objective	Potential evaluative criteria for design objective
High inferential ability	- Ability to answer questions at appropriate scale. - Ability to supply adequate information for clients' decisions. - Spatially representative of larger unit of interest. Ability to legitimately aggregate data required for decisions.
Strong Statistical Performance	- Precision (relative to required precision for management decisions). - Statistical power to detect various effect sizes of management importance over relevant time periods. - Coverage i.e., how often does the true value fall within the 95% confidence interval of the estimate. This depends on both bias and precision of the method used. - Bias (estimated by comparisons to very best measurement possible, close to census).
Reasonable Cost	- Cost/year at scale of interest. Cost for duration of M&E program. - Hybrids: Precision / cost, coverage/cost, accuracy/cost. - Ability to leverage other funding sources. Use overlapping domains of interest from different agencies.

1.3 CSMEP's Strategic Approach

Decisions on regional M&E designs need to be based on a quantitative evaluation of the costs and benefits of alternative designs, including Status Quo approaches. Alternative designs should build on the strengths of each subbasin's existing monitoring infrastructure and data, remedy some of the major weaknesses, and adapt to regional variations that affect monitoring protocols. Selected designs should improve the reliability of management decisions related to the status and trends of fish populations and should also improve evaluations of the effectiveness of habitat, harvest, hatchery and hydrosystem recovery actions within the Columbia River Basin.

CSMEP assembled detailed inventories[1] of fish population data for thirteen subbasins in Washington, Oregon and Idaho, and completed rigorous assessments of the strengths and weaknesses of these data for addressing high priority questions about salmon populations. These inventories were not intended to document all M&E actions everywhere – rather they were intended to evaluate the quality of information available by subsampling among the various subbasins. We have been exploring how best to integrate the most robust features of these existing monitoring programs with new approaches, and implementing the structured processes described in Section 1.2 to evaluate the costs, benefits and tradeoffs of different M&E designs.

Systematically developing and evaluating alternative M&E designs is complex. CSMEP, therefore, initially focused on spring/summer Chinook salmon in the Snake River Basin ESU, as a test case to refine design methods and analytical tools that will ultimately benefit the entire Columbia River Basin and Pacific Northwest (see Figure 1.3).

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[1] CSMEP's metadata inventories are available at http://csmep.streamnet.org/ (CSMEP/CSMEP)

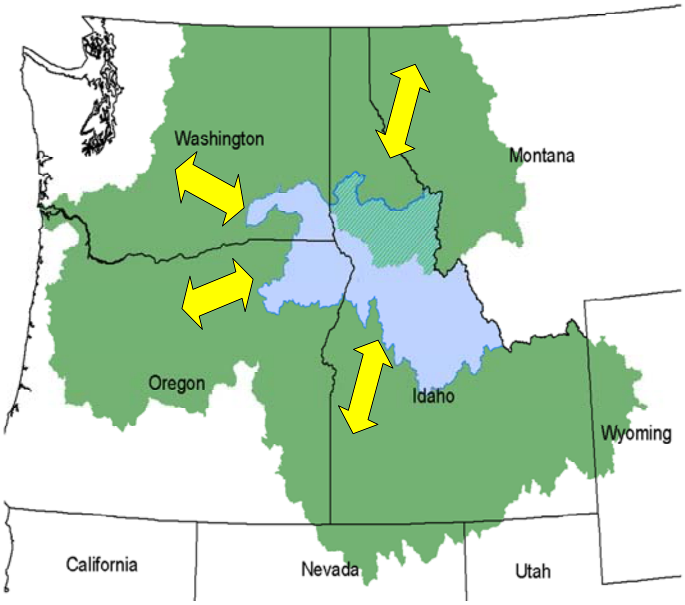


Figure 1.3. Insights gained from the CSMEP Snake River Basin Pilot study (blue shaded area) will have applications to other areas of the Columbia River Basin (CRB) and will similarly benefit from analyses being undertaken elsewhere in the CRB.

1.3.1 CSMEP's Snake River Basin Pilot

Salmon and steelhead occupying the Snake River Basin have declined precipitously to abundances warranting protection under the Endangered Species Act (ESA). The causes most commonly cited for these declines are grouped into four domains:

- *Habitat:* historical spawning areas have been isolated and degraded by human activities.
- *Hydropower:* the construction and operation of mainstem and tributary hydropower structures has altered population connectivity, altered life-history timing and increased mortality.
- *Harvest:* fisheries have exerted mortality on targeted and non-targeted stocks of anadromous, adfluvial, and resident species.
- *Hatcheries:* although intended to provide mitigation and/or conserve salmonid resources, hatcheries pose a multitude of potential risks to extant salmon and steelhead populations as well as other taxa of concern.

CSMEP chose the Snake River Basin as pilot study to develop M&E designs for the following reasons:

- In addition to salmon, there are ESA listed steelhead and bull trout populations, so it presents the challenge of integrating designs across multiple species.
- It has a broad diversity of current monitoring activities and has undergone a thorough CSMEP inventory of existing data, as well as detailed strengths and weaknesses assessments of these data for answering key questions.
- It provides an opportunity to explore an approach with Basin-wide applicability: 'hybrid' sampling designs that build on the existing strengths of monitoring data (e.g., long time series of index counts), but supplement current efforts with more representative sampling.

- It lies within the states of Idaho, Oregon and Washington and is an area of great interest to various client groups (e.g., NOAA, USFWS, NPT, CTUIR, SBT, IDFG, ODFW, WDFW, USFS, BLM, BoR, USACE).
- It is large enough to present many of the M&E challenges typical of the entire Columbia River Basin, including consideration of tradeoffs among monitoring objectives.
- There are hydro, hatchery, habitat and harvest actions requiring evaluation.
- It is one of the three pilot study areas (together with the John Day and Wenatchee subbasins) to be addressed by NOAA as part of their Integrated Status and Effectiveness Monitoring Program (ISEMP).
- The Snake River Basin forces CSMEP scientists to use relevant data from other regions, particularly for hydro, hatchery and harvest questions that are Columbia River Basin-scale in nature. For these domains CSMEP designs must, by necessity, extend beyond the bounds of the Snake River Basin.

For each of the five M&E domains illustrated in Figure 1.4, CSMEP biologists have developed quantitative tools and analyses to project the consequences and tradeoffs of alternative M&E designs in their Snake River Basin pilot, in terms of both the qualitative and quantitative evaluative criteria outlined in Table 1.1. For each domain an ‘Objectives by Alternatives’ matrix has been developed that provides managers a useful way to organize and assess the performance of each alternative design (i.e., Status Quo, ‘Low’, ‘Medium’, ‘High’) across a suite of critical objectives, and to identify trade-offs for making decisions on monitoring designs. These evaluations are described in Chapter 2.

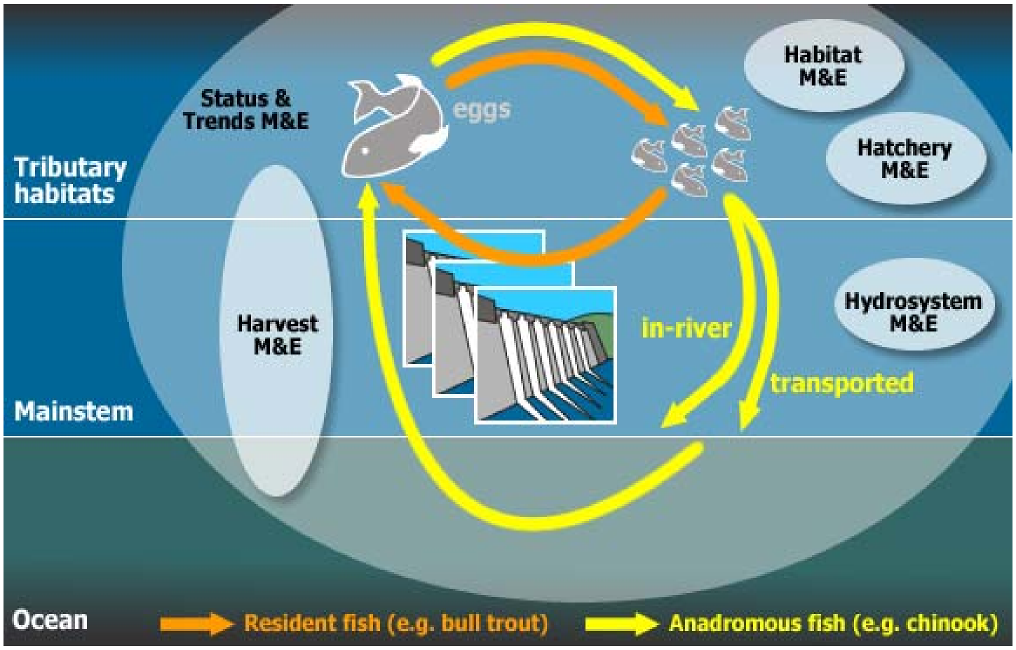


Figure 1.4. Anadromous and resident fish lifecycles and associated M&E domains. Status & Trends M&E (larger darker colored ellipse) encompasses the full range of habitats utilized within fish lifecycles and can be informed by the monitoring being undertaken within the other four M&E domains.

2. Status and Trends

2.1 Introduction

Status and trends monitoring represents the foundation on which the overall performance of salmonid populations is tracked as shaped by natural environmental factors, anthropogenic stressors, and management actions. The Interior Columbia Technical Recovery Team (IC-TRT) has developed population viability criteria for application to the Interior Columbia Basin salmonid ESUs (July 2005). The criteria are based on four types of information: abundance, productivity, spatial structure and diversity (McElhany et al. 2000). The IC-TRT defined rules for taking this information at the population scale and assessing the viability at the population, MPG, and ESU scale (IC-TRT 2007). We developed a simulation model that can be used to evaluate monitoring designs for spring/summer Chinook salmon at the population, MPG, and ESU scales in the Snake River basin using the IC-TRT rules. Alternative status and trend monitoring designs were compared in terms of cost ($/yr) and their ability to correctly assess the status of each population using a simulated adult abundance dataset. This modeling exercise begins the final steps in the EPA Data Quality Objectives process (DQO) we used to optimize the monitoring design. Earlier work undertaken by CSMEP addressed steps 1-5 of the DQO process (Marmorek et al. 2005)) and is outlined in Table 2.1. The modeling approach to develop an optimal spring/summer Chinook salmon ESU-scale status and trends monitoring and evaluation design (DQO steps 6 and 7) and results are presented in this report.

Table 2.1. Data Quality Objectives Steps 1-5.

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of the Snake River spring/summer Chinook ESU	
Stakeholders:	States—Washington, Oregon, Idaho Tribes—NPT, SBT, CTUIR, CTWSR, YIN Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, PSC, NPCC Other—Idaho Power, conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal (need to each footnote acronym or include them in Glossary)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	What is the ESA listing status for Snake River spring/summer Chinook salmon?	
Alternative Actions:	If status is “listed,” then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). If status is “de-listed,” then recovery or sustainable harvest strategies. If status is “recovered,” then sustainable harvest strategies	✓

<table>
<tr><th>DQO STEPS</th><th>SNAKE RIVER BASIN PILOT</th><th>Policy Inputs[1] (✓)</th></tr>
<tr><td>Decision Statements:</td><td>Has there been sufficient improvement in population status of Snake River spring/summer Chinook ESU to justify delisting and allow removal of ESA restrictions?
Are additional management actions required for regional, ESA recovery and NPCC SAR goals?</td><td>✓</td></tr>
<tr><td colspan="3">3. Identify the Inputs</td></tr>
<tr><td>Information Required:</td><td><table>
<tr><th>Information required</th><th>Abundance</th><th>Productivity</th><th>Spatial structure</th><th>Diversity</th></tr>
<tr><td>Abundance of spawners</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>Abundance/distribution of redds</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Origin of spawners</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Age-structure of spawners</td><td>✓</td><td>✓</td><td></td><td>✓</td></tr>
<tr><td>Sex ratio of spawners</td><td>✓</td><td>✓</td><td></td><td></td></tr>
<tr><td>Abundance/distribution of juveniles</td><td></td><td></td><td>✓</td><td></td></tr>
<tr><td>Juvenile survival</td><td></td><td></td><td></td><td>✓</td></tr>
</table></td><td></td></tr>
<tr><td>Sources of Data:</td><td>State, tribal, and federal programs and NGSs identified in CSMEP metadata inventories</td><td></td></tr>
<tr><td>Quality of Existing Data:</td><td>Data varies in level of precision and bias. Major issues:
• Abundance of spawners: 14 of 32 populations have weirs in combination with redd counts, 17 of 32 populations rely on redd abundance as a surrogate for spawner abundance, one population has no abundance data. Weir data can provide precise information on abundance of spawners but no information on spawner distribution. Redd count data provide less precise information on abundance but provides information on distribution of spawners.
• Abundance/distribution of redds: populations vary in spatial and temporal extent and resolution. Fixed index sites are used in most populations in Idaho.
• Origin of spawners: mark quality is high for hatchery origin adults, but sample sizes are low especially during years of low abundance.
• Age-structure of spawners: Can be obtained at weirs. Carcass recoveries can provide estimates but they may be imprecise and likely biased. As an alternative, application of a basin-wide estimate is also imprecise and likely biased at the population-level.
• Sex ratio of spawners: same as for age-structure data
• Abundance/distribution of juveniles: 15 of 32 have juvenile traps, 22 of 32 populations have snorkel. Trap data is more precise for abundance but give no information on distribution; snorkel data are imprecise for abundance but provide high quality information on distribution.
• Survival of juveniles: PIT-tags can provide precise estimates but sample sizes are low in less productive populations.</td><td></td></tr>
<tr><td>New Data Required:</td><td>• MPG and population scale data needed for sex ratios, age of spawners, origin of spawners. Redd counts in many populations need to be expanded both temporally (multiple counts) and spatially (include all spawning areas).
• Existing methods to estimate adult abundance by expanding redd counts may require calibration and validation to improve their utility.
• Analysis of available data may indicate performance measures for which higher quality data are needed to evaluate decisions</td><td></td></tr>
<tr><td>Analytical Methods:</td><td>IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.</td><td>✓</td></tr>
</table>

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
4. Define the Boundaries		
Target Populations:	Snake River spring/summer Chinook Salmon	
Spatial Boundaries (study):	Population, MPG, and ESU levels for spring/summer Chinook salmon in the Snake River basin.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance data, generational productivity data, and spatial structure and diversity data collected at unspecified intervals. Data on historical distribution and productivity also are needed.	✓
Practical Constraints:	Legal and logistical issues with access, interagency coordination across jurisdictional boundaries.	✓
Spatial Boundaries (decisions):	Delisting decision made at level of ESU.	
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10 year series of annual data. IC-TRT rules require spatial structure and diversity data collected at unspecified intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓
If-Then Decision Rules: IC-TRT Draft, 2005	MPG-level Viability Criteria: Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the MPG (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the ESU cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements. 3. The populations at high viability within an MPG must include proportional representation from populations classified as “Large” or “Intermediate” based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult “races,” A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. ESU-level Viability Criteria: 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk. 2. ESUs that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND b. Have at least two populations categorized as meeting more than minimum viability requirements.	✓

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the ESU • Socio-economic consequences to stock collapse Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

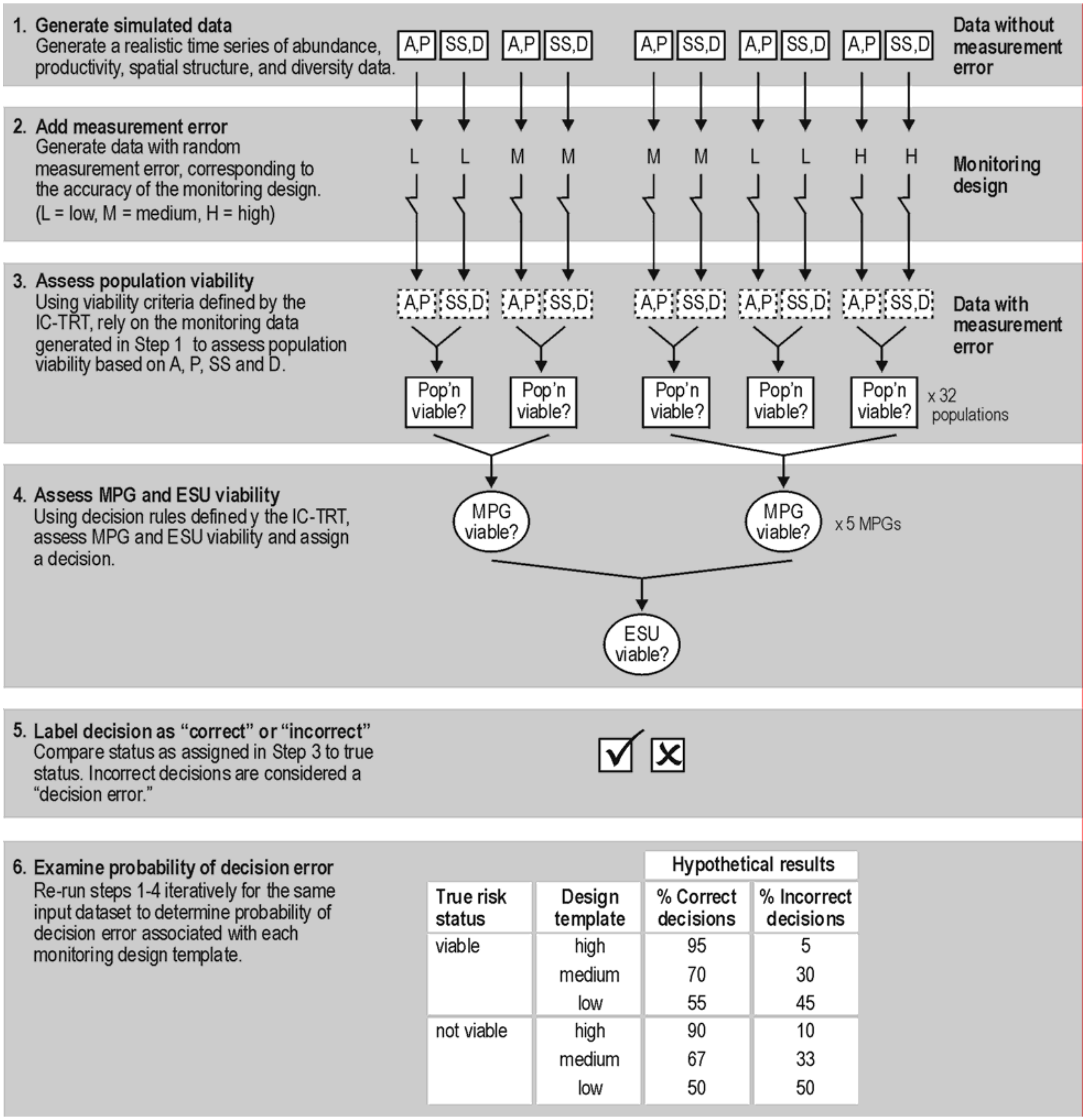
[1] Policy Inputs - indicates with a check steps where group really needs policy feedback

2.2 Methods

We modeled the ability of monitoring programs to correctly assess spring/summer Chinook salmon population viability in the Snake River ESU using a simulated spawner abundance dataset. The model was built with the cooperation of the Interior Columbia Technical Recovery Team (IC-TRT), who provided the decision framework for our model. Using the model and simulated monitoring data, status assessments can be simulated for different types of monitoring programs under various scenarios of salmon abundance, productivity, spatial distribution and diversity. The immediate objective of this model is to evaluate alternative design templates for determining the viability status of Snake River spring/summer Chinook salmon and estimating the cost of each design. We assessed a design scenario approximating the monitoring currently being done in the Snake River Basin ("Status Quo"), a "low" design that relies on M&E methods that are less precise than used in the Status Quo design, a "medium" design that strengthens some of the shortcomings of the Status Quo design, and a "high" design that incorporates more precise M&E methods in all populations.

2.2.1 Model overview

A time-series of simulated but realistic abundance, productivity, spatial structure and diversity data is generated for each population. Variability is then added to the data on each run of the simulation to produce data with measurement error corresponding to alternative monitoring designs. The amount of variability added is determined by user defined model inputs representing the level of monitoring for each population. The IC-TRT rules are then applied to the data with measurement error and, subsequently, the ability to correctly determine the viability status is assessed (Figure 2.1).



1. Generate simulated data
Generate a realistic time series of abundance, productivity, spatial structure, and diversity data.

2. Add measurement error
Generate data with random measurement error, corresponding to the accuracy of the monitoring design. (L = low, M = medium, H = high)

3. Assess population viability
Using viability criteria defined by the IC-TRT, rely on the monitoring data generated in Step 1 to assess population viability based on A, P, SS and D.

4. Assess MPG and ESU viability
Using decision rules definedy the IC-TRT, assess MPG and ESU viability and assign a decision.

5. Label decision as "correct" or "incorrect"
Compare status as assigned in Step 3 to true status. Incorrect decisions are considered a "decision error."

6. Examine probability of decision error
Re-run steps 1-4 iteratively for the same input dataset to determine probability of decision error associated with each monitoring design template.

		Hypothetical results	
True risk status	Design template	% Correct decisions	% Incorrect decisions
viable	high	95	5
	medium	70	30
	low	55	45
not viable	high	90	10
	medium	67	33
	low	50	50

Figure 2.1. Flow chart of the simulation process.

2.2.2 Test datasets

Simulated data resembling currently collected monitoring indicators were generated to allow testing of the viability decision criteria processes. The viability decision process requires the input of 14 metrics for each population for each year. The required metrics are Abundance, Productivity, the twelve Spatial Structure and Diversity Metrics (IC-TRT Viability Criteria document, Table 12. July 2005).

A time series of adult abundance was generated to represent each population in the Snake River spring/summer Chinook ESU. The abundance time series were 60 years in length, and were generated as independent instances of a population process engine. The population process engine was a two stage population model designed by the IC-TRT to mimic time series data that are representative of current stage-specific population processes. The two stage model uses an input spawner abundance and a Beverton-Holt smolt production function based on a SAR of 1%, a smolt capacity of 100,000 and a B-H productivity term of 216, to generate an estimate of brood year smolt production. The smolt production estimate is multiplied by a random variate (lognormal, median = 1, variance = 0.443), and a year-specific SAR that mimics the variance and autocorrelation of the SAR time series from Lower Granite Dam. This process is repeated iteratively to generate time series of spawners that mimic natural population processes.

Productivity time series were generated for each of the Abundance time series in the manner of simple Recruits per Spawner run reconstructions. Assuming a spawner age structure of 50:50 for 4- and 5-year-olds, for each run year the corresponding recruits were accumulated by brood year. When the run year abundance was <5% of the time series average, a productivity was not calculated as these productivities tended to be artificially high, and thus biased the distribution of the metric.

The 12 Spatial Structure and Diversity Metrics for the viability decision simulations were generated annually for each population and scored: as numerical values ranging from -1, 0, 1, 2. These values represent High, Moderate, Low or Very low risk for the metric, respectively. Since the risk scores for each Metric are somewhat abstract categorizations of actual monitoring data based on the IC-TRT Spatial Structure and Diversity criteria, there are no existing time series of values for Snake River Spring/Summer Chinook populations. The 60-year simulated data set was based on the current Status Assessments for each population) and constraints due to the rule set (e.g., some populations can never reach Very Low risk levels due to the geographic distribution of minor and major spawning areas). We used the following principles to generate the dataset:

1. Populations within a MPG were more similar to each other in risk score than between MPGs.
2. Risk scores could vary annually, but were usually held constant for 5–10 years.
3. Risk scores changed only one level at a time, e.g. 0 to -1 or 1.
4. We arbitrarily chose some MPGs to have better spatial structure and diversity scores than others to allow us to observe contrast in the results. An underlying viability was assigned to each MPG and the risk scores for each metric in each population were generated to preserve this expectation through time.

An example of input data for a single SS/D metric is shown in Table 2.2.

Table 2.2. An example of input data for a single SS/D metric, risk levels (-1, 0, 1, 2) by year for each population.

MPG	Lower Snake		Grande Ronde / Imnaha Rivers							
Year	Tucannon River	Asotin Creek	Wenaha River	Lostine River	Minam River	Catherine Creek	Grande Ronde	Imnaha River	Big Sheep Creek	Lookingglass Creek
2006	2	2	1	-1	0	1	0	0	0	-1
2005	2	2	1	-1	0	1	0	0	0	-1
2004	2	2	1	-1	0	1	0	0	0	-1
2003	2	2	1	-1	0	1	0	0	0	-1
2002	2	2	1	-1	0	1	0	0	0	-1
2001	2	2	1	-1	0	1	0	0	0	-1
2000	2	2	1	-1	0	1	0	0	0	-1
1999	2	2	1	-1	0	1	0	0	0	-1
1998	2	2	1	-1	0	1	0	0	0	-1
1997	2	2	0	-1	1	0	-1	1	0	-1
1996	1	2	0	-1	1	0	-1	1	0	-1
1995	1	2	0	-1	1	0	-1	1	0	-1
1994	1	2	0	-1	1	0	-1	1	0	-1
1993	1	2	0	-1	1	0	-1	1	0	-1
1992	1	2	0	-1	1	0	-1	1	0	-1
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.

2.2.3 Measurement error overview

The monitoring design defines the measurement error or noise that will be added to the data at the population level. The structure of the noise added to the input data depends on the type of data. For abundance data, noise with a log-normal distribution is generated and multiplied by the “true” abundance data in order to simulate abundance data with measurement error (Figure 2.2a). For spatial structure and diversity data, a probability transition matrix is used to define the conditional probability of classifying the data in each of the 4 categories given the truth. These multinomial probabilities are applied to the true SS/D risk data in order to simulate categorical data with occasional misclassification due to measurement error (Figure 2.2b).

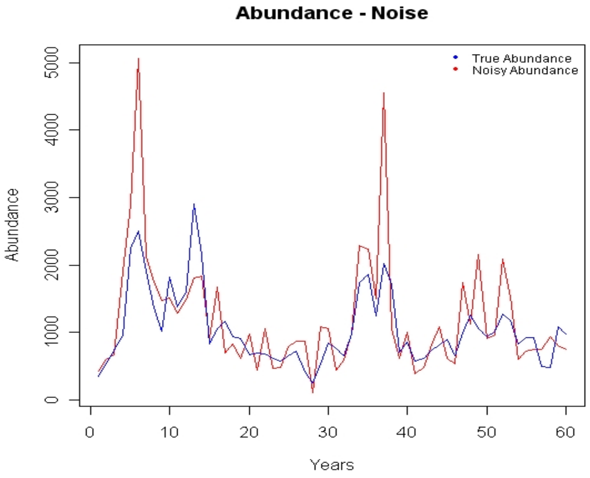


Figure 2.2a. Example of random noise added to abundance data.

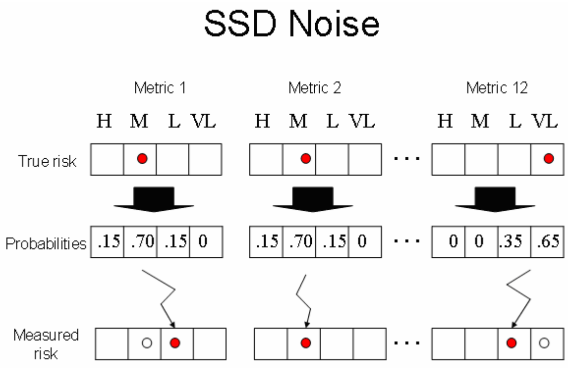


Figure 2.2b. Example of random noise added to Spatial Structure and Diversity data.

Abundance is often well approximated by a log-normal distribution, as abundance data must be non-negative and will often have a long right tail (Hilborn and Mangel 1997). We assumed that the measurement or observation error was also log-normally distributed. Simulating data with random observation error or noise included was completed by generating noise that was log-normally distributed with an expected value of 1, and then multiplying the true data by this noise (Equation 2.1). This results in noisy abundance data whose expected value is the same as that of the true abundance data (this is what we would expect with unbiased monitoring methods). We also considered the situation where the monitoring design resulted in biased results by generating log-normal noise with an expected value other than 1. Bias was incorporated in cases where index sites alone were used for abundance estimates. Snake River spring/summer Chinook abundance estimates based on index site redd counts have been shown to have variable bias (Courbois et al. In Press). Methods for extrapolating information from index sites to the rest of the population may differ by agency and will affect the size and direction of the bias. One method is to assume that the density within the index site is representative of the remaining spawning area and use this assumption to calculate an estimate for total spawner abundance. Another method is to use habitat assessments to determine how much 'good' or 'poor' quality habitat exists outside the index area and use an assumption about how the densities compare between the index areas and these defined habitat types. Another method is to use a fixed correction factor to estimate the total number of spawners from the index area densities. The method used may have changed over time, by agency or individual. For this model we assumed that the first method was used to extrapolate from index counts and that this would result in positive bias. When index sites alone are used in this model the observations generated will have variable positive bias, or will overestimate the population. We incorporate this variable positive bias by drawing μ from a uniform (0, 0.69) distribution. The variability of the noise was determined by a user input coefficient of variation (CV). The observed abundance, N_{obs}, was generated as per Equation 2.1 (after Hilborn and Mangel 1997, eq. 7.33).

$$N_{obs,t} = N_t \exp(Z - \sigma^2_{V,t} / 2)$$

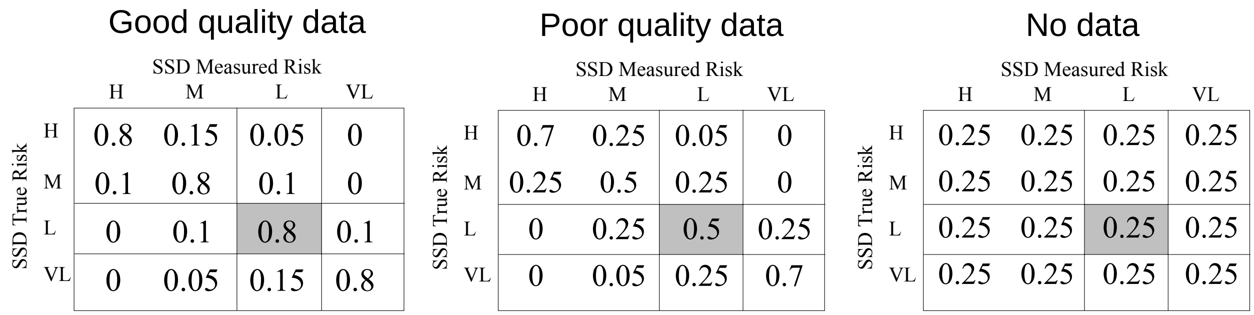
Equation 2.1

Where, Z is a normally distributed random variable with mean μ and standard deviation $\sigma_{V,t}$. The standard deviation of observation error in year t ($\sigma_{V,t}$) was calculated based on the user input CV for year t and the mean abundance over the previous ten years.

Productivity is calculated from abundance of natural-origin spawners and age-structure information. We calculate the noisy productivity from the noisy abundance data and population-specific age-structure information. We assumed the same average age structure for each population and no error in our assessment of proportion natural-origin spawners. Error in age structure may not be very influential, as mistakes in apportioning spawners into brood years dampens 'true' variability in year-class strength, but does not 'lose' fish from the population trajectory. We did not calculate productivity in years where the adult abundance was less than 5% of the mean adult abundance for the population since small errors in the age-structure could have a large impact on the productivity estimate.

The **spatial structure and diversity** risk level assessment differs from the abundance/productivity risk level assessment. Twelve different metrics are evaluated for each population. It is difficult to define the exact data required to assess risk for each of the 12 metrics. Each metric has a series of complex questions requiring a range of data along with expert opinion to evaluate them. Since the data themselves are difficult to define, adding noise to the raw data is not straightforward. Instead, we consider the 12 metrics as the input data. Each of the 12 metrics can belong to one of 4 possible risk categories: very low (VL), low (L), moderate (M) or high (H). The input dataset with known viability status is a time-series of risk categories of the 12 metrics for each of the 32 populations. Since there are only 4 possible outcomes for each metric, the data for each metric can be described as ~multinomial (n, p_1, p_2, p_3, p_4). Depending on the monitoring methods used, the probability (p_i) of choosing category i changes. More precise monitoring methods will result in a greater probability of choosing the correct category and less precise methods will spread the probability among the other categories.

A probability transition matrix is used to define the probability of classifying the data in each of the 4 categories given the truth. Figure 2.3 illustrates three examples of probability transition matrices. In the first figure, if the true risk level is low, then according to this probability transition matrix 80% of the time you would assess the correct risk level, but 10% of the time you would overestimate the risk and 10% of the time you would underestimate the risk. Obtaining realistic probability transition matrices is an ongoing task. We are working with the IC-TRT to understand and improve the estimates of misclassification rates. Our current assumptions follow the logic that: if no data is collected, the best we can do is guess the risk category, if a lot of data is collected then we have a high probability of correctly assessing the risk category and if minimal data is collected we would expect the misclassification rates to fall somewhere in the middle. A different probability transition matrix was used to represent good quality data, poor quality data and no data for each of the 12 spatial structure and diversity metrics in each of the 32 populations. The high design had good quality data for all 12 metrics, the medium design varied between good and poor quality data, the low design generally had no data, but in some populations had good or poor quality data, and the status quo design was a mix of all three data types (Appendices 2A, 2B, 2C and 2D).



Good quality data

	SSD Measured Risk			
SSD True Risk	H	M	L	VL
H	0.8	0.15	0.05	0
M	0.1	0.8	0.1	0
L	0	0.1	0.8	0.1
VL	0	0.05	0.15	0.8

Poor quality data

	SSD Measured Risk			
SSD True Risk	H	M	L	VL
H	0.7	0.25	0.05	0
M	0.25	0.5	0.25	0
L	0	0.25	0.5	0.25
VL	0	0.05	0.25	0.7

No data

	SSD Measured Risk			
SSD True Risk	H	M	L	VL
H	0.25	0.25	0.25	0.25
M	0.25	0.25	0.25	0.25
L	0.25	0.25	0.25	0.25
VL	0.25	0.25	0.25	0.25

Figure 2.3. Example of probability transition matrices used to define misclassification rates of spatial structure and diversity risk assessments.

2.2.4 Viability assessments

Population level

There are multiple ways to achieve a particular viability status at the population level. Table 2.3 determines the viability status resulting from each of the 16 possible combinations of AP and SSD risk levels (Table 13 of the IC-TRT July 05 viability draft, reprinted with revisions described by Pete Hassemer, personal communication).

Table 2.3. Shows the viability status for all 16 possible A/P and SS/D risk combinations. There are four possible outcomes: HV= highly viable, V= viable, M= maintained, and NV= not viable.

		SS/D risk			
		Very Low (VL)	Low (L)	Moderate (M)	High (H)
A/P risk	Very Low (VL) <1%	HV (1)	HV (2)	V (3)	M (4)
	Low (L) 5%	V (5)	V (6)	V (7)	M (8)
	Moderate (M) 25%	M (9)	M (10)	M (11)	NV (12)
	High (H) >25%	NV (13)	NV (14)	NV (15)	NV (16)

Every run of the simulation assigns a viability status to each population in each decision year. The results for a single population can be plotted over all runs and all decision years to provide information about how the A/P and SS/D risk levels affect the viability status.

MPG level

The IC-TRT defines seven MPG specific rules that must all be met for an MPG to be viable (Table 2.4). The frequency that each of the rules is violated for each of the monitoring designs can be plotted to describe which MPGs fail to meet viability standards, as well as which of the seven criteria are responsible for the failure.

Table 2.4. IC-TRT viability criteria for an MPG.

Criteria	Description*
1	At least one population in the MPG must be highly viable (HV)
2	At least half the populations in the MPG must be viable (V)
3	At least x Intermediate – V. Large populations must be viable (V)
4	At least x Large-V. Large populations must be viable (V)
5	At least x spring life history populations must be viable (V)
6	At least x summer life history populations must be viable (V)
7	There can be no populations that are not viable (NV)

* The number of populations required to meet criteria 3 through 6 (represented by an x) is MPG specific.

ESU Level:

For the Snake River Spring/Summer Chinook Salmon ESU to be viable, the IC-TRT has decided that all five of the MPGs must be viable (Pete Hassemer, personal communication).

2.3 Evaluation of Status Quo and three specific monitoring alternatives

2.3.1 Design tradeoffs

The ability to correctly evaluate viability using the IC-TRT criteria depends on the accuracy and precision of the data needed to assess the four Viable Salmonid Population (VSP) criteria: abundance, productivity, spatial structure, and diversity (McElhaney et al. 2000). Our low, medium, and high designs were constructed to evaluate the viability of the Snake River ESU using the IC-TRT criteria (Table 2.5 & Figure 2.4). They were not constructed to answer any other management decision. The status quo design was an assemblage of all monitoring being done annually in the Snake River ESU, for any reason, that could be used in a viability assessment.

The status quo monitoring design has 14 weirs but none in the MF Salmon River MPG. Abundance was estimated using index areas with a one-time redd count in 22 populations and multi-pass census redd counts in eight populations. There are no redd counts in two populations. There was no estimate of abundance made in the non-index areas for the 22 populations without weirs and spatial structure information outside of the index areas was not obtained.

The high design collects abundance and life-history diversity data (age structure, length, sex ratio, proportion natural origin) for all 32 populations using weirs. In five populations where weirs are thought to capture < 40% of the spawners, multi-pass ground index redd counts supplement the abundance and diversity estimates. The spatial structure of each population was obtained from a single census redd survey through out the entire spawning area. This design collects the most precise and accurate data from all populations. It requires the most effort and cost nearly 3 times the status quo (Table 2.7)—primarily due to placing a weir in each population (18 additional weirs were needed).

The medium design uses only five weirs, but ensures that each MPG had a weir. The reduction in weirs increases the uncertainty of the age-structure, proportion natural origin, and other life-history diversity statistics at the population level since life-history data collected at each weir will be assumed to represent all of the populations within the MPG. Abundance in the remaining 27 populations was estimated using multi-pass redd counts in index areas plus a one-time census redd count. The uncertainty of these 27 abundance estimates is due to expansion of redds to non-index areas, using an MPG level redd per female estimate, and an MPG level sex ratio. The single pass spatial census redd count can reduce uncertainty in the abundance estimate since the proportion of redds in the index areas and outside the index areas can be determined. Spatial structure of each population was obtained from the same single pass census redd count.

The low design has no weirs and abundance estimates are based on a single redd count in index areas expanded to the entire population using IC-TRT assumptions. The population abundance estimates have the highest uncertainty in this design. The limited field sampling provides no estimates of spatial structure in populations with more than one MaSA or MiSA, and the number of carcasses recovered may not be representative of the population life-history diversity parameters.

Table 2.5. Description of four monitoring design alternatives and how they differ for each performance measure.

Performance Measures Required	Description of Monitoring Design Alternatives			
	Status Quo	Low	Medium	High
Abundance of Fish	Weir with Mark-Recapture (MR) in 13 populations, weir count only in one population.	No weirs (however there are hatchery weirs in 12 populations that will be operating).	Weir with MR in one population for each of 5 MPGs. (an additional 8 populations have a hatchery weir that will be operating)	Weir with MR in all 32 populations.
Abundance / Spatial Distribution of Redds	Single pass aerial index redd counts in 15 populations. Single pass ground index redd counts in 5 populations. Multi pass ground census redd counts in 8 populations. Single pass census redd count in 2 populations. No redd counts in 2 populations.	Fixed single redd counts for all 32 populations, using index sites. 26 aerial & 6 ground (2 wilderness, 4 road access)	Multi-pass (3x) index redd sites in all populations. Includes 18 aerial and 14 ground counts with a one-time census of the entire spawning area of the population to address spatial structure (6 ground and 27 aerial census surveys). The one time pass provides a ratio of redds within and outside of the index sites, improving the estimate of abundance as well.	Multi-pass redd counts in 5 populations where the weir captures < 40% of spawners in the population (two raft surveys and 3 ground surveys). A one time census survey of the entire spawning area of each population will be done to assess spatial structure (6 ground and 26 aerial census surveys).
Age Structure of Spawners (for the initial run, we are using a fixed age-structure for the simulated data)	Scale analyses in 13 populations with a weir and 10 populations having multi-pass redd counts (9 populations done by the ISS study that are not considered Status Quo redd counts for abundance estimates).	Representative samples taken at Lower Granite Dam provide a single estimate for age structure for all populations in the ESU.	Age structure estimated in 5 populations (one population in each MPG) from adults sampled at the weir. In addition, age structure estimated in 14 other populations surveyed with ground redd counts. Age-structure data collected at each weir will be assumed to represent all of the populations within the MPG.	Age-structure estimated in all 32 populations from adults sampled at weirs and during ground redd counts where this occurs. Each population will have a unique age-structure estimate.
Origin of Spawners (for the initial simulation we are assuming we know the origin of spawners)	Examine hatchery marks on carcasses or at weirs in 21 populations (plus an additional 5 populations surveyed by ISS); detect pit-tags at each weir	Examine hatchery marks on carcasses in 6 populations.	Examine fish for hatchery marks at weir for 5 populations; examine carcasses during all ground redd counts (14 populations).	Examine fish for hatchery marks at weirs and during ground and raft redd counts where they occur.
Sex Ratio of Spawners (We are not considering this parameter explicitly-next round)	Carcass survey or handle at weir in 21 populations (5 additional populations are surveyed by ISS).	Samples taken at Lower Granite Dam for entire ESU. Single estimate for sex ratio for all populations in ESU.	Examine fish at weir in 5 populations; examine carcasses in the 14 populations surveyed with ground redd counts.	Examine fish at weirs and during ground and raft redd counts where they occur

ISS = Idaho Supplementation Study. This is a BPA funded Chinook supplementation research project being done in Idaho. It began in 1992 and is funded at least until December 31, 2009 (funded for the BPA FY07-09 proposal period).

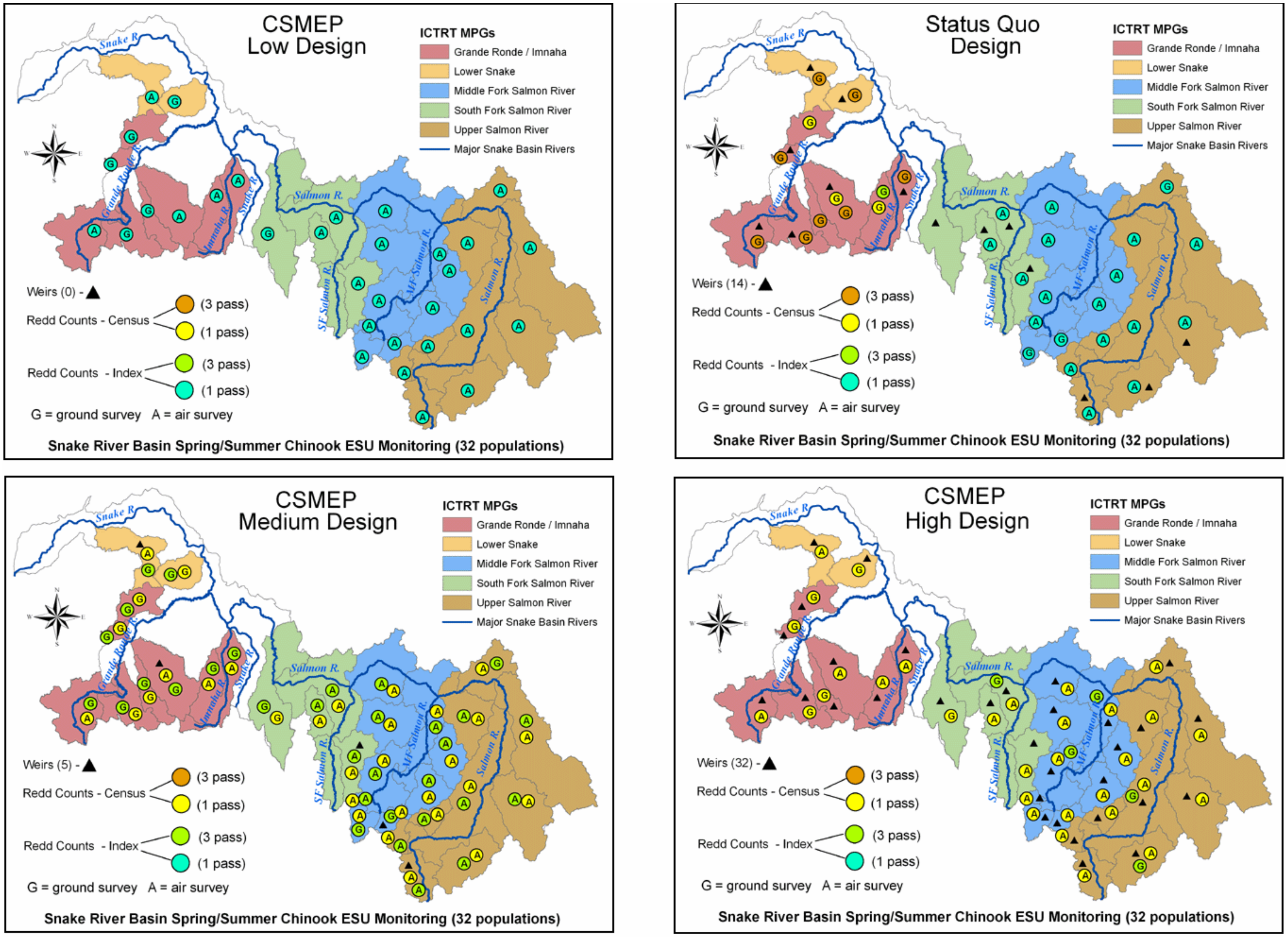


Figure 2.4. CSMEP monitoring designs (status quo, low, medium, high) for assessing viability of TRT populations in the Snake River Basin spring/summer Chinook ESU.

2.3.2 Design detailed assumptions

The simulation model requires input on the quality of the data for abundance, productivity, spatial structure and diversity for each population in each of the four designs. The detailed assumptions by population and design are presented in Appendices 2A, 2B, 2C and 2D. The general principles/assumptions applied are outlined here:

Redd counts

- Assume that all error due to the sampling protocol is captured by between observer variability.
- We have not accounted for timing of these single pass redd counts. All were considered equal.
- Assume no bias due to the sampling protocol. Observers don't tend to always over or underestimate for ground counts they tend to have errors in both directions (C. McGrath, unpublished data).
- Assume that aerial redd counts have the same variability and bias as ground counts.
- Assume that ground counts provide access to carcasses (diversity data) and aerial counts do not.
- Assume single pass counts are less precise and have less chance of finding carcasses than multi-pass counts.

Redd counts using index sites

- Abundance estimates based on index site redd counts are expanded to the rest of the population based on an expansion factor assuming some relationship between the density of redds within and outside of the index site. We do not have the information for each population over the history of the time series to know how these expansions were done. Index sites have often been chosen because they have high redd abundance so expansion to other areas could overestimate the abundance in the entire stream.
- For this model we assumed a variable positive bias where index redd counts were the only method used to estimate adult abundance.

Spatial redd census

- We assumed spatial redd census data provided unbiased estimates for spatial structure and adult abundance.

Redd counts using index sites with a one time spatial census

- Use the counts from the index sites to estimate abundance within the index site and then use the proportion of total redds in non-index sites (obtained from the single pass spatial census) to adjust the expansion factor for non-index areas.

Mechanical weirs

- Assume they catch most spawners passing upstream.
- Assume they are in before first spawner arrives and remain intact for the entire spawning season.
- Assume no bias due to the weirs (no avoidance).
- Assume they provide the most accurate assessment of spawner abundance; assume little or no pre-spawn mortality.

- Assume many fish can be sampled for diversity metrics such as age structure and proportion natural-origin (for productivity calculations).
- Assume mis-clipped hatchery fish can be identified as hatchery origin.

Didson weirs

- Same assumptions as mechanical weirs except: (1) no fish are handled hence no diversity data can be collected, (2) hatchery fish can not be identified, (3) length estimates are possible and can be used as a surrogate for age-structure, and (4) assume all fish enumerated are spring/summer Chinook.
- In our model only the Secesh River population had a DIDSON weir. This is a wild population, assume only wild fish returned to this population.

2.3.3 Summary of assumptions

Abundance: Unbiased and precise estimates can be obtained by weirs that cover a substantial portion of the population or weirs combined with redd counts. Multi-pass index redd counts combined with a single-pass spatial census redd count can also obtain unbiased estimates although they are assumed to be less precise. Index sites alone are assumed to result in biased abundance estimates.

Productivity: Relies on the spawner abundance estimate so the same assumptions apply. However productivity is also influenced by estimates of age-structure, proportion natural origin, and reproductive success of hatchery origin fish. As a result the ability to ‘get hands on fish’ is important. The productivity estimates are best in populations with weirs or ground redd surveys. Assume that productivity data is improved in populations without weirs or ground redd surveys that are near another population that has a weir or ground redd counts. .

Spatial Structure: Requires sampling to occur in each of the MiSAs and MaSAs. A spatial redd census will accomplish this, or in populations with a single spawning area index sites are sufficient. A weir alone can not assess spatial structure in a population with more than one spawning area.

Diversity: Requires the ability to ‘get hands on fish’. This can occur at mechanical weirs or through ground redd counts. Weirs that cover a large proportion of the population and multi-pass redd counts are the best opportunity to sample fish.

Table 2.6. Errors in monitoring the following data were not considered explicitly in the model.

Data type	Assumption
Age structure & hatchery fraction	if we have reliable information for this data then the precision of abundance and productivity estimates will be better
Pre-spawn mortality	our simulated dataset is true spawners. We are assuming that what is caught at the weir is the escapement (assuming little or no pre-spawn mortality)
Male:female ratio	no error due to the male:female ratio
Age structure	50:50 age 4 & 5 year olds, based on TRT assumptions for creating viability curves
Hatchery fraction	our spawner abundance simulated dataset is 100% natural. Although, natural counts at hatchery weirs may be inflated due to hatchery misclips.

2.3.4 Design cost assessment

In order to analyze the cost of the various designs considered as part of the Snake River pilot we input each sampling design into the cost database. The status quo plus the high medium and low designed were defined in term of the inputs used within the cost database and are presented in Table 2.7. Cost assumptions were made to derive a relative index by which to compare the various designs not to accurately portray the actual cost of implementing a given design. Although we attempted to base our cost on real world values we feel confident that our estimates are likely to be conservative as it is more likely that we missed items rather than included items that would not be needed. We would caution the reader not to consider these costs as true dollar values but rather to think of them as relative and conservative value needed to answer our specific status and trend question. Table 2.7 presents our detailed assumptions made to derive these relative costs.

Table 2.7. Detailed assumptions used to derive relative cost assessments.

Performance Measures Required	Status Quo	Low	Medium	High
Abundance of Fish				
	Weir with Mark-Recapture (MR) in 13 populations, weir count only in one population.	No weirs (however there are hatchery weirs in 12 populations that will be operating).	Weir with MR in one population for each of 5 MPGs. (an additional 8 populations have a hatchery weir that will be operating)	Weir with MR in all 32 populations.
Cost assumptions	Ongoing operating costs are:12 medium river weirs, 2 man crew, 3.5 months/weir Assumes 12 months for biometrician, 12 months project lead time for reporting and coordination and 12 months of office staff time for contracting. One time cost to design and construct weirs based upon permanent or semi permanent designs are $190,000/weir with an $8,000/year/weir maintenance cost not included in per year price.	0 weirs	5 medium river weirs, 2 man crew, 3.5 months/weir. Assumes 5 months for biometrician, 5 months project lead time for reporting and coordination and 5 months of office staff time for contracting. One time cost to design and construct weirs based upon permanent or semi permanent designs are $190,000/weir with an $8,000/year/weir maintenance cost not included in per year price.	32 medium river weirs, 2 man crew, 3.5 months per weir Assumes 32 months for biometrician, 32 months project lead time for reporting and coordination and 32 months of office staff time for contracting. One time cost to design and construct weirs based upon permanent or semi permanent designs are $190,000/weir with an $8,000/year/weir maintenance cost not included in per year price.
Cost/year	$891,017	$0	$324,850	1,809,360
Abundance / Spatial Distribution of Redds				
	Single pass aerial index redd counts in 15 populations. Single pass ground index redd counts in 5 populations. Multi pass ground census redd counts in 8 populations. Single pass census redd count in 2 populations. No redd counts in 2 populations.	Fixed single redd counts for all 32 populations, using index sites. 26 aerial & 6 ground (2 wilderness, 4 road access)	Multi-pass (3x) index redd sites in all populations. Includes 18 aerial and 14 ground counts with a one-time census of the entire spawning area of the population to address spatial structure (6 ground and 27 aerial census surveys). The one time pass provides a ratio of redds within and outside of the index sites, improving the estimate of abundance as well.	Multi-pass redd counts in 5 populations where the weir captures < 40% of spawners in the population (two raft surveys and 3 ground surveys). A one time census survey of the entire spawning area of each population will be done to assess spatial structure (6 ground and 26 aerial census surveys).

Performance Measures Required	Status Quo	Low	Medium	High
Cost assumptions	Total: Fixed wing: 1-Flight day, 2 people covers all 8 wilderness sites. Multi-pass foot/boat surveys: road-0.42 months. Assume that both index and census areas can be surveyed in one day and multi-pass represents 3 surveys. Ongoing overhead 15% Assumed 1 month of biometrician time for analysis, 1 month of project lead time for reporting, and 1 month of office support for contracting.	Total: Fixed wing: 0.14 months Foot surveys: road-0.14 months; Wilderness-0.2 months; Ongoing overhead 15% Assumed 1 month of biometrician time for analysis, 1 month of project lead time for reporting, and 1 month of office support for contracting.	1 pass: Flight: 1 day, 2people, fixed wing Foot:14 days, 2 people (road access) Spatial structure: fixed wing, 2 people, 1 day Ongoing overhead 15% Assumed 1 month of biometrician time for analysis, 1 month of project lead time for reporting, and 1 month of office support for contracting.	Total: Fixed wing: 0.2 months Foot surveys: Road-0.14 months; Wilderness-0.2 months Ongoing overhead 15% Assumed 1 month of biometrician time for analysis, 1 month of project lead time for reporting, and 1 month of office support for contracting.
Cost/year	$364,030	$172,697	$348,200	$263,105
Age Structure of Spawners (NOTE: for initial run of S&T model age-structure will be the same for all populations, we'll expand on this next round)				
	Scale analyses in 13 populations with a weir and 10 populations having multi-pass redd counts (9 populations done by the ISS study that are not considered Status Quo redd counts for abundance estimates).	Representative samples taken at Lower Granite Dam provide a single estimate for age structure for all populations in the ESU.	Age structure estimated in 5 populations (one population in each MPG) from adults sampled at the weir. In addition, age structure estimated in 14 other populations surveyed with ground redd counts. Age-structure data collected at each weir will be assumed to represent all of the populations within the MPG.	Age-structure estimated in all 32 populations from adults sampled at weirs and during ground redd counts where this occurs. Each population will have a unique age-structure estimate.
Cost assumptions	Assume that it would be possible to collect 200 scale samples at 8 of the 12 weir sites and no additional cost are required to utilize length @ age or the MPG average	500 scale samples@$5.00/sample	200*5 (from weirs) scale samples +100*22 (from carcasses)	200*32 scale samples (if possible)
Cost/year	$8,000	$2,500	$16,000	$32,000
Origin of Spawners (for the initial simulation we are assuming we know the origin of spawners)				
	Examine hatchery marks on carcasses or at weirs in 21 populations (plus an additional 5 populations surveyed by ISS); detect pit-tags at each weir	Examine hatchery marks on carcasses in 6 populations.	Examine fish for hatchery marks at weir for 5 populations; examine carcasses during all ground redd counts (14 populations).	Examine fish for hatchery marks at weirs and during ground and raft redd counts where they occur.

Performance Measures Required	Status Quo	Low	Medium	High
Cost assumptions (Equipment only)	Use same crews as already in use at the weirs and for the redd counts. (no additional time). CWT recovery costs were approximated at $1,750/carcass survey crew for detection equipment and for Pit-tag detection it is estimated that cost would be about $2,500/crew/site. These costs would be for start-up and would require periodic replacement of equipment anticipated to reoccur every five years. It is assumed these data would be used to help determine origin in addition to external marks.	Assumed that this work will continue at LGD regardless of design	Use same crews as already in use at the weirs and for the redd counts. (no additional time). CWT recovery costs were approximated at $1,750/carcass survey crew for detection equipment and for Pit-tag detection it is estimated that cost would be about $2,500/crew/site. These costs would be for start-up and would require periodic replacement of equipment anticipated to reoccur every five years. It is assumed these data would be used to help determine origin in addition to external marks.	Use same crews as already in use at the weirs and for the redd counts. (no additional time). CWT recovery costs were approximated at $1,750/carcass survey crew for detection equipment and for Pit-tag detection it is estimated that cost would be about $2,500/crew/site. These costs would be for start-up and would require periodic replacement of equipment anticipated to reoccur every five years. It is assumed these data would be used to help determine origin in addition to external marks.
Cost/year	$19,450	$0	$20,850	$20,250
Sex Ratio of Spawners (We are not considering this parameter explicitly-next round)				
	Carcass survey or handle at weir in 21 populations (5 additional populations are surveyed by ISS).	Samples taken at Lower Granite Dam for entire ESU. Single estimate for sex ratio for all populations in ESU.	Examine fish at weir in 5 populations; examine carcasses in the 14 populations surveyed with ground redd counts.	Examine fish at weirs and during ground and raft redd counts where they occur
Cost assumptions	again, use same crews as already in use at the weirs and for the redd counts. (no additional time)	Assumed that this work will continue at LGD regardless of design	again, use same crews as already in use at the weirs and for the redd counts. (no additional time)	again, use same crews as already in use at the weirs. (no additional time)
Cost/year	$0	$0	$0	$0
Summary over all performance measures				
Annual estimated relative cost	$1,282,497	$175,197	$709,900	$2,124,715

2.3.5 Results

Population level results

Making a correct viability decision does not mean that the population is viable—only that we were able to correctly assess the viability status. The correct viability assessment was made 60% of the time with the status quo design. There was an improvement in the percent of correct decisions from the status quo using the medium (73% correct) and high (84% correct) designs. The low design correctly assessed the viability 41% of the time. A larger proportion of correct viability assessments were made using the medium design than the status quo and at a lower cost. The high design correctly assessed the viability 84% of the time but it was nearly 3 times the cost of the medium design and 1.7 times the cost of the status quo design.

The intent of the IC-TRT was to ensure a precautionary approach when making viability assessments. Our results confirm that the majority of incorrect decisions under all four designs tend to be false negatives and if the data are poor the tendency to underestimate viability increases. In the low design the viability decisions[2] were 41% correct, 55% underestimated, and 5% overestimated. In the high design where more precise methods were used to collect better quality data the viability decisions were 84% correct, 10% underestimated, and 6% overestimated. The same trend in the percent of correct, underestimated, and overestimated viability assessments was observed in the status quo and medium design results (Table 2.8& Figure 2.5 & Figure 2.6).

The ability of the designs to correctly assess viability will also be influenced by the true population viability. For example, populations in the Grand Ronde MPG where the simulated 'truth' is generally 'Not Viable'' will usually be assessed correctly (Figure 2.5), because the viability cannot be underestimated. This is due to the fact that underestimates of viability occur much more frequently than overestimates. Consequently, if the simulated true viability is 'Not Viable' (i.e., as low as you can go) then you will be more likely to correctly assess the viability.

Table 2.8. Probability of correctly assessing viability for each of the four alternative designs.

	Status Quo	Low	Medium	High
Pr (correct ESU viability)	59.5%	40.9%	72.9%	84.1%
Pr (underestimating viability)	32.7%	54.5%	17.5%	10.1%
Pr (overestimating viability)	7.8%	4.6%	9.6%	5.8%

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[2] Percentages do not add to 100% due to rounding error.

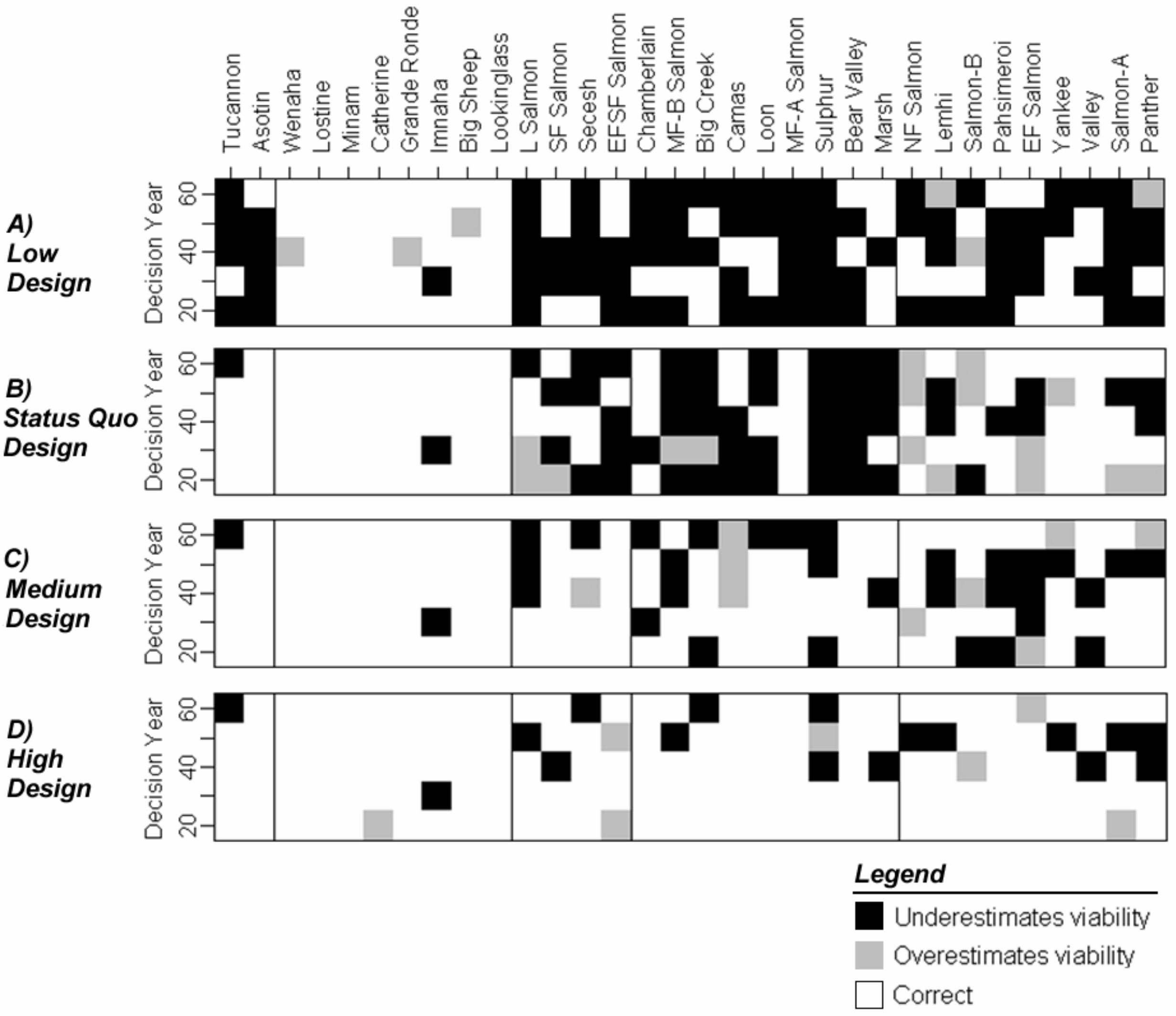

Figure 2.5. This figure shows an example of a ***single*** run of the simulation. Each plot has the 32 populations across the top and decision years along the side (to simplify the output we simply show a decision being made every 10 years). Each small square represents a population level viability assessment. White squares indicate that the viability was correctly assessed, black squares indicate viability was underestimated and grey squares indicate viability was overestimated. The results are shown for the four alternative designs (L, SQ, M, H). This figure illustrates that more correct assessments (white squares) are made as we move from the Low to High designs and that viability is underestimated (black squares) much more frequently than overestimated (grey squares).

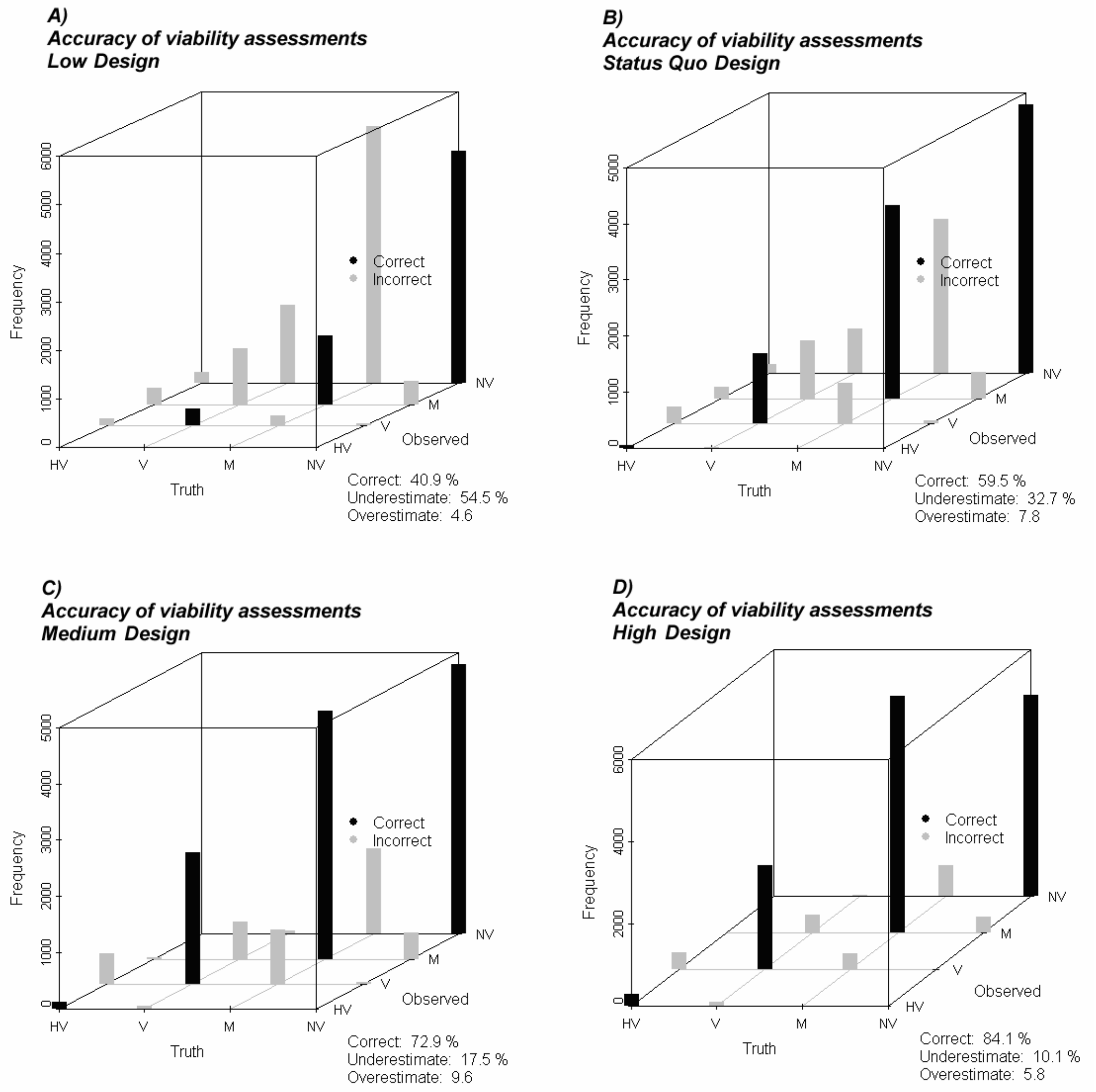

Figure 2.6. This figure shows summary results over 100 runs of the simulation. The “Truth” axis represents the true viability category, while the “Observed” axis represents the measured viability category. The “Frequency” axis represents the frequency of decisions that fall into each of the 16 possible combinations. For example, the height of the top right bar, indicates how many times the observed viability category was “Not Viable” given that the true viability category was “Not Viable”. Recall: Not Viable = NV, Maintained = M, Viable = V, Highly Viable = HV. The on-diagonal (black) bars represent correct viability assessments and the off-diagonal (grey) bars are incorrect assessments.

MPG level results

There are seven criteria in the IC-TRT rule set that must be met for an MPG to be assessed as viable (Table 2.4). The probability of assessing the MPG as ‘Not Viable’ and the criteria which caused this rating are plotted in Figure 2.7. The results show that we are unlikely to assess any of the MPGs as viable (Figure 2.7) even with the best monitoring data (High design). Even in the MPGs where the input datasets were generally healthy, there were one or two criteria that were not always satisfied. In the MPGs where the input datasets had low viability most of the criteria failed most of the time. These results may provide feedback to the IC-TRT to help refine and understand the effectiveness of the IC-TRT viability criteria at the MPG level.

The ability to evaluate each criterion used to make an MPG level assessment changed with each monitoring design. For example, MPG 4 does not fail criteria 3-6 in the high design, but as the data quality declines using the medium, status quo, and low designs, these criteria are more likely to be assessed as failures (Figure 2.7).

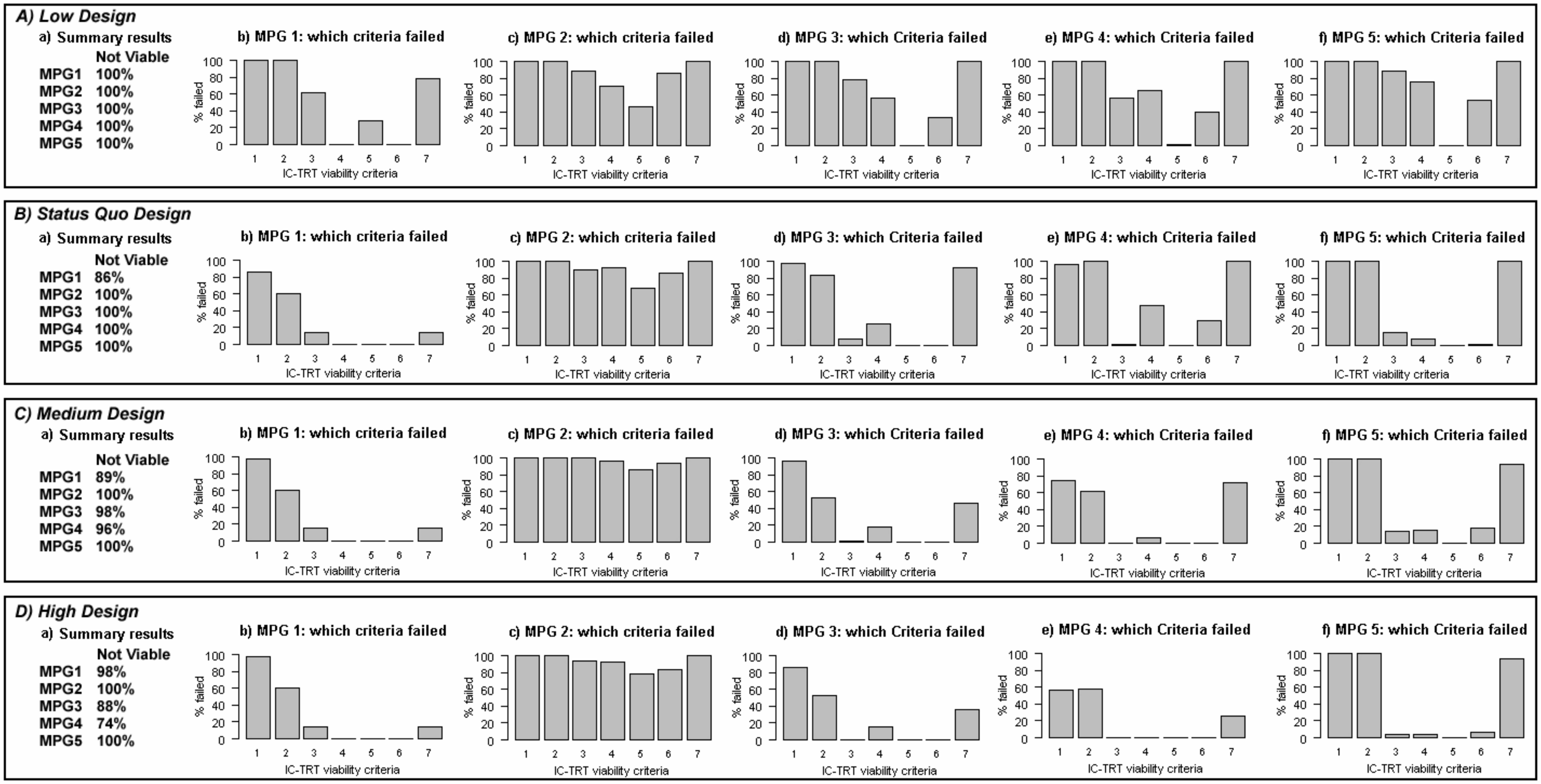

Figure 2.7. A summary of the MPG level results of each design: (a) the frequency that each MPG fails the viability criteria; (b) through (f) the frequency that each of the criteria cause the MPG to be not viable.

2.4 ESU level results

The five MPGs must be viable for the Snake River Spring/Summer Chinook Salmon ESU to be viable. In our model runs MPG 2 was not viable with any design (Figure 2.7) therefore the ESU was never viable in our simulations.

Discussion

The model provides a framework to help managers understand the variability in the information used to make decisions about viability status. The process of assessing the effectiveness of current monitoring methods is in itself a very useful tool. This information can help the manager to determine where it is feasible to improve monitoring methods, and the model can be used to test how much value would be gained by making those improvements. The model can evaluate the sensitivity of the IC-TRT viability criteria to changes in the quality of data. The tool is flexible and information specific to the ESU can be used.

The status quo Snake Basin Spring Summer Chinook monitoring design contains weaknesses for assessing viability at the population level as per the IC-TRT viability criteria. The current monitoring does not assess spatial structure information (not all MaSA and MiSA are surveyed) in 11 populations. It lacks an abundance estimate in the non-index areas for populations without weirs or multiple redd counts (22 populations) preventing the assessment of bias inherent in index counts (Courbois et al in press). The Middle Fork Salmon MPG lacks a weir, but all other MPG's have at least one weir providing life-history data (also referred to as diversity) such as sex ratio, percent female, percent natural origin, length, age, tissue samples for genetics in addition to abundance information.

The cost of the medium design is significantly less than the status quo, yet performs better to answer the question: is the ESU viable? Although the medium design cost less than status quo, the status quo design is a consortium of weirs, redd counts, and other monitoring that is being done for many different purposes. The major difference in cost between the status quo and the medium design is the number of weirs (14 vs. 5). Although, it may not be necessary to have 14 weirs to answer this one question, these weirs can be used to answer other management questions. Most of the weirs in the status quo design are associated with hatchery programs and will operate yearly. If the hatchery weirs were included in the medium design we would expect to see a higher percentage of correct viability assessments (somewhere between the medium and the high design). A reallocation of resources in the status quo design could address its weaknesses and improve the viability assessment. This would require: (1) changing the redd survey program to the medium design where all populations have multiple redd counts and spatial structure assessed; and (2) installing a weir in the Middle Fork Salmon River MPG.

The IC-TRT rule set is conservative, so high uncertainty generally results in underestimating viability. This point should be considered when choosing monitoring designs, along with implementation cost and the consequences of incorrect viability assessments. Our results confirm that the most likely error was finding a population not viable when the population was in fact viable. This point is important when evaluating the tradeoffs among designs. While a lower cost design may save money in the short term, if the resulting data is of lower quality then there is the possibility of incurring higher costs over the long term due to the inability to make a correct assessment of the ESU.

The process of identifying key information needs for the status and trends priority question and assessing alternative monitoring designs also enabled us to identify opportunities for integration. CSMEP’s Hydro designs rely heavily on PIT-tagging efforts which could be also be used to provide age structure data for the Status and Trends domain within an integrated design. A significant portion of Status Quo status and trends monitoring data is a result of hatchery effectiveness monitoring (e.g., hatchery managed weirs).

Ground-based redd surveys and weirs used to collect status and trends information can also provide the data needed for straying/RRS study designs developed by CSMEP's Hatchery group. Since carcass surveys are a key component of the hatchery straying design, we could replace aerial redd surveys with ground-based redd/carcass counts in order to address both questions. As we better understand the key information needs (scale/frequency) for each question the opportunities for integration become more apparent.

3. Harvest

3.1 Introduction

Targeted fisheries on salmon are managed by setting allowable catch, catch allocations and open periods for each fishery prior to opening a fishery (considering escapement goals and preseason/updated run predictions) and then adjusting those regulations as runs develop. However, both mark-selective and non-selective fisheries can exert mortality on non-targeted stocks of anadromous, adfluvial, and resident species that are incidentally intercepted. Removal of fish in fisheries can potentially affect spawners, life history diversity and the spatial structure of populations. The Harvest Subgroup has therefore been focused on developing alternative monitoring designs that can answer two general classes of Harvest questions:

1. What are the in-season estimates of run size and escapement for each stock management group (target and non-target) and how do they compare to preseason estimates?
2. What is the target and non-target harvest and when is it projected to meet allowable levels?

Because Upper Columbia spring Chinook and Snake River spring/summer Chinook stocks (referred to hereafter as upriver spring Chinook) are managed for a maximum harvest rate, these questions focus attention on the key issues of identifying the number of fish that are impacted by fisheries while still working toward recovery of the stocks, and how managers project when that number is achieved. The key management decisions are how and when to operate fisheries.

Earlier work by CSMEP addressed steps 1-5 of the DQO process in relation to harvest questions (Marmorek et al. 2005) and is outlined in Table 2.1.

Table 3.1. Data Quality Objectives Steps 1-5 for the Harvest domain.

DQO STEPS	SNAKE RIVER BASIN PILOT (Snake River spring/summer chinook ESU)	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Targeted fisheries on Chinook, steelhead, coho, and (in some years) sockeye are managed by setting allowable catch and catch allocation limits and open periods for each fishery prior to opening a fishery (considering escapement goals and preseason and updated run predictions) and then adjusting those openings and limits as runs develop and catches are totaled. Both mark-selective and non-selective fisheries exert mortality on non-targeted stocks of anadromous, adfluvial, and resident species that are incidentally intercepted. Removal of fish in fisheries can potentially affect the number of mature adults that spawn in natural and artificial production areas on a seasonal basis and potentially affect diversity and spatial structure of population components on a longer term basis if removals are selective of phenotypes (e.g., size, sex or age). Fishing opportunity in areas with mixed stocks and species inevitably results in bycatch of non-targeted species or stocks. Because such bycatch counts towards the harvest of the bycaught species, it must be accounted for. If the bycatch in a particular non-targeting fishery exceeds allowable catch or impacts set for that fishery or some other pre-specified limit, then management actions will come into play. The type of action will depend on the fishery, on the bycaught species and on management agreements in place. Take includes direct harvest, indirect harvest (released fish that die or non-target landed fish). It may also be worth considering the impact on fitness of catch and released fish.	

DQO STEPS	SNAKE RIVER BASIN PILOT (Snake River spring/summer chinook ESU)	Policy Inputs[1] (✓)
Stakeholders:	State agencies and tribes that co-manage fisheries impacting anadromous fish populations: • Confederated Tribes of the Umatilla Indian Reservation • Confederated Tribes of the Warm Springs Reservation • Yakama Nation • Idaho Department of Fish & Game • National Oceanic and Atmospheric Administration Fisheries • Nez Perce Tribe of Idaho • Oregon Department of Fish & Wildlife • Shoshone-Bannock Tribes of Fort Hall • U.S. Fish & Wildlife Service • Washington Department of Fish and Wildlife	
Non-technical Issues:	Impacts to fish from other "H's" and changes to fish marking programs are both technical and policy issues; other non-technical issues are changes to artificial production schedules, consumer market demands and health concerns (toxins).	
Conceptual Model:	Track components of run size and the methods of estimating them through the Columbia River tribal, commercial and sport fisheries from the lower estuary to the tributaries of the Snake River basin for Snake River spring-summer chinook salmon. For example, natural origin Snake River spring Chinook salmon can be intercepted in mark-selective commercial and sport fisheries downstream of Bonneville Dam, selective sport fisheries between Bonneville and McNary dams, and in the lower Snake River; in traditional Treaty fisheries between Bonneville and McNary dams; and in terminal selective sport and Treaty fisheries in Snake Basin tributaries. Snake River natural spring /summer chinook are assumed by managers to have very low impact rates in ocean fisheries.	
2. Identify the Decision		
Principal Questions:	What are the inseason estimates of run size and escapement for each management group (target and non-target) and how do they compare to preseason estimates? What is the target and nontarget harvest and when is it projected to reach allowable levels?	✓
Alternative Actions:	Open or close various fisheries; Increased or decreased harvest opportunities for fishers.	✓
Decision Statements:	Open Fishery *X* during periods *a, b, and c* subject to the catch not exceeding *Y* for target species *M* and *Z* for non-target species *M*. Once the bycatch is projected to reach to quota, then the fishery would be halted, postponed, or reshaped.	✓
3. Identify the Inputs		
Information Required:	Run size estimates, Catch, Effort, CPUE, release rates, post-release mortality rates, stock identification (for mainstem spring season fisheries, the only stock identification used in season is for below Bonneville fisheries where separation between Willamette and Upriver stocks are made. Age-specific estimates of the numbers of each management unit (stock) in the escapement. Age specific data is only used in forecasting, not in in-season fishery management.	
Sources of Data:	Mainstem commercial, subsistence, ceremonial, and sport fisheries, Hatcheries, dams, previous fisheries, natural spawning estimates, and mark samples.	
Quality of Existing Data:	The main source of uncertainty is statistical sampling error and perhaps bias due to assumption violations, such as error in assumptions regarding release mortality rates. Decision making is typically based on point estimates of take and addresses the uncertainties by adopting conservative actions.	

DQO STEPS	SNAKE RIVER BASIN PILOT (Snake River spring/summer chinook ESU)	Policy Inputs[1] (✓)
New Data Required:	More data, more research on mortality rates resulting from interceptions with varying gears (e.g., hook and release, tangle net release, and others). There is considerable uncertainty in tangle net release mortality rates. There have also been wide ranging estimates made for hook and release mortality rates. There are debates about whether hook location, barbed vs. barbless or environmental (i.e., temperature) are the most important determinant of release mortality. There are no estimates currently in use for net dropout rates for Columbia River net fisheries. Expansion of Genetic Stock Identification (GSI) baseline sampling and in-season sampling of catch and escapement. There has been only limited GSI sampling of fish from harvest.	
Analytical Methods:	Stock-recruitment relationships have been used to set escapement goals for some Columbia Basin salmon populations. Cohort analyses have been used to develop pre-season expectations. There are no agreed to escapement goals for the entire Snake River spring/summer chinook ESU. There are some tributary return goals, but these have not been useful for mainstem fishery management.	
4. Define the Boundaries		
Target Populations:	ESA listed salmonids including Snake Basin Chinook, sockeye, and steelhead ESUs. It should be noted that the Snake River spring/summer ESU includes all naturally spawning spring/summer chinook populations in the Snake Basin except from the Clearwater. This fact complicates management below the Mouth of the Clearwater, because estimates of natural origin Snake River spring/summer chinook below the Clearwater are a mix of listed and non-listed fish. All anadromous populations impacted by mainstem and tributary fisheries during the time that Snake River spring Chinook are migrating upstream.	
Spatial Boundaries (study)	The Columbia River below Priest Rapids dam, Snake River to the WA, ID border, as well as terminal fisheries in Snake River tributaries.	
Temporal Boundaries (study)	Annual March through June for all mainstem fisheries May through July for Snake Basin tributary fisheries.	
Practical Constraints:	Budget; time required to analyze sample data in-season.	
Spatial Boundaries (decisions):	The Columbia River below the mouth of the Snake River, Snake River to the WA, ID border, as well as terminal fisheries in Snake River tributaries.	
Temporal Boundaries (decisions):	Annual and in-season when data are available.	
5. Decision Rules		
Critical Components and Population Parameters:	Harvest number, harvest rate, age and stock composition, escapement by stock.	✓
Critical Action Levels (Effect Sizes):	Varies by return size. Formulas set by compact and treaty requirements.	✓

DQO STEPS	SNAKE RIVER BASIN PILOT (Snake River spring/summer chinook ESU)	Policy Inputs[1] (✓)
If-Then Decision Rules:	1. *If* the catch of upriver spring chinook and Snake River spring or summer Chinook approaches X% of the total upriver spring chinook and Snake River spring summer chinook run size at the Columbia River Mouth in the mainstem Columbia River tribal spring management period Zone 6 fishery, *then* the fishery will be closed. X% depends on the allowed harvest rate in the management agreement that is based on the updated river mouth run size. There is a stepped harvest rate schedule in the current mainstem management agreement. 2. *If* the catch and/or handling mortality of wild upriver spring chinook and Snake River spring/summer Chinook approaches X% of the wild run size in the mainstem Columbia River non-tribal commercial or select area fishery, *then* the fishery will {decision type here – in-season adjustments to effort level, gear type, duration, etc.}. The decision will depend on if the sport/commercial allocation limit is being approached or if the overall wild impact limit is being approached. 3. *If* the catch and/or handling mortality of wild upriver spring chinook and Snake River spring /summer Chinook approaches X% of the cumulative run in the mainstem Columbia River recreational fishery, select area sport fishery, or Washington Lower Snake River sport fishery, *then* the fishery will {decision type here – in-season adjustments to effort level, gear type, duration, etc.}. The decision will depend on if the sport/commercial allocation limit is being approached or if the overall wild impact limit is being approached. 4. *If* the catch and/or handle of the Snake River spring or summer Chinook approaches X% of the cumulative run in the terminal area tribal fishery in any part of the Snake River Basin, *then* the fishery will {decision type here – in-season adjustments to effort level, gear type, duration, etc.}. The actual harvest limits in any terminal fishery depend both on the allowed ESA take if any and the state tribal allocation agreements and escapement objectives that may be in place in any year. 5. *If* the catch and/or handle of the Snake River spring or summer Chinook approaches X% of the cumulative run in the terminal area non-tribal fishery of the Columbia River, *then* the fishery will {decision type here – in-season adjustments to effort level, gear type, duration, etc.}. The actual harvest limits in any terminal fishery depend both on the allowed ESA take if any and the state tribal allocation agreements and escapement objectives that may be in place in any year.	✓
Consequences of Decision Errors:	Management is dependent on point estimates rather than on hypothesis testing so a discussion of precision is relevant as opposed to a discussion of Type I and Type II error. There is no defined precision criteria except that a 20% sample is the goal for species composition.	✓

3.2 Methods

To date, the harvest group has primarily focused on target and non-target harvest of upriver spring Chinook. Currently, non-tribal in-river fisheries for these stocks are mark-selective, requiring the release of all fish not marked with an adipose fin clip (hatchery stocks). While this technique allows for harvest of more abundant hatchery stocks while protecting sensitive wild stocks, it also requires a great deal of information to allow for in-season management of fisheries. Needed information includes, but is not limited to: mark rate in fisheries, mark rate in the population at large, estimated fishery-specific post-release mortality, estimates of number of fish released and harvested, and whether harvested and released fish were upper river stock (destined for areas above Bonneville Dam), or lower river stock. While these information needs are substantial, current sampling protocols used during spring fisheries are able to provide this information, and are better able to meet management needs than sampling for some fisheries (steelhead for instance).

Harvest rates for upriver spring Chinook are limited to maximum rates specified in NMFS Biological Opinion on these stocks. Currently, allowable harvest rate is scaled to the run size of upriver spring Chinook at the Columbia River mouth. In years with large runs, fisheries are allowed to harvest up to 17% of upriver spring Chinook. However, in years with smaller runs, harvest rates are restricted to less than 5.5% of the total run. Because individual stocks of wild upriver spring Chinook cannot be identified in fisheries nor in escapement counts at mainstem dams, managers assume that fish from all upriver spring Chinook stocks are handled at about the same rate in fisheries. Therefore, the percent harvest rate of upriver spring Chinook is calculated as follows: the total number of upriver spring Chinook handled in a fishery is divided by the total number of upriver spring Chinook returning to the Columbia River mouth; the result is then multiplied by the estimated post-release mortality rate for the individual fishery. There are three different post-release mortality rates used in this calculation. Two for commercial fisheries, based on type of gear used (tangle net or regular gill net); and one for recreational fisheries. These post-release mortality rates are derived from published research conducted to estimate mortality from these fisheries. Treaty Indian fisheries are non-selective fisheries; therefore 100% of the handle of upriver spring Chinook in these fisheries is considered in calculating total impact.

Given the method of calculating impacts, the two key measures of interest are how many upriver spring Chinook return to the river and how many of those fish are handled in fisheries. The number of upriver spring Chinook returning to the river mouth is calculated as the number of Chinook counted at the Bonneville Dam fishway between January 1 and June 15 of each year, plus the number of upriver spring Chinook harvested in fisheries below Bonneville Dam, plus the number of upriver spring Chinook released in fisheries below Bonneville Dam.

Because lower river fisheries occur below Bonneville Dam, these fisheries take place well before a robust estimate of the run size for upriver spring Chinook is available. Instead, managers rely upon preseason forecasts for preseason planning of fisheries, and for estimating impact rates in early-season fisheries (see Appendix 3A). Around the time that 50% of the run has historically passed Bonneville Dam (usually mid- to late-April), the US v Oregon Technical Advisory Committee (TAC) is usually able to provide an updated projection of expected final run size. This projection becomes more robust as the run progresses, and in-season estimates of run size are generally updated weekly thereafter.

This updated run projection then becomes the new denominator in the calculation of impacts, and fisheries are adjusted accordingly as necessary. For instance, if the preseason expectation was for a run of about 82,000 upriver spring Chinook, non-Indian fisheries would be planned around impacts of 9% of the run, or a total mortality of about 7,400 upriver spring Chinook. However, if that run was later updated to an expected run size of 55,000 fish, the allowable impact rate would only be 8.5% of 55,000, or 4,675 fish. If fisheries to that point had already impacted 4,675 or more upriver spring Chinook, managers would close the fisheries, but that years fisheries would end up over the specified limits for the year. Conversely, in years where fisheries are planned around a low impact rate or small run, and the impact rate and/or run size increases late in the season, fisheries are often not able to utilize the full impact allowance. Because managers recognize the potential for fisheries to exceed impacts in any given year, they generally take a conservative approach in managing fisheries in-season.

Fisheries are spread throughout the basin, and each fishery is allotted a portion of the total impact limitation. However, managers from the different agencies work together to insure that the total impact from all fisheries does not exceed the limit. Because these fisheries are spread out along the migration route of upriver spring Chinook, managers are often able to adjust upriver fisheries in response to lower river fisheries being over the current impact limits, resulting in overall impacts below the limits in most years, even if individual fisheries have exceeded their expected or allotted impacts.

Hyun et al. (2006) assessed performance of the traditional (first-order linear regression) preseason forecasts of Columbia River fall Chinook salmon runs, and developed new models. They found that (i) the traditional forecast models had autocorrelation problems, (ii) the routine inclusion of intercept term in the models was sometimes not necessary, and (iii) predicted runs from the models were provided without uncertainty measurement. We expect that the traditional preseason forecast of upriver spring Chinook salmon run has similar problems to those of Columbia River fall Chinook salmon runs, because the forecast methods are similar, and uncertainty in forecast of upriver spring Chinook salmon run is not expressed. As we collect historical data on upriver spring Chinook salmon, we will assess the preseason forecast of the fish run (see Appendix 3A).

3.2.1 Related decisions: harvest timing

An important consideration in managing fisheries is the timing of harvest of stocks of concern. Fisheries are not only managed for total catch, but for duration of season, which directly controls total catch. Managers must therefore project what a fishery will catch over some time period. Most often, this is accomplished by examining average catch rates over some period of time. In the case of recreational fisheries, this is most often the most recent average catch-per-unit-effort multiplied by the expected effort for the period of concern. For commercial fisheries, total effort is market- and opportunity-driven and is difficult to estimate. For these fisheries, the landings during fisheries of similar duration, gear, and time of year are typically examined and used to estimate the expected landings for a fishery.

Stock composition of catch is a second critical component in projecting the impacts of a fishery. Most often, managers utilize the most recent available stock composition information to project expected composition of upcoming fisheries. This may be replaced by pre-season composition estimates if projections for early-season fisheries are needed and tag recovery information is not yet available. Managers may also adjust expected composition based on historic information regarding the run timing of key stocks. In other words, if historic data suggests that the stock composition during a planned fishery will likely contain more fish from one component, managers will often adjust estimates of composition to account for this information.

3.2.2 What are the consequences of making a wrong decision?

Overestimating harvest impact has the same effect as an individual fishery exceeding its impact allocation. The individual fishery (or fisheries) may be constrained to stay below the impact guideline, creating lost opportunities for harvest for that fishery, and/or for upriver fisheries. Underestimating harvest impact has the opposite effect. An individual fishery may be allowed to exceed it’s allotted impact, or fisheries throughout the basin may overharvest the stock. This may delay recovery of the stocks.

The TAC defines the impact of a fishery on a fish population as total mortality attributable to in-river harvest effects. This would include both direct mortality and indirect, or post-release mortality. During the return season of a fish population, the TAC updates impact estimates for use in making harvest decisions. For fisheries that may use multiple fishing gears, each with a different assumed mortality rate, the impact calculation is complicated. If the fishery utilizes two fishing gears (e.g., gill net and tangle net), seven quantities are required for the calculation of impact: forecast of run size, catch from two gears, release from two gears, and post-release mortality from two gears. CSMEP analyses presented in Appendix 3A describe how Impact is related to these input quantities, and more importantly shows how sensitive Impact is to those quantities. It is difficult to generalize the effect of run forecast on impact because of the other six quantities involved in the calculation. However, assuming that the other six quantities are fixed, over-forecasting run size will underestimate impact whereas under-forecasting run size will overestimate impact. Preseason forecasts of run size are usually not accurate enough for in-season harvest management decisions. In-season adjustments are made using data and information updated during fish run. The in-season forecast is then used to supply the run size quantity needed for calculation of impacts. The TAC is generally not able to confidently update run size until around April 15, which is the average date of 50% cumulative passage of spring Chinook at Bonneville Dam.

3.2.3 Monitoring design alternatives and trade-off analyses

Current monitoring designs are adequate to address the basic questions identified in section 3.1. However, some key assumptions are being made in managing upriver spring Chinook stocks in this way. Notably, it is currently assumed that all upriver spring Chinook stocks are handled in approximately equal proportions in all fisheries. This is likely not the case. Given the diversity of locations and techniques used in pursuing these fish, it is highly likely that some fisheries harvest upriver spring Chinook from different natal streams at different rates. However, current stock identification techniques do not allow managers to uniquely identify fish from these areas. If certain stocks are in fact impacted at a much higher rate in one or more fisheries, and if those rates were high enough to adversely effect recovery of the stock, then continued fisheries under the current management strategies would not be consistent with recovery of these stocks.

Other metrics currently used in managing upriver spring Chinook may cause inaccurate estimates of impacts, if the underlying assumptions are not appropriate. Abundance of these stocks are calculated by adding Bonneville Dam fishway counts to losses from lower river fisheries. If either the fishway counts or estimates of losses from lower river fisheries are inaccurate, estimates of run size will be incorrect. There is probably little room for improvement in fishway counting techniques, and all Chinook passing the ladder from January – June 15 are considered upriver spring Chinook, so stock identification is not needed under the current designs.

Estimates of losses from lower river fisheries are subject to a number of potential sources of error. Total harvest for recreational fisheries is estimated using creel surveys. The lower Columbia River creel survey was developed and instituted in the late 1960s under consultation with the Oregon State University Department of Statistics. It has been modified over the years to adapt to changing fisheries, however, it was not originally designed to provide the level of resolution currently needed for managing spring Chinook fisheries.

Estimates for number of fish released by anglers in the lower river are also derived from creel interviews. Anglers are asked how many fish they caught and kept and how many they released. All fish released are assumed to have been unmarked. The number of fish released is expanded in the creel analysis using the same techniques used to estimate the number of fish harvested. However, because released fish cannot be examined by surveyors, stock identification of released fish is not possible by direct examination, and estimates of the number of fish released are dependent upon the angler's memory/honesty.

Estimated harvest of spring Chinook in lower river commercial fisheries is derived from landing tickets submitted to ODFW and WDFW. Commercial buyers are required to report all harvest (in pounds per species) on landings tickets, which are then submitted to ODFW and WDFW. Fishers and buyers have a vested interest in insuring accuracy of these reports, as fishers want to be paid for each pound of fish landed, while buyers want to pay for as few pounds as possible. Fish are sampled by agency staffs at buying stations to collect biological and mark sample data. Average weights per species are applied to the total reported pounds landed from all landing tickets to estimate the total number of fish landed. Therefore, the estimated number of fish landed is subject to error due to variances in individual fish weights. Preliminary analyses indicate that this error is likely small. An alternative technique would be to count all individual fish landed, however, given the geographic range of buying stations and relatively short duration of fishing periods, combined with the high volume of fish at some stations, this method would be impracticable for agency staffs to conduct, and would likely depend upon individual buyers to count the fish.

Once fish pass Bonneville Dam, they are known to be upriver spring Chinook. However, fish encountered in the lower river may be from upriver for lower river populations. Therefore, in lower river fisheries, stock identification, to the level of upriver versus lower river population, is a key metric for estimating total impact. Currently, for kept fish, identification to upriver or lower river is possible through Visual Stock Identification (VSI). The head, mouth, and jaws of upriver spring Chinook are consistently darker in coloration than those of lower river Chinook, making it possible for experienced surveyors to categorize examined fish as upriver or lower river stocks. CWTs are applied to many lower river Chinook stocks and a few upriver stocks, but are not applied to upriver fish at rates high enough to provide a robust stock identification by CWTs alone. They are useful for verifying VSI identifications overall, however. VSI calls by field staff are reviewed and corrected using paired VSI and CWT data for upriver and lower river fish. In general, VSI identification is over 95% accurate in most years, depending on the experience level of surveyors.

Stock identification of released fish is more difficult. These fish cannot be examined by surveyors, and because of differences in the percentage of marked fish between upriver and lower river stocks, stock identification of released fish is assumed to not be equal to the proportions of upriver versus lower river fish in the kept catch. In most cases, managers must use preseason expectations of abundance of upper and lower river spring Chinook, combined with the expected marking rates for each group, to estimate the composition of released fish. This is a key assumption, and it can have a large effect on estimated impacts, however, given current tools available, it is the best available option for lower river fisheries. The statistical precision of estimates generated using this method have not been reviewed, and potential biases have been identified but not quantified. Concerns regarding biases largely center around the potential for intentional or unintentional misreporting by anglers, since releases of fish are rarely observed by sampling staff. Recreational fisheries above Bonneville Dam encounter only upriver spring Chinook, and tribal commercial fisheries retain all fish caught, meaning that stock identification of released fish is not necessary for either of these fisheries.

Commercial fisheries below Bonneville Dam are subject to examination by onboard observers in order to estimate the number of upriver spring Chinook released from these fisheries. During each open fishery, staff from ODFW and WDFW patrol open fishing areas in boats looking for actively fishing commercial fishers. Monitors randomly select boats to board and observe the catch of one or more nets as they are retrieved. The monitors record the number of marked and unmarked Chinook and steelhead captured in the nets, and the percentage of marked and unmarked Chinook that were upriver spring Chinook (by VSI). The ratio of unmarked to marked Chinook for all observations from a fishery is then multiplied by the total number of marked fish landed to estimate the total number of Chinook released. VSI information is used to identify released fish as upriver or lower river. Kept fish are identified to stock during sampling at buying stations. While fishers are randomly selected for onboard observation, number of staff available for surveys, the amount of area that can be patrolled, and the amount of time staff can spend on individual boats are all limited, making for relatively small sample sizes. Additionally, the effect of variances in catch and release of upriver fish among individual fishers has not been examined to date. Concerns regarding bias largely center around the methods for selecting fishers to observe. Stratification of sampling among fishers by average number of fish landed, number of upriver fish landed, or by area fished may provide better estimates of total handle of upriver stocks than the current methodology.

Although PIT tags are widely used in the Columbia Basin, their use in estimating stock composition in Lower River fisheries is limited. To illustrate this, consider estimating the proportion of wild Snake River ESU fish encountered by the observer program in the commercial fishery. Assuming a binomial sampling process where a tagged or observed fish is either from the Snake River or not. The number of samples required to estimate the proportion of wild, Snake River fish in the fishery for a given error rate ε and alpha level α is calculated as follows,

$$n = \frac{\varepsilon^2}{Z^2_{1-\alpha/2}\, p(1-p)}, \qquad \textit{Eq. 1}$$

where ε = the absolute error, i.e., $|\hat{p} - p|$;

p = the proportion of wild Snake River fish in the fishery;

$Z_{1-\alpha/2}$ = the Z-statistic for a given significance of alpha level, e.g., $Z_{1-0.1/2} = 1.645$;

n = the number if fish sampled or tags observed.

Note that the number of samples is a function of the proportion p. Figure 3.1 gives the numbers of observed tags required to estimate p with an errors of $\pm 5\%$ and 10%, either 95% or 90% of the time.

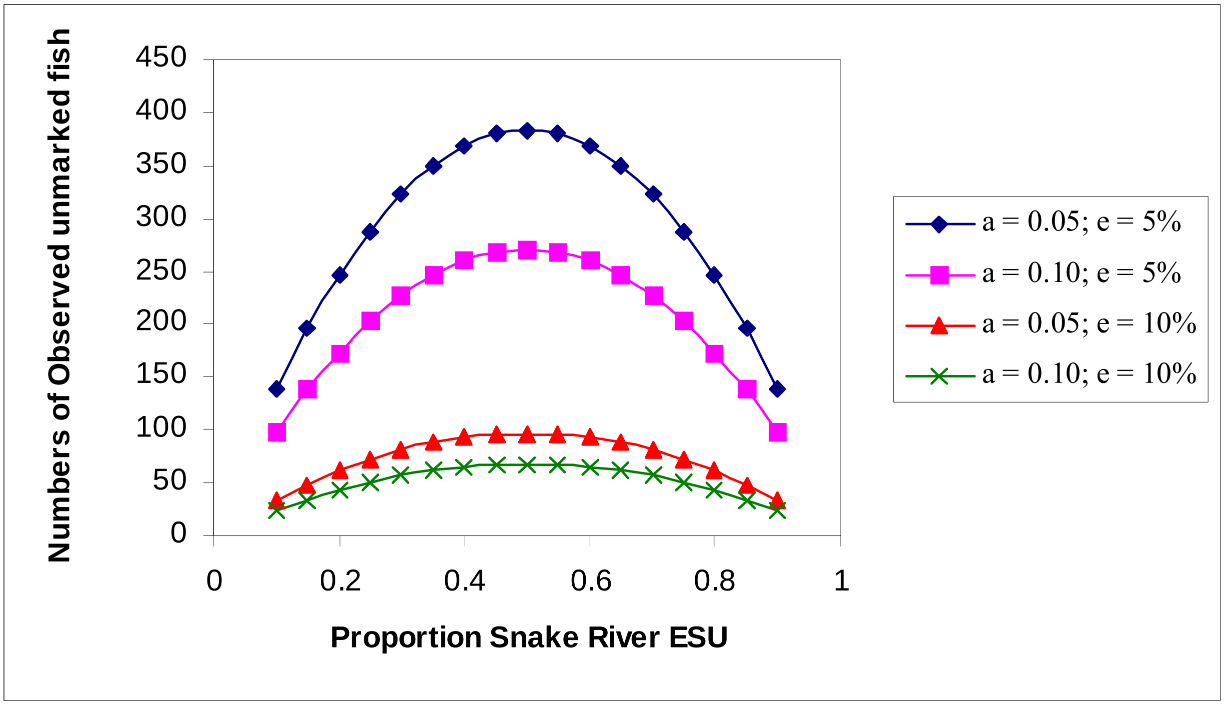

Figure 3.1. The numbers of samples required to estimate the proportion of wild Snake River fish in the Lower River commercial fishery for given alpha levels and error rates.

During the 2005 fishery, observers counted 160 unmarked fish in the fishery. If all of the fish had been tagged, then the proportion of wild Snake River fish could have been estimated with an error rate of ± 10%. However, tagging rates of wild smolts are not nearly as high as on hatchery stocks. To gain a sense of the numbers of tagged wild fish needed to obtain useable information, consider the probability of obtaining at least 10 tags under the following set of conditions:

- The probability of a wild fish returning to the lower river as an adult is 0.02, i.e., $SAR = 2\%$.
- The probability that a fish will be encountered in the lower river fishery is 0.05, i.e., the exploitation rate is 5%, $ER = 0.05$.
- The sampling rate is 10% (reasonable for the observer program).

The probability that an unmarked tagged fish is observed is calculated as follows:

$$P(observed) = SAR * ER * SampleRate$$
$$P(observed) = 0.02 * 0.05 * 0.1 = 0.0001 .$$

Figure 3.2 shows how the probability of observing at least 10 tags in the fishery increases with the number of tagged smolts. Unfortunately, the number of tagged wild smolts is generally less than 20,000 and the probability that no tags are observed in the fishery is about 14%. The probability that at least 24 tags are observed out of a release of 20,000 is zero. Hence, the use of PIT tags to estimate the stock composition of unmarked fish in this fishery is limited.

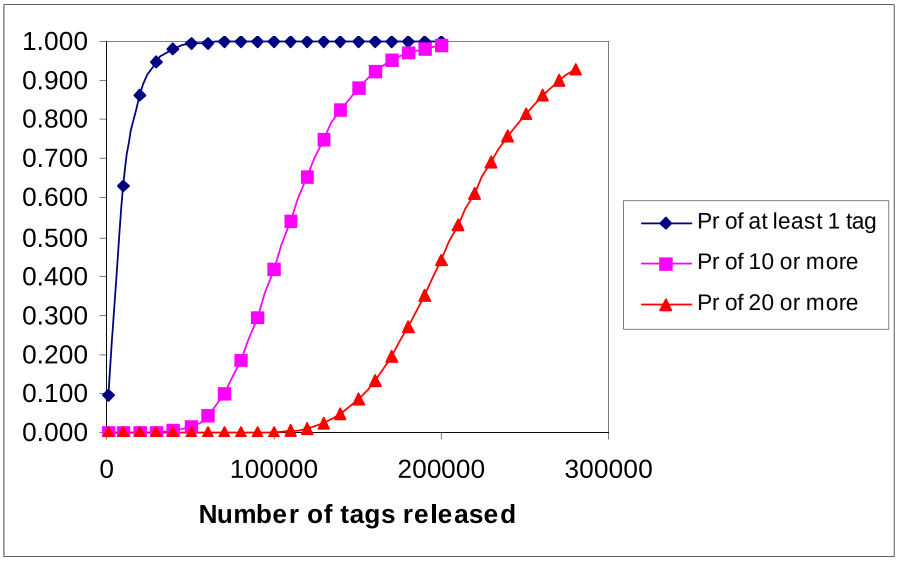

Figure 3.2. The probabilities of observing at least 1, 10, or 20 tagged wild fish given the release numbers on x-axis (SAR = 2%, exploitation rate = 5%, and observer sampling rate = 10%).

Genetic stock identification (GSI) could offer an alternative to tagging with regard to estimating the stock composition of the spring Chinook fishery. Sampling to identify Snake River ESU fish through genetic analysis is currently being performed at Bonneville Dam. The genetic baseline for the Columbia River includes 51 populations (Narum, CRITFC). Identification of groups of fish to ESU is less problematic than identification to major population groups. To get an idea of the number of samples required estimate the proportion of Snake River ESU fish (or any other stock of interest), consider estimating a proportion within an absolute error of ε, $1-\alpha$ percent of the time (the same reasoning as Eq. 1). This is expressed mathematically as follows,

$$P\left(\left|\hat{p}-p\right|<\varepsilon\right)=1-\alpha .$$

The expression in Equation 1 was derived using the sampling error for a proportion, $p(1-p)/n$, because there was no error associated with assigning fish to a group. However, in GSI there is some measurement error associated with identifying a fish to a particular stock. Hence, the variance of the estimated proportion, $Var(\hat{p}_i)$, is written as follows,

$$Var(\hat{p}) = \frac{p(1-p)}{n} + \left(\frac{(\phi(1-\phi))}{n}\right),$$

where the expression $\left(\frac{(\phi_i(1-\phi_i))}{n_i}\right)$ is the measurement error associated with identifying fish to stock..

The probability, ϕ is conditional on the true stock membership of an individual fish, $P(\hat{I}|I)$, the probability fish is identified to a particular stock given it is actually of that stock. Under the assumption that the measurement error is X% of the binomial sampling error, the sample size required to meet a specified error rate, $(1-\alpha)\%$ of the time is calculated as follows,

$$n = \frac{\varepsilon^2\left(1+(X/100)\right)}{Z^2_{1-\alpha/2}\,p(1-p)} \qquad \text{Eq. 2.}$$

Table 3.2. The number of samples needed to estimate the proportion of Snake River ESU fish in the commercial fishery for a measurement error equal to X% of the binomial sampling error.

	Error = 10%; alpha = 0.05		
	X		
P	0.25	0.5	1
0.10	43	52	69
0.15	61	73	98
0.20	77	92	123
0.25	90	108	144
0.30	101	121	161
0.35	109	131	175
0.40	115	138	184
0.45	119	143	190
0.50	120	144	192
0.55	119	143	190
0.60	115	138	184
0.65	109	131	175
0.70	101	121	161
0.75	90	108	144
0.80	77	92	123
0.85	61	73	98
0.90	43	52	69

Note that if the measurement error is equal to or less than the sampling error, the sample sizes needed for GSI identification are close to the numbers of unmarked fish observed during the fishery. Sampling for GSI analysis has been conducted in the non-treaty Chinook fishery off the coast of Washington to estimate stock composition with some success (Blankenship et al., WDFW).

Estimates of total run size also play a critical role in estimating impacts. Because individual fisheries may be managed on harvest rates as low as 0.01%, small changes in estimates of run size of upriver spring Chinook can have large impacts on the management of individual fisheries. Additionally, higher-than-expected catches in lower river fisheries often necessitate closures of upriver fisheries in order to maintain total impacts below ESA limits. Although current methods for projecting run size can result in poor accuracy, projections have overestimated and underestimated actual returns with roughly equal frequency. However, underestimates are slightly more frequent than overestimates. Estimates of precision are not provided with these projections. Adding estimates of precision, and if possible, indications of directional biases, would aid managers in determining how much weight to put on individual estimates, and in weighing the likelihood of over- or under-estimating run size. Additionally, new methods for projecting run size, such as relationships to environmental variables, may be available to help improve forecasting accuracy.

In status quo monitoring, in-season post-release mortality rates are not monitored. Instead standard rates from previous studies are applied. Conducting long-term, fishery-specific mortality studies is inherently difficult and expensive. In addition, due to the difficult nature of conducting such studies, the results will always be questioned in some forums. This can lead to conflict and disagreement over what the “true” mortality associated with a fishery is. Actual mortality of fish released from a fishery is dependent not only upon the fishing gear used, but upon the handling methods and water conditions experienced by the fish immediately before and after capture, as well as on the overall condition of the fish prior to capture. Incorporating such variables into estimates of release mortality is extremely difficult.

Other options are available to assess total mortality, but these do not provide fishery-specific estimates of release mortality, nor do they specify variable rates for different fishing gears or environmental conditions. Double Index Tagging (DIT) is a method that has been proposed for use in assessing mortality of fish stocks. This methodology utilizes the existing CWT program, and consists of applying CWTs to juvenile fish which are not marked with a fin clip. The difference in mortality rates between DIT groups and regular CWT groups from the same hatchery release is assumed to be due to differences in fishery mortalities experienced by the two groups; DIT groups should be subject only to post-release mortality, while CWT groups would be subject to direct impacts from harvest. This methodology relies upon some key assumptions. Notably, that DIT groups are representative of other unmarked wild fish that they co-occur with in fisheries. This assumption is relatively untested, and DIT groups are currently geographically limited and cannot be used to infer mortality information for many stocks of concern. The method also requires electronic monitoring for any fishery that is not mark-selective, in order to separate removals of DIT groups via harvest from post-release mortality. Currently, most non-mark-selective fisheries do not conduct monitoring sufficient to gather this data.

Results

Alternative monitoring designs developed by the CSMEP Harvest Subgroup are described in Table 3.3 and the subgroup’s qualitative evaluations of these alternative designs are presented in Table 3.4.

Table 3.3. Description of harvest monitoring design alternatives.

Required Metrics	Description of Monitoring Design Alternatives			
	Status quo	Low	Medium	High
Pre-season Forecast	Cohort regression and expert opinion.	Incorporate precision estimates in addition to point estimates.	Incorporate precision estimates in addition to point estimates.	Apply new methods, and/or incorporate additional data (e.g. autocorrelation and/or incorporating environmental data). Incorporate precision estimates in addition to point estimates
Harvest Estimate – targeted (all fisheries)		Examine the sampling rate and the likely precision it provides. Incorporate precision estimates in addition to point estimates.	Estimate and incorporate illegal harvest.	Estimate and incorporate illegal harvest.
Harvest Estimate – Lower Columbia Commercial	Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery.	Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery.	Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery. Enumerate the landings.	Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery.
Harvest Numbers – Mainstem Sport	Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery.	Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery.	Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.	Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.
Harvest Numbers – Zone 6	Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).	Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).	Enumerate the landings. Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms). Validate net counts. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.	Enumerate the landings. Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms). Validate net counts. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.

Required Metrics	Description of Monitoring Design Alternatives			
	Status quo	Low	Medium	High
Number unmarked encounters (released fish) – Lower Columbia Commercial	Product of landed catch and the unmarked:marked fish ratio from onboard observer program.	Product of landed catch and the unmarked:marked fish ratio from onboard observer program. Incorporate precision estimates in addition to point estimates.	Increase monitoring effort for unmarked:marked fish ratio.	Increase monitoring effort for unmarked:marked fish ratio. Examine alternative means to incorporate fishing effort.
Number unmarked encounters (released fish) – Sport fishery	Unmarked fish release rate from interviews.	Unmarked fish release rate from interviews. Incorporate precision estimates in addition to point estimates.	Unmarked fish release rates from observation. Review and update sampling procedures to ensure an unbiased design. Incorporate precision estimates in addition to point estimates.	Unmarked fish release rates from observation. Review and update sampling procedures to ensure an unbiased design. Incorporate precision estimates in addition to point estimates.
Stock composition of unmarked fish	Visual Stock Identification (observed fish only). The method is accurate but does not separate upper Columbia River ESU from Snake River ESU. <u>Zone 6 fishery</u>: Dam counts inform stock composition and unmarked:marked fish ratio. Post season run reconstruction verifies this through CWT-tag recoveries.	Visual Stock Identification (observed fish only). The method is accurate but does not separate upper Columbia River ESU from Snake River ESU. PIT-tag sampling of kept catch under current tagging programs. (86K juveniles/year at LGR = hydro medium design). <u>Zone 6 fishery</u>: Dam counts inform stock composition and unmarked:marked fish ratio. Post season run reconstruction verifies this through CWT-tag recoveries.	PIT-tag sampling of released fish from a PIT-tagged wild fish population large enough ensure adequate recovery information. (10 recoveries/tag group/year) ESU-level resolution. [186K juveniles/year= hydro high design]. Development of CWT-indicator stock(s) to represent wild Sp/Su Snake River Chinook ESU(s). Genetic Stock Identification – sampling of released catch to describe ESU-level stock composition.	Development of CWT-indicator stock(s) to represent wild Sp/Su Snake River Chinook MPG(s). GSI sampling of released catch sufficient to describe MPG-level stock composition.
Post-release mortality	Standard values from literature (18.5% and 40% for commercial; 10% for sport).	Standard values from literature (18.5% and 40% for commercial; 10% for sport). Incorporate precision estimates in addition to point estimates.	Incorporate precision estimates in addition to point estimates. New treatment control experiments. Estimate drop-off mortality rate.	Double Index Tag program. (Analysis by the expert panel of PSC is supportive. The US v OR TAC is less supportive.)

Table 3.4. Evaluation of monitoring design alternatives.

Performance Measures	Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3= good; 2= fair; 1=poor; ?= Unknown; n.a. not applicable.			
	Status quo	Low	Medium	High
Ability to estimate pre-season abundance (at CR mouth)	(2) Cohort regression and expert opinion Bias and precision unquantifiable owing to the incorporation of expert opinion.	(2) Consider (or calculate) mean squared error (MSE) to estimated run size [MSE = (predicted – actual)^2] and prediction intervals calculated on preseason forecasts.	(3) Incorporates additional information such as environmental correlates.	N/A
Stock composition of the kept catch in Lower River fisheries	(1) VSI of sampled fish - distinguishes between lower river and upper river fish only. Does not identify to Snake R. ESU.	(1) Incorporate precision estimates. PIT-tag sampling of kept and released catch under current tagging programs. (86K juveniles/year at LGR = hydro medium design) Rationale Not enough tag recoveries to reliably estimate stock.	(2) PIT-tag sampling of kept and released catch from a PIT-tagged wild fish population large enough ensure adequate recovery information (10 recoveries/tag group/year) ESU-level resolution. [186K juveniles/year= hydro high design; Rationale: Tagging at this level will require hatchery fish which will not improve information on stock composition of wild fish. (3) Development of CWT-indicator stock(s) to represent wild Sp/Su Snake River Chinook ESU(s); Genetic Stock Identification – sampling of released catch to describe ESU-level stock composition. Rationale: Indicator stocks (if possible) could provide more accurate information on exploitation rates of SR stocks GSI (ESU) – provide information on stock composition of released fish in the fishery	(4) GSI sampling of released catch sufficient to describe MPG-level stock composition. Rationale: If greater resolution than ESU level stock composition. possible, will provide information that will better serve status and trends, hatchery and habitat groups. (Resolution needed for integration at finer scale)

Performance Measures	Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3= good; 2= fair; 1=poor; ?= Unknown; n.a. not applicable.			
	Status quo	Low	Medium	High
Stock composition of Zone 6 (tribal fishery)	(2) Dam counts inform stock composition and unmarked/marked fish ratio. Post season run reconstruction verifies this through CWT-tag recoveries. <u>Rationale</u>: Still does not inform stock composition of wild fish, but we have better enumeration of unmarked harvest.	(2) Incorporate precision estimates in addition to point estimates. PIT-tag sampling of harvested catch under current tagging programs. (86K juveniles/year at LGR = hydro medium design). <u>Rationale</u>: Although possible to detect PIT tags in wild fish, tag return rates still insufficient to provide reliable information on wild stock composition.	(2) PIT-tag sampling of harvest from a PIT-tagged wild fish population large enough ensure adequate recovery information (10 recoveries/tag group/year) ESU-level resolution. [186K juveniles/year= hydro high design. <u>Rationale</u>: Tagging at this level will require hatchery fish which will not improve information on stock composition of wild fish. (3) Development of CWT-indicator stock(s) to represent wild Sp/Su Snake River Chinook ESU(s); Genetic Stock Identification – sampling of catch to describe ESU-level stock composition. <u>Rationale</u>: Indicator stocks (if possible) could provide more accurate information on exploitation rates of SR stocks. GSI (ESU) – provide information on stock composition of unmarked fish in the fishery.	(4) GSI sampling of catch sufficient to describe MPG-level stock composition. <u>Rationale</u>: If greater resolution than ESU level stock composition ***possible***, will provide information that will better serve status and trends, hatchery and habitat groups. (Resolution needed for integration at finer scale)
Estimate stock composition of mainstem sport fishery	(1) Inseason stock comp from preseason estimates and mark rates; verified post season.	(1) Inseason stock comp from preseason estimates and mark rates; verified post season. Incorporate precision estimates in addition to point estimates.	(1) Incorporate precision estimates in addition to point estimates. (2) PIT-tag sampling from commercial fishery or kept catch; ESU level. (3) GSI ESU-level stock composition from commercial fishery Development of CWT indicator stock to represent wild Sp/Su Snake River Chinook.	

Performance Measures	Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3= good; 2= fair; 1=poor; ?= Unknown; n.a. not applicable.			
	Status quo	Low	Medium	High
Post-release Mortality Rate Lower Columbia River.	(2) Apply standard values from literature (estimated as 18.5% and 40% for commercial; 10% for sport).	(2) Incorporate precision estimates in addition to point estimates.	(3) Incorporate precision estimates in addition to point estimates. New treatment/ control experiments to estimate post release mortality. Estimate drop-off mortality rate.	(4) Develop Double Index Tag (DIT) program. To assess impacts on unmarked fish.
Post release mortality - Mainstem sport fishery	(2) Apply standard values for catch and release mortality from literature (10%).	(2) Incorporate precision estimates in addition to point estimates for catch and release mortality.	(3) Incorporate precision estimates in addition to point estimates. New treatment/ control experiments to estimate catch and release mortality. Estimate drop-off mortality rate.	(4) Develop Double Index Tag (DIT) program. To assess impacts on unmarked fish.
Post-release Mortality Rate Zone 6 fishery	N/A	N/A	(3) Estimate drop-off mortality rate.	N/A
In-season estimates of release numbers – Lower River Commercial	(2) Product of landed catch and the unmarked to marked fish ratio from onboard observer program. Rationale: Not well estimated early in season.	(2) Product of landed catch and the unmarked to marked fish ratio from onboard observer program. Incorporate precision estimates in addition to point estimates. Rationale: Not well estimated early in season.	(3) Increase monitoring effort for unmarked:marked fish ratio.	(3) Increase monitoring effort for unmarked:marked fish ratio. Examine alternative means to incorporate fishing effort.
Harvest Estimates – All fisheries		(2) Examine the sampling rate and the likely precision it provides. Incorporate precision estimates in addition to point estimates.	(3) Examine the sampling rate and the likely precision it provides. Incorporate precision estimates in addition to point estimates. Estimate and incorporate illegal harvest.	(3) Examine the sampling rate and the likely precision it provides. Incorporate precision estimates in addition to point estimates. Estimate and incorporate illegal harvest.

Performance Measures	Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3= good; 2= fair; 1=poor; ?= Unknown; n.a. not applicable.			
	Status quo	Low	Medium	High
Harvest Estimates – Lower Columbia Commercial	(4) Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery.	(4) Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery.	(4) Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery. (3) Enumerate the landings.	(4) Product of total landed weight from mandatory landing tickets and average weight of landed fish from sampling. Note: only marked fish are harvested in this selective fishery. (3) Enumerate the landings
Harvest Estimates – Mainstem Sport	(2) Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery.	(2) Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery.	(3) Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.	(3) Product of catch rate and total effort. Note: only marked fish are harvested in this selective fishery. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.
Harvest Estimates – Zone 6, All fisheries	(3) Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).	Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).	Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).	Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms).
Harvest Estimates – Zone 6, Over-the-bank-sales and “take home” fish	(2) Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms) - adjusted for landings at buyers during commercial seasons.	(2) Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms) - adjusted for landings at buyers during commercial seasons.	(3) Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms) - adjusted for landings at buyers during commercial seasons. Validate net counts. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.	(3) Product of effort (aerial net counts and platform fishery observations) and catch rate (from interviews at ramps and platforms) - adjusted for landings at buyers during commercial seasons. Validate net counts. Increase sampling rate. Review and update sampling procedures to ensure an unbiased design.

3.3 Conclusions and recommendations

Conclusions

Status quo harvest monitoring generally does not provide precision estimates; however, such estimates would be useful for managers by allowing them to quantify the risk of available harvest management decision options. Uncertainty or errors in harvest impact estimates can limit evaluation of status, trends, and viability, while also potentially resulting in lost harvest opportunities or over harvest of listed stocks. Estimates of total harvest are generally robust, with commercial landings estimates more accurate than sport catch estimates, in general. Estimates of release rates are less robust than catch, with commercial release rate estimates being likely less biased than are sport release rate estimates. Accuracy estimates for commercial release rates are available, but such estimates are not available for sport fisheries. Post-release mortality estimates are based on limited studies but improvement with new studies will be very difficult.

Recommendations

- Include estimates of precision in vital estimates.
- Develop new analytical techniques for preseason and in-season abundance forecasts.
- Continue to evaluate new technologies/techniques for stock identification and composition estimates (PIT tags, GSI).
- Evaluate and refine methods for estimating number of fish released from selective fisheries.
- Evaluate the potential development of an indicator stock to represent Snake River spring/summer Chinook in in-river fisheries.
- Improve coordination between entities collecting fisheries monitoring and evaluation information.

4. Hydro

4.1 Introduction

As described in Section 1.2 CSMEP applied EPA's Data Quality Objectives (DQO) process to demonstrate the development and evaluation of alternative M & E designs. In fiscal year 2005, CSMEP scientists assigned to the Hydro M & E domain went through steps 1 to 5 of the DQO process (Table 4.1) to: state the problem; identify possible decision and questions; identify inputs to those decisions; bound the problem in space and time; and consider example decision rules, recognizing that such rules are within the purview of the agencies with statutory authority.

Figure 4.1. Data quality objectives: Steps 1 through 5 as they pertain to hydrosystem recovery actions. From CSMEP 2005 Annual Report.

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Needed (✓)
1. State the Problem		
Problem:	The existence and operation of the Federal Columbia River Power System (FCRPS) is one of the more important anthropogenic factors influencing mainstem survival of three ESUs of concern to this Snake River [SR] pilot study: SR spring/summer chinook, SR fall chinook, and SR steelhead. ESA-listed bull trout are also affected, but are not considered in this pilot study. Decisions on FCRPS actions directly or indirectly affecting survival of these stocks are conducted under the authority of the ESA. Information on the expected and actual effectiveness of these actions (e.g., juvenile collection, bypass, and transportation; water management; offsite mitigation) is essential for reliable decisions. There is a need to assess what quality of data are required to: 1) reliably detect the effects of FCRPS actions on fish survival rates; and 2) reliably compare survival rates to pre-defined goals.	
Stakeholders:	NMFS makes FCRPS management decisions under the ESA for the three ESUs considered in this preliminary analysis. USFWS also assesses FCRPS effects on bull trout under ESA. Other stakeholders affected by these decisions: state agencies and tribes that co-manage the fisheries resource; federal fishery agencies that implement ESA and hydropower mitigation management; federal agencies that operate and market electricity from the FCRPS and fund mitigation activities; commercial, recreational and tribal fishers: power users.	
Non-technical Issues affecting M & E:	Funding, legal authority to handle and mark fish, legal authority to place detection structures in fishways, decisions on dam operations that affect detection rates and/or influence contrasts among different groups (e.g., volume of spill, bypass/barging operations); ongoing BiOp/Remand considerations.	
Conceptual Model:	Assessment of hydrosystem impacts involves a suite of four sets of indices: 1) direct survival (project pathway, reach, entire hydrosystem); 2) SAR overall; 3) SAR ratios (T/I, D, upriver / downriver stocks); and 4) recruits/spawner (spatial/temporal patterns). SARs and recruits / spawner indices provide an assessment of indirect effects over a larger portion of the life cycle, but also have more confounding from other factors (ocean conditions, hatcheries, harvest) than do direct survival measurements.	

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Needed (✓)
2. Identify the Decision		
Decisions / Alternative Actions	Hydro Action Effectiveness Questions	
Are SARs, and important SAR ratios relating to effectiveness of transportation, meeting NPCC and BiOp targets?	Is SAR sufficient for 1) NPCC goal[3] (example of feedback required from managers); and 2) recovery goals? Is transportation more effective than in-river passage? What is the relative survival of transported fish post-BONN, compared to in-river fish (D)? {*no regulatory target*} Has hydrosystem complied with performance standards set out in 2000 FCRPS BiOp? *{If targets not met (by how much?), then may need to consider changes in FCRPS operations (e.g., when, how much to transport) or configuration.}*	✓
Should FCRPS change timing of transportation of some species within season?	How does effectiveness of transportation change over the course of the season? *{Are Snake R wild chinook equally important as wild steelhead? Are wild chinook more important than hatchery chinook?}*	✓
Is the cumulative effect of hydrosystem actions and estuary-ocean conditions leading to stock recovery? *{No regulatory target}*	What's the incremental mortality of Snake R fish populations (passing 8 dams) as compared to lower Columbia stocks passing 1-3 dams? What is the inferred delayed mortality of both in-river and transported fish?	✓
Are current flow and spill management actions meeting survival targets? If not, should FCRPS change these actions?	What is the effect of different flow management actions in the hydrosystem on SAR and Sp/Sp ratios? What is the effect of different flow and spill management actions on in-river survival? *{Need to confirm targets}*	✓
Is offsite mitigation working? *{No regulatory target}*	Have freshwater habitat restoration actions been sufficient to compensate for hydrosystem direct and delayed mortality, as measured on the Snake R aggregate sp/sum chinook stock?	✓

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[3] Pg. 13 of NPCC mainstem amendments of 2003-2004. www.nwcouncil.org/library/2003/2003-11.pdf ; interim goals of 2-6% SAR

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Needed (✓)
Are dam project operations maintaining desired targets for fish survival rates and condition? *{FCRPS Biological Opinion and other targets}*	What are the survival rates and condition of fish past turbines, spillway and bypass routes of passage? How would RSWs change SARs and Sp/Sp? Would RSWs be an effective alternative to transportation? Would the reduced spill associated with RSWs affect fish survival and condition? *Review current operational targets for project survival, fish guidance, etc. with BPA, Army Corps*	✓
Decision Statements:	Decision rules are within purview of agency with statutory authority. Logically, decision rules should: • anticipate survival changes in the mainstem;, • address management measures for all the Hs, • incorporate adult and juvenile data (consider indirect effects); • project stock abundance over many decades; and • accommodate gradual improvements in habitat condition and habitat deterioration that could offset hydrosystem effects.	✓
3. Identify the Inputs		
Information Required:	Estimates of *direct survival rates and SARs* for a contrasting range of: mainstem passage timings and routes (transported vs. in-river; bypass vs. spillway vs. turbine); species (spring/summer chinook, fall chinook, steelhead, sockeye); stock origins (upstream vs. downstream; wild vs. hatchery). Estimates of *estuary/ocean survival rates* are required to assess delayed mortality; these are inferred from estimates of in-river survival, SARs, recruits / spawner, and the proportion of fish below Bonneville Dam that were transported. *Estimates of the feasibility of achieving survival improvements* across all H's need to be merged for evaluating the most promising suite of actions for recovering populations.	
Sources of Data:	*Direct survival estimates through the hydro system and estuary/ocean through tagging and recapture:* coded wire tags, PIT tags, balloon tags, radio tags, hydro acoustic technologies. *Other survival and recruitment estimates used to estimate estuary/ocean survival, climate/ocean effects and delayed mortality:* dam counts, redd counts, carcass counts, age analysis from scales.	
Quality of Existing Data:	Data quality varies by the question of interest, species and stock origin: • Precision of survival estimates greatly improved since the use of PIT tags; • Precision of survival estimates varies with number of fish tagged: estimates for hatchery spring/summer chinook and steelhead more precise than for wild fish; estimates for entire year's migration more precise than for within-year groups; poor estimates for fall chinook • Tagging methods to determine the relative survival rates of fish through different dam passage routes have various weaknesses • Recruit/spawner estimates have various limitations but also have long time series; contrasts in SARs provide better signal of hydrosystem effects • Intensive studies of smolt health and estuary survival not yet linked to SAR data for various PIT-tagged groups, to understand mechanisms of delayed mortality	

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Needed (✓)
New Data Required:	• Higher precision in SARs to improve reliability and speed of responses to key questions • PIT-tag based SAR data for fall chinook (hatchery) • Improved ability to assess differences in spring/summer chinook SARs across contrasts in passage route, timing, and stock origin • Better linkage of physiology studies below Bonneville with SAR data	
Analytical Methods:	Methods for estimating precision of reach survival, SARs and SAR ratios (e.g., T:I, D) are well developed. Methods for inferring delayed mortality are indirect, involve many inputs, and are less precise. Challenge is to develop evaluation methods that filter out sampling variation and account for natural year to year variation (as well as other confounding factors) to isolate hydrosystem effects and answer key questions in an acceptable timeframe.	
4. Define the Boundaries		
Target Populations:	Snake River spring/summer chinook, fall chinook, steelhead and sockeye examined to date; bull trout also of interest	
Spatial Boundaries (study)	From entrance into hydrosystem at Lower Granite to various points beyond (reach survival, Bonneville Dam, estuary, return to Bonneville Dam, return to Lower Granite Dam, return to spawning ground)	
Temporal Boundaries (study)	Studies must be of a sufficient duration to detect the effect of contrasting actions. Thus the required duration of monitoring depends on the hydrosystem action being evaluated, and the effect size of interest (longer for more subtle effects). Time scales range from daily detections of PIT-tags, to seasonal contrasts of SARs, to annual SARs, to decadal-scale contrasts in spawner-recruit data.	
Practical Constraints:	Difficult or impossible to: determine causes of mortality after fish pass into ocean; disentangle effects of hatchery operations and # of dams passed on hatchery SARs (these factors covary); relate condition of PIT-tagged smolts in the estuary with their ultimate SAR. Not enough wild fish in some years to obtain reliable estimates of mainstem survival rates or SARs; year to year variation in survival means that ‘average effects’ may hide important information	
Spatial Boundaries (decisions):	Entire Columbia Basin. Decisions on hydrosystem operations and configuration have implications over the scale of the electricity grid to which generated power is distributed.	
Temporal Boundaries (decisions):	NOAA and USFWS Biological Opinions on FCRPS are released every 5 to 10 years. Analyses need to consider actions such as habitat restoration which may take decades to become fully effective.	
5. Example Decision Rules (actual rules are purview of agencies with statutory authority)		
Critical Components, Population Parameters and Action Levels:	• Compare hydrosystem survival rates to NOAA FCRPS BiOp targets, • Compare SARs to NPCC interim targets of 2-6% and other recovery goals; Compare T:I ratios to assess transportation benefit (e.g., T/I > 1.0?); • Compare D to level indicative of substantial delayed mortality of transported fish (e.g., D < 0.7?) • Compare probability of extinction and probability of recovery to NOAA and USFWS targets	✓

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Needed (✓)
Example If-Then Decision Rules:	**If** juvenile survival rates through the hydrosystem, SARs **or** the probability of recovery are consistently below target levels, **and** this can be clearly shown to be related to the direct and indirect effects of the hydrosystem, **then** alternative mitigative actions will be considered (e.g., changes to hydrosystem operations, removal of predators from reservoirs, changes to hydrosystem project structure or configuration)	✓
Consequences of Decision Errors:	Failure to make required changes in hydrosystem operation or configuration may result in extinction of fish species, or failure to recover stocks. Making ineffective changes in operations or configuration may waste significant amounts of money.	

Table 4.1 includes a wide range of questions. In 2006 and 2007, CSMEP scientists narrowed their focus to just the four questions listed in Table 4.1.

Table 4.1. List of management decision and related questions being evaluated.

Decisions / Alternative Actions	Hydro Effectiveness Questions
Are SARs, and important SAR ratios relating to effectiveness of transportation, meeting NPCC and BiOp targets? If targets are not met (by how much?), then decision makers may need to consider changes in FCRPS operations (e.g., when, how much to transport and spill) or FCRPS configuration	1. Is SAR sufficient for a) NPCC goal and b) recovery goals? 2. Is transportation more effective than in-river passage
Has hydrosystem complied with performance standards set out in 2000 FCRPS BiOp? If not, what changes are required?	3. How does annual in-river survival of spring / summer chinook and steelhead (Lower Granite River (LGR) to Bonneville (BON)) compare to 2000 FCRPS BiOp performance standards?
Should FCRPS change the timing of transportation of some species within the season to improve survival?	4. How does effectiveness of transportation change over the course of the season?

Following steps 6 and 7 of the DQO process, CSMEP scientists developed some alternative M & E designs (Table 4.2), and evaluated the cost and statistical reliability of those designs relative to the Status Quo M & E. The purpose of this report is to describe the example M & E designs summarized in Table 4.2, outline the analytical methods used, and present results demonstrating the relative reliability and costs of these designs.

Table 4.2. Description of alternative monitoring designs. Monitoring designs are described as High, Medium, and Low, in reference to the number of PIT tags and levels of accuracy and precision in data that are collected.

Description of Monitoring Design Alternatives[4]				
Performance Measures	Status Quo	Low	Medium	High
SARs, TIRs, mainstem survival	*SR Hatchery Chinook:* • # tags=255,000 *SR Wild Chinook:* • # tags=66,000 (29 stream RSTs) *Lower and Mid-Col R Hatchery Chinook*: • # tags=70,000 *Lower and Mid-Col R Wild Chinook:* • 6,000 PIT-tags @ John Day River	Background level of PIT-tagging. *SR Hatchery Chinook:* • # tags=40,000 *SR Wild Chinook:* • Same as Status Quo • # tags=66,000 (29 stream RSTs) *Lower and Mid-Col R Hatchery Chinook*: • Same as Status Quo but drop Carson • # tags=55,000	*SR Hatchery Chinook:* • Distribute tags in proportion to hatchery releases across all SR hatcheries; distribute fish (i.e.,% transported) according to run at large • # tags=275,000 *SR Wild Chinook:* • # tags=86,000 (40 stream RSTs) *Lower and Mid-Col R Hatchery Chinook*: • Same as Status Quo • # tags=70,000 *Lower and Mid-Col R Wild Chinook:* • # tags=6,000	*SR Hatchery Chinook:* • Distribute tags proportionately as for Medium; increase # • # tags=375,000 *SR Wild Chinook:* • # tags=186,000 (29 stream RSTs + 8 large traps to cover 6 MPG strata, incl. Clearwater; <u>not</u> by population) *Lower and Mid-Col R Hatchery Chinook*: • # tags=100,000 *Lower and Mid-Col R Wild Chinook:* • # tags=6,000
Abundance	*Snake Basin:* as described for Status Quo alternative under Status and Trend (section 2.1)	*Snake Basin:* as described for Low alternative under Status and Trend (section 2.1); SARs estimated from run reconstructions. *Downstream stocks:* John Day redd counts to provide contrast.	*Snake Basin:* as described for Medium alternative under Status and Trend (section 2.1). *Downstream stocks:* one population / regional stock group in Lower & Mid Columbia (John Day, Deschutes/Warm Springs, Yakima, Wind, Klickitat).	*Snake Basin:* as described for High alternative under Status and Trend (section 2.1). *Downstream stocks:* Possibly weirs John Day, Wind and Klickitat (not essential if High level PIT-tagging is implemented, which is more precise).

4.2 Methods

Passive induced transponder (PIT) tags are used to mark individual fish (smolts of hatchery and wild origin) with a unique code that allows them to be identified at a later date and location. Detection and identification of fish occurs at weirs, dam bypasses, or during harvest. The array of detection sites in the Snake and Columbia Rivers is analogous to multiple recaptures of tagged individuals allowing for standard multiple mark-recapture survival estimates over several reaches of the hydrosystem. Tagging data used in the analyses described below is from the period 1994 – 2004 for wild spring / summer and 1997 – 2004 for hatchery[5] chinook. PIT tag M & E is completed through the efforts of many agencies and projects, including long running foundational projects (with NPCC proposal numbers): Smolt Monitoring Program – 198712700; PTAGIS – 199008000; UW Statistical Support – 198910700; Passage Survival Estimates – 199302900; and CSS – 199602000. For a more detailed description of the PIT tagging program refer to Chapter 3 of Schaller et al. 2007.

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[4] Details of alternatives are described in CSMEP fy06 report.

[5] Tagging data is available for five hatcheries in the Snake River drainage system: Dworshak, McCall, Catherine Creek, Rapid River, and Imnaha.

4.2.1 Methods directly related to results presented in Volume 1

Annual estimate of in-river survival and management targets

To estimate survival rates, one must know the initial number of tagged fish released and the number of tagged fish that pass through each dam while migrating downstream to the ocean. Fish can pass the dams either through the turbines or over the spillway (fish not detected in both cases), or through the bypass/collection system that is equipped with PIT tag detectors (refer to Figure 4.2 for dam and fish detection locations). By comparing the number of smolts detected at two dams to the number detected at each dam, one can estimate of the probability of being detected, and rate of survival. The array of detection sites in the Snake and Columbia Rivers is analogous to multiple recaptures of tagged individuals, allowing calculations of standard multiple mark-recapture survival estimates over several reaches of the hydrosystem. CSS estimates the survival rates of various life stages for up to six reaches between release site and tailrace of Bonneville Dam (survival estimates S_1 through S_6) using the Cormack-Jolly-Seber (CJS) method (Cormack 1964; Jolly 1965; Seber 1965). From the CJS method CSS obtains point estimates of survival and corresponding standard errors. CSS considers an estimate of survival unreliable when its coefficient of variation exceeded 25%.

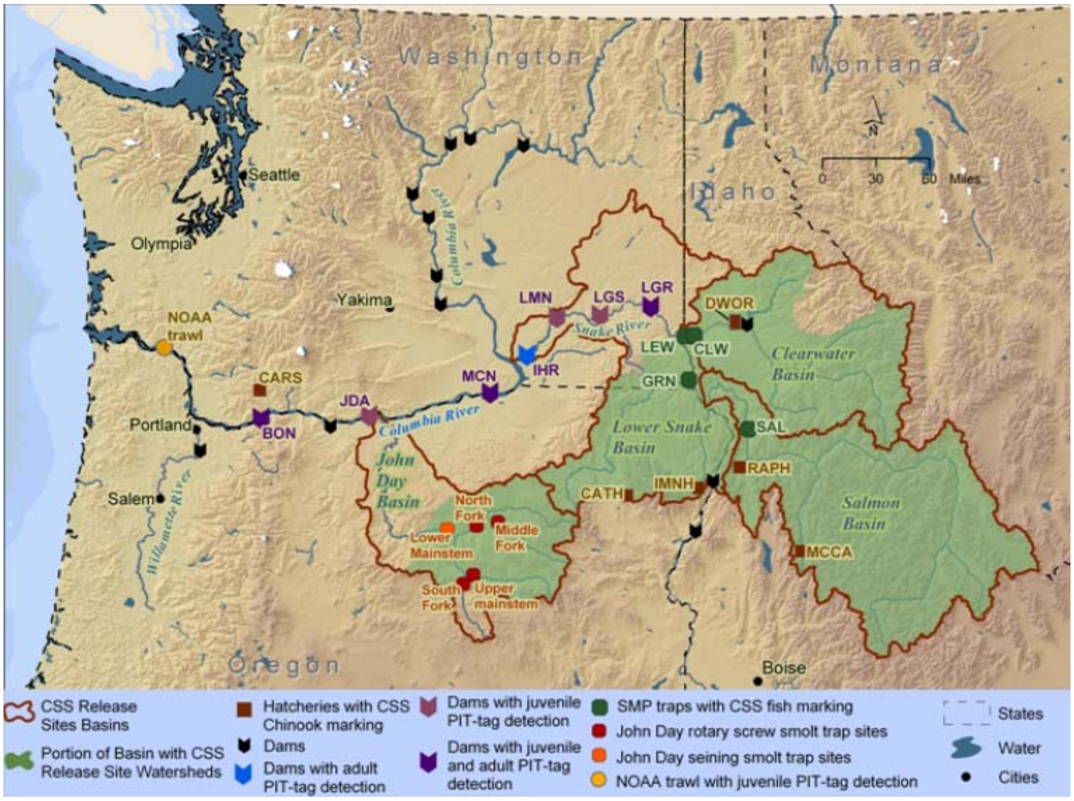

Figure 4.2. CSS PIT tag release locations and PIT tag detection sites in the Columbia River Basin.

In-river survival of hydrosystem (S_R) describes the cumulative impacts of the hydrosystem on the in-river population of smolts, and is the product of the individual reach survival estimates between LGR tailrace and BON tailrace,

$$S_R = S_2 \cdot S_3 \cdot S_4 \cdot S_5 \cdot S_6 . \quad (1)$$

For more detail regarding the calculation of survival estimates (S_2 through S_6) refer to Chapter 3 of Schaller et al. 2007. Ninety-percent confidence intervals (CI) for annual survival rates are computed using nonparametric bootstrapping methods (Efron and Tibshirani 1993).

Annual S_R rates are evaluated to determine compliance with the performance standards laid out by the Federal Columbia River Power System (FCRPS). The FCRPS BiOp standards states that a minimum S_R of 49.6 percent for smolt survival from LGR TO BON dam must be maintained. We developed an example decision rule using 90 percent confidence intervals to assess compliance. Compliance is achieved with 95 percent confidence in years where the lower 90 percent CI is above 49.6 percent and is not achieved when its upper 90 percent CI is below 49.6 percent. Compliance is only achieved with 95 percent confidence because the 90% CI excludes 5% of the distribution on the low end. If the 90 percent CI straddles 49.6 percent (i.e., lower CI is below 0.496 and upper CI is above 0.496) it is not possible to determine whether the BiOp standard was met with 95 percent confidence.

Annual SAR estimates and management targets

Smolt-to-adult survival rates (SARs) are estimated for spring/summer chinook released from five Snake River hatcheries, as well as for wild spring/summer chinook (Snake Basin as a whole). The population of PIT tagged study fish arriving at LGR is partitioned into three categories of smolts related to the manner of passage through the hydrosystem. The three categories of hydro system are C_0 (in-river, undetected at collector projects), C_1 (in-river, detected at one or more collector projects) and T_0 (detected transported). For details on how the number of smolts in each category is estimated using in river survival rates, refer to Chapters 3 of Schaller et al. 2007. The categorization of smolts allows SARs to be compared between routes of passage, for example smolts that were barged around the hydrosystem versus those that migrated through the hydrosystem. Combining the SARs for each category provides a SAR estimate for the entire population.

The SAR estimate is simply the number of adults returning to LGR divided by estimated number of smolts at either LGR or BON (i.e., LGR to LGR and BON to LGR survival rates including time spent in the estuary and ocean). Adults detected at LGR are assigned to a particular study category based on the study category they belonged to as a smolt. For example, fish with no previous detections at any dam are automatically assigned to category AC_0, fish detected as smolts at collector projects are assigned to AC_1, and fish transported as smolts are assigned to either AT_{LGR}, AT_{LGS}, or AT_{LMN} (depending on where they were collected). The formulas used for computing SARs by study category are:

(2a) $$SAR(T_0) = \frac{AT_{LGR} + AT_{LGS} + AT_{LMN}}{T_0};$$

(2b) $$SAR(C_0) = \frac{AC_0}{C_0}; \text{ and}$$

(2c) $$SAR(C_1) = \frac{AC_1}{C_1}.$$

SAR estimates are calculated from CSS data for both wild and hatchery chinook. For a detailed description of annual SAR estimate calculations using the SARs from each study category refer to Appendix B of Schaller et al. 2007. The annual SAR (SAR_{Total}) for the population is subsequently computed using a weighted equation of the form:

$$(3) \qquad SAR_{Total} = pr[T_o] \cdot SAR_2(T_0) + pr[C_0] \cdot SAR(C_o) + (1 - pr[C_0] - pr[T_0]) \cdot SAR(C_1),$$

where *pr[T₀]* and *pr[C₀]* are the estimated proportion of the total smolt population (tagged and untagged) at LGR. These values incorporate SARs of both transported (T_0) and in-river (C_0, C_1) study groups, with the contribution of each category to the overall estimate being weighted by its relative abundance in the run at large (during outmigration). SAR_{Total} is therefore a SAR estimate for the entire population. Ninety-percent CIs for all SAR estimates are computed using nonparametric bootstrapping methods (Efron and Tibshirani 1993).

We also calculate five and ten year SAR averages for hatchery and wild chinook under the Status Quo scenario. The rationale for doing so is that combining data from multiple years may provide more precise estimates of the expected values of SARs during and subsequent to the hydrosystem migration, thereby increasing the likelihood of correct decisions.

We evaluate the efficacy of alternative designs scenarios (High, Medium, Low) to provide reliable SAR estimates relative to the Status Quo. We assume that the expected values of SARs, calculated from data collected under the Status Quo design, remain the same for all design alternatives, and that only the CIs would change. We calculate the expected lower confidence limits for the SAR estimate that would result under each design alternative using the following logical test,

$$(4) \qquad \textbf{if } SAR_{SQ} - (SAR_{SQ} - CI_{lowSQ}) \cdot \left(\frac{1}{\sqrt{\frac{PIT_{Alt}}{PIT_{SQ}}}} \right) < 0 \text{ then } CI_{lowAlt} \leftarrow 0$$

$$\textbf{else } CI_{lowAlt} \leftarrow SAR_{SQ} - (SAR_{SQ} - CI_{lowSQ}) \cdot \left(\frac{1}{\sqrt{\frac{PIT_{Alt}}{PIT_{SQ}}}} \right),$$

where SAR_{SQ} is the SAR estimate calculated from data collected under Status Quo conditions, CI_{lowSQ} is the lower end of the CI of SAR_{SQ}, CI_{lowAlt} is the lower end of the CI of the design alternative being evaluated, PIT_{SQ} is the number of PIT tags used in the Status Quo for the group of interest (e.g., wild aggregate, and PIT_{Alt} is the number of PIT tags proposed for the design alternative being evaluated. This is an approximate estimate of the change in CIs with numbers of PIT tags. More accurate estimates would require a bootstrapping approach. Equation 4 is also used to calculate the upper end of the CI where CI_{highSQ} and $CI_{highAlt}$ are substituted into the expression in place of CI_{lowSQ} and CI_{lowAlt}, respectively. Equation 4 is based on the assumption that an increase in the number of PIT tags used in a design alternative would decrease the size of the CI relative to that of the Status Quo. For example, a fourfold increase in the number of PIT tags used in an alternative design would result in the CIs for that alternative being halved relative to those of the Status Quo. In addition, we felt it appropriate to bound the lower CI so that it cannot fall below zero, as survival rates cannot be negative.

Reliability of SAR estimates is assessed using an example decision rule modified from the minimum Northwest Power and Conservation Council (NPCC) interim goal of 2 to 6 percent SAR, set in 2003[6].

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[6] Pg. 13 of NPCC mainstem amendments of 2003-2004. www.nwcouncil.org/library/2003/2003-11.pdf ; interim goals of 2 to 6% SAR.

While this target is primarily for listed (i.e. wild) populations, we can also examine the performance of hatcheries against this same SAR goal. Using our decision rule, a SAR estimate is deemed reliable if the lower end of its 90 percent CI is above 2 percent (strong evidence of compliance) or its upper 90 percent CI is below 2 percent (strong evidence of lack of compliance). If the 90 percent CI straddles 2 percent (i.e., lower CI is below 2 and upper CI is above 2) the SAR estimate is deemed unreliable in so far that it is not possible to conclusively determine whether the minimum 2 percent SAR threshold has been met.

Annual TIR estimates and management targets

TIR is a ratio of SARs that relates survival of transported fish to in-river migrants. The ratio is the SAR of smolts transported from LGR to BON and returning to LGR as adults (T_0), divided by the SAR of smolts outmigrating in-river from LGR to BON and returning to LGR as adults (C_0), undetected in-river fish,

(6)
$$TIR = \frac{SAR_{LGR-LGR}(T_0)}{SAR_{LGR-LGR}(C_0)}.$$

TIR estimates are calculated from CSS data for both wild and hatchery chinook. TIR estimates are naturally log transformed prior to calculating CIs because the theoretical TIR distribution is log normal. Ninety-percent CIs for the original TIR estimates (i.e., Status Quo design) were computed using nonparametric bootstrapping methods (Efron and Tibshirani 1993).

Combining data from multiple years increases the number of PIT tags, which permits calculation of more precise estimates of the long-term distributions and expected values of TIRs. Five and ten year TIR averages are therefore calculated for hatchery and wild chinook under the Status Quo scenario.

The theoretical sampling variance of TIR estimates depends on the number of transported and in-river smolts and returning adults (Equation 7) (Katz et al. 1978),

(7)
$$Var[\ln(TIR)] = \frac{1}{n_T} + \frac{1}{n_C} - \left(\frac{1}{N_T} + \frac{1}{N_C}\right).$$

N_T is the number of PIT tagged smolts transported, N_C is the number of PIT tagged smolts outmigrating in-river, n_T is the number of returning adults that were transported as smolts, and n_C is the number of adults that migrated in-river as smolts. For the purpose of these analyses we assume that the number of PIT tagged smolts, both in-river and transported, is so large that the latter term becomes negligible and can be dropped. Consequently, to compare the standard error (SE) for TIR estimates under different M&E alternatives, we used the following simplification of equation (7):

(8)
$$SE[\ln(TIR)] \approx \sqrt{\frac{1}{n_T} + \frac{1}{n_C}}.$$

The efficacy of the three design alternatives (High, Medium, and Low) to provide reliable estimates of TIR is evaluated using a similar approach as that described in the above section on annual SAR estimates. We assume that the best estimate of the TIR, calculated using data collected under Status Quo, remains the same under all alternatives and that only the variance of the TIR changes with the alternatives. Approximate estimates of CIs are calculated under each alternative using equations:

(9)
$$CI_{lowAlt} = \ln(TIR_{SQ}) - \left(\ln(TIR_{SQ}) - \ln(CI_{lowSQ})\right)\cdot \beta \text{ and}$$

(10) $$CI_{highAlt} = \ln\left(TIR_{SQ}\right) - \left(\ln\left(TIR_{SQ}\right) - \ln\left(CI_{highSQ}\right)\right) \cdot \beta,$$

where β is a multiplier representing the fractional change in the CI width of $\ln\left(TIR\right)$,

(11) $$\beta = \sqrt{\frac{\frac{1}{\alpha} + \frac{1}{\varphi}}{2}}.$$

α and φ are ratios of the number of proposed tagged fish to the annual average number of tagged fish detected under Status Quo for transported and in-river groups, respectively. The formulas used to calculate α and φ are based on alternative specific conditions (Table 4.3). For example, a quadrupling of the number of PIT tags for both in-river and transported fish (i.e., $\alpha = \varphi = 4$), generates a value of $\beta = 0.5$, which would halve the CIs observed under the Status Quo option. To estimate the hypothetical number of tagged fish that will be detected under each alternative we assume that tagged fish, both transported and in-river, have a probability of 0.5 of being detected at LGR and a survival probability of 0.7, from where they are tagged to LGR. Fish that are PIT tagged at LGR are not subject to the survival and detection assumption. The values calculated for α and φ are in Table 4.4.

Table 4.3. Formulas used to calculate values of α and φ under the three alternative designs (see Table 4.2 for description of design alternatives). α and φ are ratios of the number of proposed tagged fish to the annual average number of tagged fish detected under Status Quo for transported and in-river groups, respectively. Values are based on the number of tagged fish proposed for each alternative and the number of tagged fish detected under Status Quo.

	Low Design	Medium Design †	High design †
Tagged Hatchery (H) Fish Transported	$\alpha = \frac{\text{\# H transported in low}}{\text{\# H transported in SQ}}$	$\alpha = \frac{\text{(\# of H transported in med – 20,000}^{\ddagger}\text{)*0.5*2/3*0.7}}{\text{\# of H transported in SQ}}$	$\alpha = \frac{\text{(\# of H transported in high – 20,000}^{\ddagger}\text{)*0.5*2/3*0.7}}{\text{\# of H transported in SQ}}$
Tagged Hatchery (H) Fish In-River	$\varphi = \frac{\text{\# H in-river in low * 0.5 *0.7}}{\text{\# H in-river in SQ}}$	$\varphi = \frac{\text{20,000 + (\# of H in-river in med – 20,000}^{\ddagger}\text{)*0.5*1/3*0.7}}{\text{\# of H in-river for SQ}}$	$\varphi = \frac{\text{20,000 + (\# of H in-river in high – 20,000}^{\ddagger}\text{)*0.5*1/3*0.7}}{\text{\# of H in-river for SQ}}$
Tagged Wild (W) Fish Transported	$^{*}\alpha = \frac{\text{\# W transported in low}}{\text{\# W transported in SQ}}$	$\alpha = \frac{\text{\# W transported in low + 20,000*0.5*2/3*0.7}}{\text{\# W transported in SQ}}$	$\alpha = \frac{\text{(\# of W tagged in high)*0.5*2/3*0.7}}{\text{\# of W transported in SQ}}$
Tagged Wild (W) Fish In-River	$^{*}\varphi = \frac{\text{\# of W in-river for low}}{\text{\# of W in-river for SQ}}$	$\varphi = \frac{\text{\# of W in-river for low + 20,000*0.5*1/3*0.7}}{\text{\# of W in-river for SQ}}$	$\varphi = \frac{\text{(\# of W tagged in high)*0.5*1/3*0.7}}{\text{\# of W in-river in SQ}}$

† The Medium and High design assumes that 1/3 of tagged wild and hatchery fish will out-migrate in-river and 2/3 of tagged fish will be transported.

‡ 20,000 tagged fish are put in-river at LGR.

* The number of wild fish transported and in-river under the Low scenario is assumed to be equal to the number of wild fish that are actually transported or detected in river under Status Quo. The rationale for this is that both Low and Status Quo have identical designs with respect to tagging of wild fish.

Table 4.4. Values used for α and φ under each of the three alternative designs.

	Variable	Low Design	Medium Design	High design
Tagged Hatchery (H) Fish	α	0.36	1.08	1.51
	φ	0.16	1.16	1.43
Tagged Wild (W) Fish	α	1.02	1.56	4.94
	φ	0.98	1.07	0.79

The TIR is often used to examine whether it is more beneficial to transport fish or allow them to outmigrate in-river. When the TIR is greater than 1, transportation is a better passage route than in-river passage. When the TIR is less than 1, in-river transport is better. CSMEP scientists assessed the reliability of TIR estimates using an example decision rule based on a TIR value of 1 (i.e., 1:1 ratio). A TIR estimate is deemed reliable (i.e., capable of being clearly distinguished from 1) if its lower 90 percent CI is above 1 (i.e., strong evidence that TIR > 1), or its upper 90 percent CI is below 1 (i.e., strong evidence that TIR < 1). If the 90 percent CI straddles 1 (i.e., lower CI is below 1 and upper CI is above 1) the TIR estimate is deemed unreliable in so far that it is not possible to conclusively determine whether it is better to allow fish to outmigrate in river or transport them. We stress that this decision rule is only used as an example. Managers could choose to make decision rules with a lower or higher level of certainty.

Cost estimates for alternative monitoring designs

The cost for each alternative monitoring design takes into account the costs of long-running foundational projects occurring in the basin as well as the costs associated with PIT tagging. The long running foundational projects (with NPCC proposal numbers) considered within the cost estimate are: Smolt Monitoring Program – 198712700; PTAGIS – 199008000; UW Statistical Support – 198910700; Passage Survival Estimates – 199302900; and CSS – 199602000. The rationale for including the costs of these various projects is that they would be expected to continue under all monitoring designs, both proposed (L, M, and H) and the Status Quo. The one exception is for the Low alternative which reduced the cost of the CSS project by significantly lowering the number of PIT tagged for hatchery fish.

The cost of PIT tagging is a function of the number of fish tagged. We assume that the tags themselves cost $2.10. The labor cost of tagging hatchery and wild fish is estimated from existing and proposed CSS studies, as well as opportunistic use of tagging data from ongoing studies in Idaho. The Idaho data show that a large degree of variation exists in the number of spring/summer chinook caught in rotary screw traps, due to among stream variation in fish abundance and community composition. Consequently, to estimate costs for each design alternative we assume that an average number of fish per trap will be caught, and apply this number across all traps. Taking into account the type of fish and tagging proposed under each design alternative we estimated a labor cost of $1.16 per tagged hatchery fish and $12.36 per wild fish (an intermediate estimate; see Table 4.5 for a detailed breakdown of costs and associated assumptions).

Table 4.5. Summary of labor cost information.

Type of fish and tagging	Average labor cost of tagging / PIT tagged fish (min-max; n)	Assumptions
Hatchery fish	$1.16 ($0.92 - $1.51; 5 data points)	Includes all labor costs
Wild fish at tributary – population level	$30.23 (Mean across 29 traps in ID; a maximum cost as more fish could be trapped at each trap)	Estimated cost of $65,000/trap/year (taken from Idaho study). (29 traps) / (62,357 fish).
Wild fish at sub-basin / MPG level (Salmon, Clearwater, Grand Ronde)	$12.36 (3 traps)	Based on total labor costs for Salmon, Snake, and Clearwater traps operated in spring 2006 under the Smolt Monitoring Program ($359,074). 29,050 tagged fish (roughly 10,000 fish per trap).
Wild fish at major population group (MPG) level	$6.29 (estimated; not from actual data)	Combined assumptions from Idaho study and Smolt Monitoring Program: (Estimated cost of $65,000/trap/year) * (18 traps) /186,000 fish). It's assumed that 18 traps could catch 186,000 fish (about 10,000/ trap).

Evaluating tradeoffs among alternative designs

CSMEP scientists have applied the PrOACT approach (described in Section 1.2) to refine M & E alternatives. More dialogue is required with program managers to determine their information priorities, risk tolerances, and budget constraints.

4.2.2 Supportive analyses for results presented in Volume 1

Determining whether SAR and TIR estimates meet management targets over multiple years

The results presented in Volume 1 focused on evaluations of Status Quo, Low, Medium, and High alternatives, focusing mostly on annual estimates of SARs and TIRs for Snake River Aggregate wild chinook and groups of hatchery fish. CSMEP completed additional analyses that examined multiple-year estimates, which can be applied to varying scales (i.e., the Snake River aggregate, major population groups (MPGs), and in some cases individual populations).

The following description is summarized from CSMEP's 2006 Annual Report.

Estimating sampling variance in SAR estimates

Individual annual estimates of SARs and their ratios provide indicators of the efficacy of actions designed to improve hydrosystem and post-hydrosystem survival of Snake River migrating smolts. However, both measurement and process (environmental) variation in annual results make inferences about the underlying means of these metrics problematic. For example, survival rates for adult return to freshwater (SARs) are generally on the order of one percent. Because sampling variance is inversely related to the number of adult returns, the number of tagged smolts in each group of interest limits statistical inferences on between group differences in annual SARs. The confounding effect of this combined variation on inferences about these parameters can be seen in annual SAR and TIR estimates where annual confidence bounds on TIR are wide and overlap target values in most years.

Combining data from multiple years may allow us to better estimate the long-term distributions and expected values of these indicators of survival during and subsequent to the hydrosystem migration, thereby facilitating relevant inferences. When survival rates are estimated from counts of individuals (from a census or from marking a sample of the population), the sampling error is binomial at the start and end of the interval, and can be removed from the variance estimated for a time series of such survival estimates. This provides an estimate of environmental variance.

We used Akçakaya's (2002) method to estimate the variance in PIT-tag SAR estimates from sampling error, and remove it from the total variance in the time series. The mean and total variance can be estimated in different ways: unweighted (i.e., each annual estimate gets the same weight in calculating mean and variance); or weighted in some manner, where the influence of each year's estimate reflects some measure of precision and/or relevance of that estimate. Akçakaya (2002) cites Kendall (1998) as pointing out that different ways of calculating variance reflect different assumptions about the reliability of individual estimates. Akçakaya recommends that in general, weighted methods should be used when the variation in sample size results from variation in sampling effort. For our purposes, the number of PIT-tagged smolts in a category can be considered an index of sampling effort and a correlate of precision of the estimate. However, independent of considerations of sample size, individual year estimates for PIT-tagged fish in a particular category may be more or less representative, depending on how well they reflect the experience of the relevant untagged population, and how large a portion of the total population of smolts that category represented in that year. Although most of the analyses here focus on annual SAR estimates, the methods can also be used to explore within-season patterns in SARs. The migration season could be broken into segments based on arrival timing at a collector project, and the method applied to each of the segments, to test for differences in SARs among them.

We use the total weighted variance method from Akçakaya (2002) and Kendall (1998) to estimate the multiple-year mean and variance of both transport and in-river SARs. Using the weighting methods for both transport and in-river SARs ensure that the contribution of each year to demographic variance is proportional to the year's contribution to total variance. For details regarding Akçakaya's method refer to Chapter 4 in Schaller et al. (2007). The values for the mean and remaining variance of the time series for a given SAR are then converted into the parameters of a beta distribution.

Creating beta distribution of SAR estimates

We assume that the underlying environmental stochasticity is beta distributed. The beta distribution parameters *a* and *b* are calculated using:

$$a = \mu\left(\frac{\mu(1-\mu)}{\sigma^2} - 1\right) \tag{12}$$

$$b = (1-\mu)\left(\frac{\mu(1-\mu)}{\sigma^2} - 1\right), \tag{13}$$

where μ is the estimate of the mean and σ^2 is the estimate of the variance. The resulting beta distribution reflects an estimate of SAR due only to environmental stochasticity over time. For details regarding how to derive a distribution of the aggregate SAR using the beta parameters (*a* and *b*) refer to Chapter 4, Schaller et al. (2007).

Framework for monitoring simulation

We developed a model to simulate random variation in SARs of the two groups, and the process of estimating SAR from returning PIT tagged fish for a fixed number of tagged fish at LGR dam. We assume that fish are transported from one project (e.g., LGR).

SARs are modeled as beta random variables, with underlying environmental coefficient of variation and correlation coefficient as described in Chapter 4, Schaller et al. (2007). The number of smolts surviving to adult in a group in a particular cohort is determined via a beta-binomial process—i.e., the probability of survival is drawn randomly from the relevant beta distribution, and that survival probability is used in a binomial draw (with N = number of smolts) to determine adults actually surviving to and being detected at LGR. For exploration of SAR distributions, each simulation is run independently of others. For TIR distributions, with each combination of parameters in the simulation describing the expected outcome, the same sequence of "actual" realized SARs for both groups is used as the seed from which estimated SARs are derived through survival of PIT-tagged fish, for each level of PIT-tagging. This is due to the relatively low number of simulations used to explore TIR, compared to SAR. Unlike simulation of the monitoring of SARs themselves, the simulation of monitoring TIR involves simulation of the ratio of SARs, and hence is particularly computer-intensive. The model ignores correlation structure within a group. Adults returning in a given year can contribute to SARs and TIRs of different migration years (because adjacent cohorts overlap in the ocean). Actual survival rates probably exhibit some serial autocorrelation as well. Within-group correlation structure is assumed not to exist, both in the simulation model and the estimation procedure. This assumption is tenuous, and it may affect results, more for shorter time series. As an alternative to this, a more realistic simulation model could be created, based on a stochastic, age-structured projection matrix with a correlation matrix of parameters. This would likely necessitate an alternative approach to removing sampling variance that considers covariance between survival rates, such as the variance-components approach used by Gould and Nichols (1998).

The measures used to evaluate the influence of number of fish tagged and number of years on inferential ability are:

1. Width of the 90 percent CI on the standard error of the estimated mean (expected) value of the parameters.
2. For SARs, the probability of the alternative hypothesis, given that it is true (or false) at a certain effect size (i.e., true expected value of SAR). This is explored using two different values of true mean SAR: 2.2 percent and 2.5 percent and four levels of tagging (1000, 2500, 5000, and 10,000 tags).
3. For TIRs, the probability of making correct conclusion about the hypothesis, given different decision rules on transportation.

We model a range of assumptions about:

1. true value of E[SAR_C];
2. true value of TIR (in combination with SAR_C and S_R assumptions, determines true value of E[SAR_T]; and
3. number of smolts PIT-tagged at LGR or PIT-tagged smolts alive on reaching LGR.

The values used for each assumption explored are listed in Table 4.6.

Table 4.6. Range of assumptions used in generating data for TIR monitoring simulation.

	Assumption Number		
	1	2	3
E[SAR_C]	1%	2.0%	
E[TIR]	0.8	1.2	1.5
Tagged T fish @ LGR	1000	2000	5000
C:T tag ratio	1:1		

The number of marks in each group is fixed during initial simulations. In other words, for a given target number of PIT-tagged fish in the two groups, there is no inter-annual variation in the numbers of marked smolts in either transport or control groups. In practice, PIT-tagged smolts falling into the different groups vary widely over years, especially for wild fish. Generally, the control group is larger than the transport group, due in part to the need to return PIT-tagged fish to the river for use in reach survival estimation.

Twenty years of monitoring are simulated for both SAR and TIR estimation with performance measures estimated every five years. With respect to TIR simulations, each simulation run is repeated 100 times, where for each of the 100 sets of parameter estimates, 5000 simulated estimations of the TIRs are done for each of the four time periods. The combinations of parameter values explored in the TIR simulations are listed in Table 4.7.

Table 4.7. Design for TIR simulations.

Simulator Run #	Expected In-river SAR	Expected TIR	I/T tag ratio	Annual # T tags
1	1%	0.8	1	1000
2	1%	0.8	1	2500
3	1%	0.8	1	5000
4	1%	1.2	1	1000
5	1%	1.2	1	2500
6	1%	1.2	1	5000
7	1%	1.5	1	1000
8	1%	1.5	1	2500
9	1%	1.5	1	5000
10	2%	0.8	1	1000
11	2%	0.8	1	2500
12	2%	0.8	1	5000
13	2%	1.2	1	1000
14	2%	1.2	1	2500
15	2%	1.2	1	5000
16	2%	1.5	1	1000
17	2%	1.5	1	2500
18	2%	1.5	1	5000

Evaluating different management attitudes to the transportation of fish

Each set of simulations generates a unique TIR distribution which is lognormal. From that distribution, we estimated the probability that TIR > 1, given the number of tags, true in-river SAR, and true TIR, in that set of simulations. Three different decision rules were explored to test alternative management attitudes to the transportation of fish:

1. “Transportation averse”: reject conclusion that TIR > 1 unless Pr[TIR > 1] ≥ 0.8
2. “Transportation neutral”: accept conclusion that TIR > 1 if Pr[TIR>1] ≥ 0.5
3. “Transportation tolerant”: accept conclusion that TIR > 1 unless Pr[TIR>1] < 0.2 .

Each rule was applied to the estimated probabilities of TIR >1 in five year intervals.

Evaluating the effect of different within season transportation management actions TIRs

Previous work by CSS (Marmorek et al. 2004) and NOAA (Williams et al. 2005) suggests that transport to in-river (TIR) ratios may vary in a predictable way within the course of the (spring) migration season. Consequently, we investigated the relationship between SAR / TIR estimates and time of year. Our objective was to yield insights on M & E alternatives that provide cost-effective and reliable insights on when it is worth transporting fish. For each migration year, the migration season is divided into four equally long periods based on detection date at LGR. Migration data used for these analyses spans the period from 1998 to 2003. As described in CSMEP (2005)[7], the SARs for each group were assumed to

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[7] Draft document for Steps 6 and 7 of the DQO process.

follow a binomial process, and the TIRs were simply the ratio of SARs of transported and in-river groups. The 5th and 95th percentiles of the bootstrapped distribution were used to generate TIR confidence intervals from the historical data for each quartile, for both wild and hatchery groups of spring/summer chinook and steelhead. For alternative designs involving fewer PIT tags, we simply sub sampled the existing data (e.g., taking every second observation simulates halving the sample size). For alternatives with increased number of PIT tags, we randomly drew an appropriate number of observations from the bootstrapped data.

Quartile TIR estimates of reliability and compliance are assessed in the same manner described in the section below.

4.3 Results

4.3.1 Expansion of results presented in Volume 1

Annual SAR estimates and management targets

Wild spring/summer chinook

The completion of the adult returns for migration year 2003 and addition of migration year 2004 with 2-Ocean returns has shown two sequential years with extremely low estimated $SAR_{LGR\text{-to-}LGR}$ for wild spring/summer chinook (Figure 4.3), not exceeding 0.35% in any study category. SAR levels above 2% have been estimated in only a few years for specific study categories (e.g., transport T_0 Category in 1999 and in-river C_0 Category in 1997, 1999, and 2000). However, when taking into account the criteria of non-overlapping CIs (our example decision rule), the 2% minimum SAR has not been satisfied a single time. Only in 2001 was the transport $SAR(T_0)$ significantly higher than that of the in-river migrants $SAR(C_0)$ based on non overlapping 90% CIs. In 2001, a drought caused extremely low survival rates for in-river migrants (see $SAR(C_0)$ in Figure 4.3).

The trend in annual estimated $SAR_{LGR\text{-to-}LGR}$ (SAR_{Total}) is reflective of the wild Chinook run-at-large that outmigrated in 1994 to 2004 (Figure 4.3– rightmost bars). The trend in these estimates over the 11-yr period has been highly variable, rising from below 0.5% before 1997 to highs of 2.4% in 1999 before dropping each year to below 0.35% in 2003 and 2004. Historically SAR_{Total} estimates have been below the 2% SAR threshold (10 of 11 years) and are currently far below the minimum 2% SAR recommended. Wild spring/summer chinook appear to be back at the pre-1997 levels, which from an M & E perspective makes it easier to have definitive evaluations of compliance (i.e., non-overlapping CIs), but does not bode well for recovery efforts.

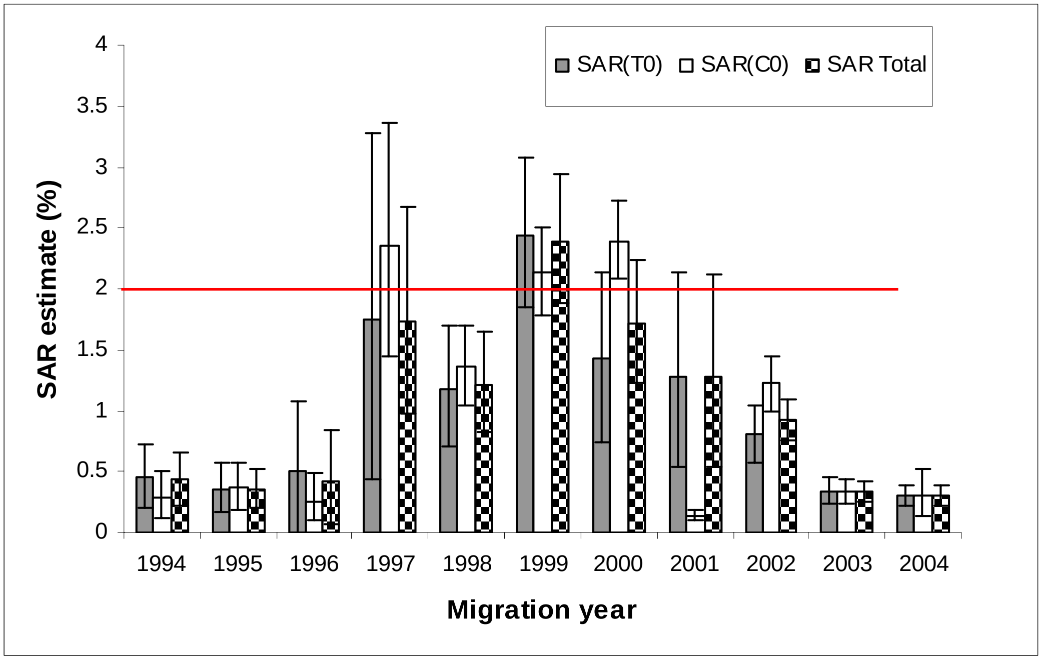

Figure 4.3 Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ for wild chinook in transport [$SAR(T_0)$] and in-river [$SAR(C_0)$] study categories, as well as the weighted SAR [SAR_{Total}] for migration years 1994 to 2004. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CI.

The ability to determine whether the 2% SAR threshold is attained does not appear to significantly improve under any of the alternative designs for wild chinook at the Snake Basin level (Figure 4.4). Evaluations of compliance can be clearly assessed in 6 of 10 years under the Status Quo, Low and Medium design. An improvement is seen under the High design, where compliance can be determined in 8 of 10 years (1999 and 2001 are the two additional years). This improvement is due to narrower 90% CI as a consequence of greater tag numbers employed by the High design.

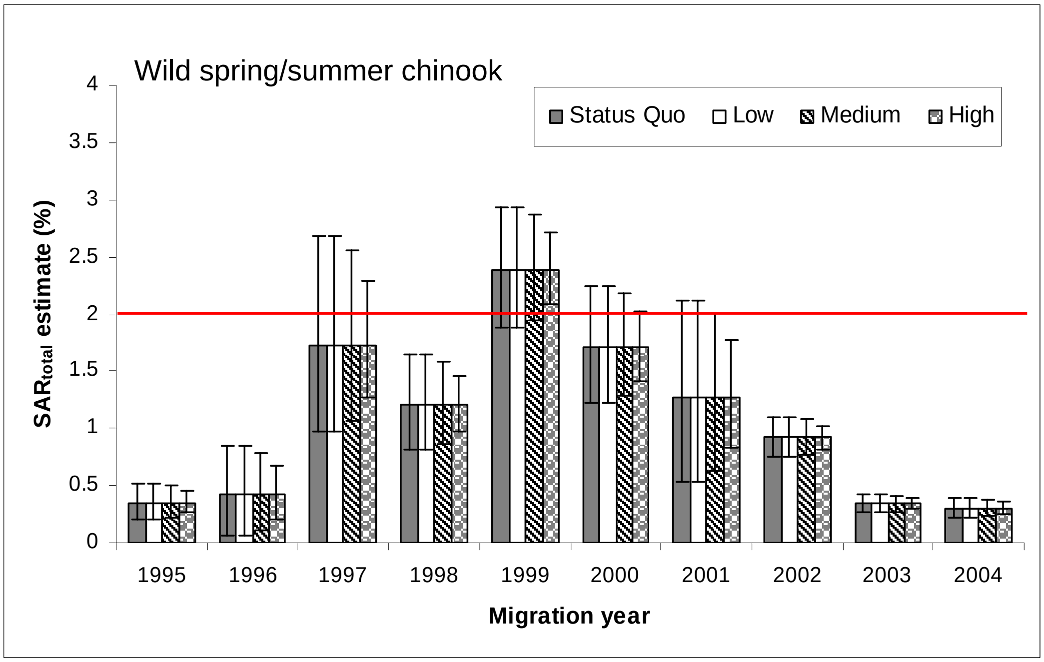

Figure 4.4 Estimated SAR_{Totoal} for PIT-tagged wild chinook for migration years 1994 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

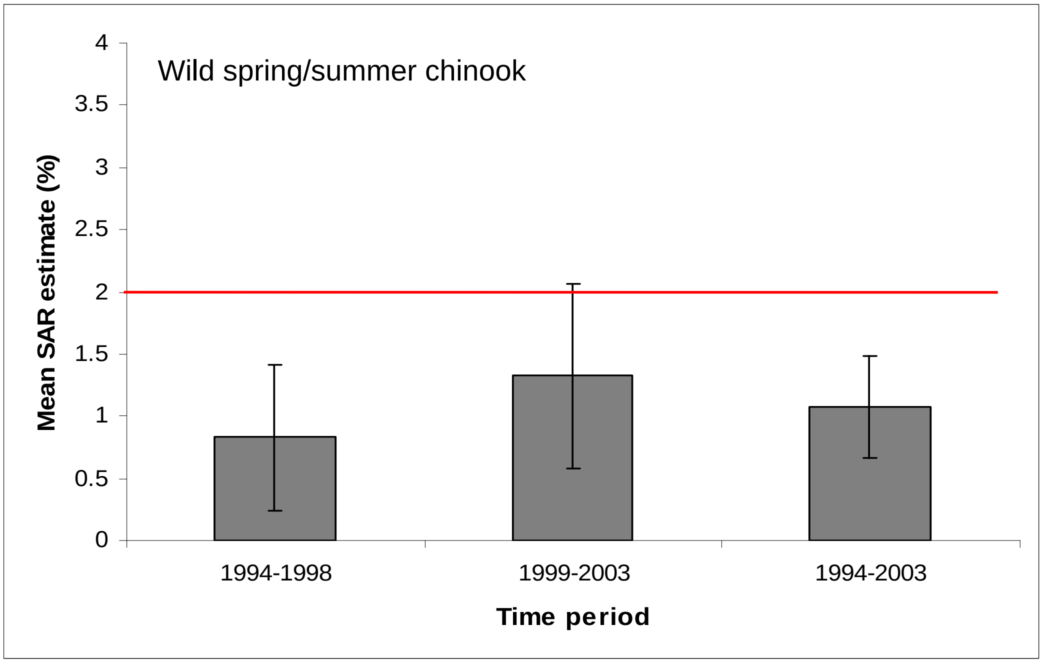

Figure 4.5 Five and ten year mean SAR estimates for PIT tagged wild chinook across migration years 1994 to 2003. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs under Status Quo conditions.

Five and ten year mean SAR estimates also allow for slightly greater precision (i.e., narrower CIs) in the estimate because of the increased number of PIT tagged fish when data from all years are pooled (Figure 4.5). The mean SAR estimate under Status Quo conditions is well below the 2% minimum goal for the periods 1994 to 1998 and 1994 to 2003. The SAR estimate for the period 1999 to 2003 also lies well below 2%, however the upper CI just crosses 2%.

Hatchery spring/summer chinook

Assessing whether or not SARs complied with the 2% minimum threshold depends on the width of the CI for SAR_{Total} estimates, and the extent to which the interval overlaps the threshold. The 90% CIs for SAR_{Total} estimates of hatchery chinook under the alternative designs exhibit similar trends across the five hatchery facilities (Figure 4.6 to 9). The ability to differentiate between compliance and non-compliance does not appear to improve significantly under the Medium and High designs relative to the Status Quo. However, the ability to determine compliance deteriorates under the Low design as a consequence of an increase in the 90% CI width, leading to a greater incidence of CIs straddling 2% SAR.

With respect to Dworshak and Catherine Creek hatcheries, extremely low SAR_{Total} estimates occurred in 5 of 8 years and 4 of 4 years, respectively (Figure 4.6 and 6, respectively (leftmost bars)). SARs have been well below the minimum 2% SAR in all years. As a result, non-compliance with the 2% SAR minimum (non-overlapping CIs) can be clearly ascertained for both hatchery facilities in all years and all scenarios.

Rapid River, McCall, and Imnaha hatcheries the 2% SAR threshold in 1, 3, and 2 of 8 years, respectively (Figure 4.8 to 9 – leftmost bars with 90% CIs that do not overlap the threshold). Based on patterns of annual SAR_{Total} estimates, Rapid River Hatchery chinook exhibit the most similar trend to that of PIT-tagged wild chinook during the period 1997 to 2004. Compliance with the 2% threshold (or non-compliance) can be assessed in 6 of 8 years for the Rapid River hatchery for all design alternatives including the Status Quo. SAR_{Total} estimates and corresponding CIs for Imnaha and McCall hatcheries allow compliance to be assigned in 8 of 8 years under the Status Quo, Medium, and High alternatives, but only in 7 of 8 years under the Low alternative.

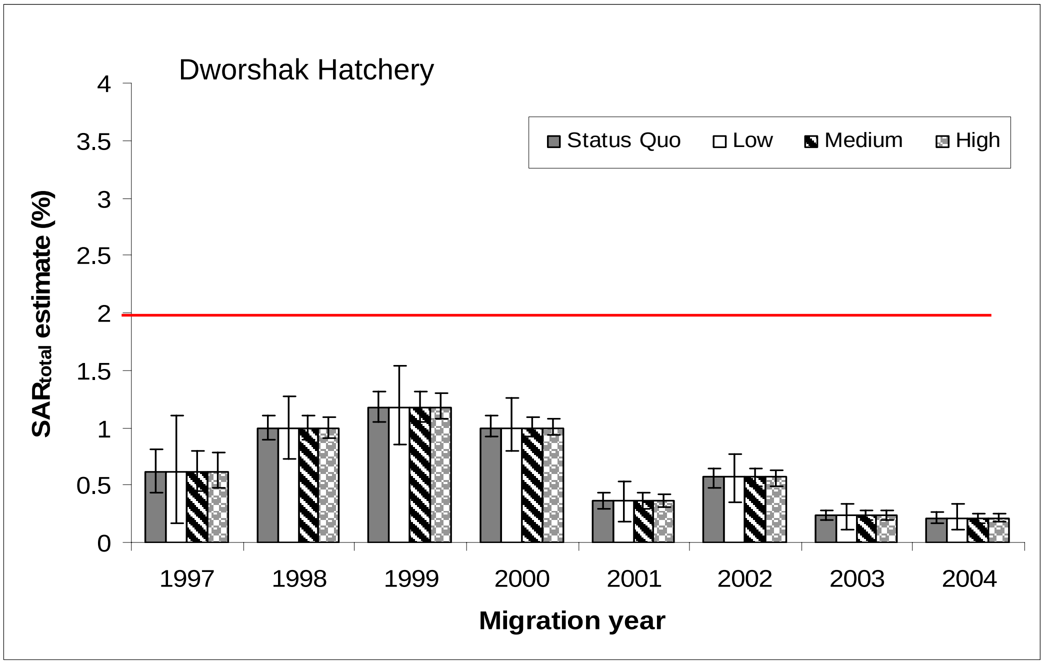

Figure 4.6. Estimated SAR$_{Totoal}$ for PIT-tagged hatchery chinook from the Dworshak facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

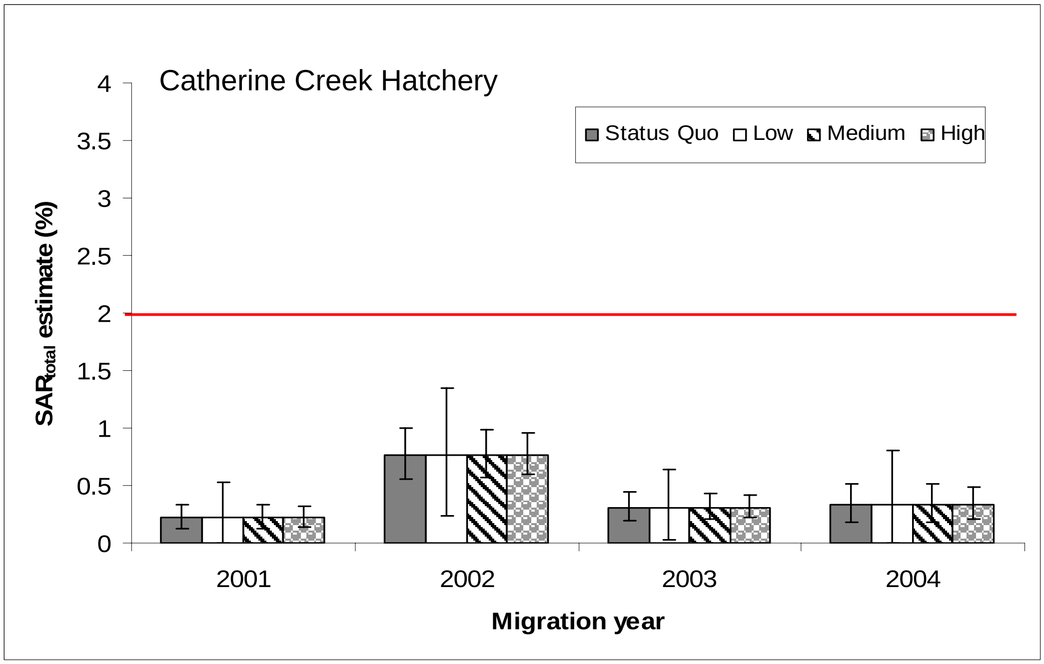

Figure 4.7. Estimated SAR$_{Totoal}$ for PIT-tagged hatchery chinook from the Catherine Creek facility for migration years 2001 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

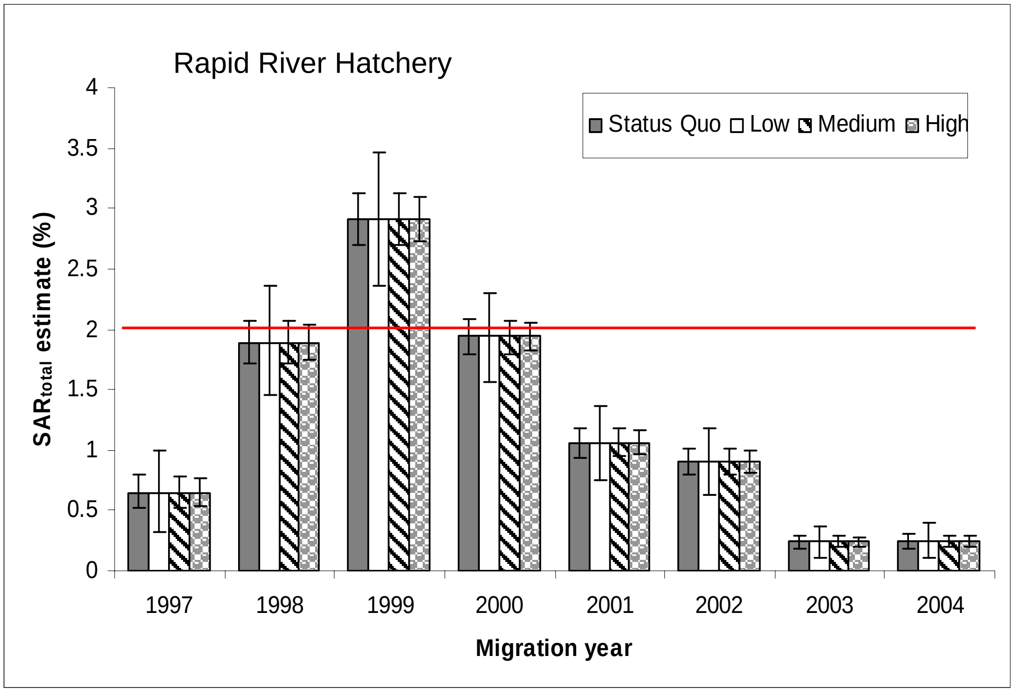

Figure 4.8. Estimated SAR$_{Totoal}$ for PIT-tagged hatchery chinook from the Rapid River facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

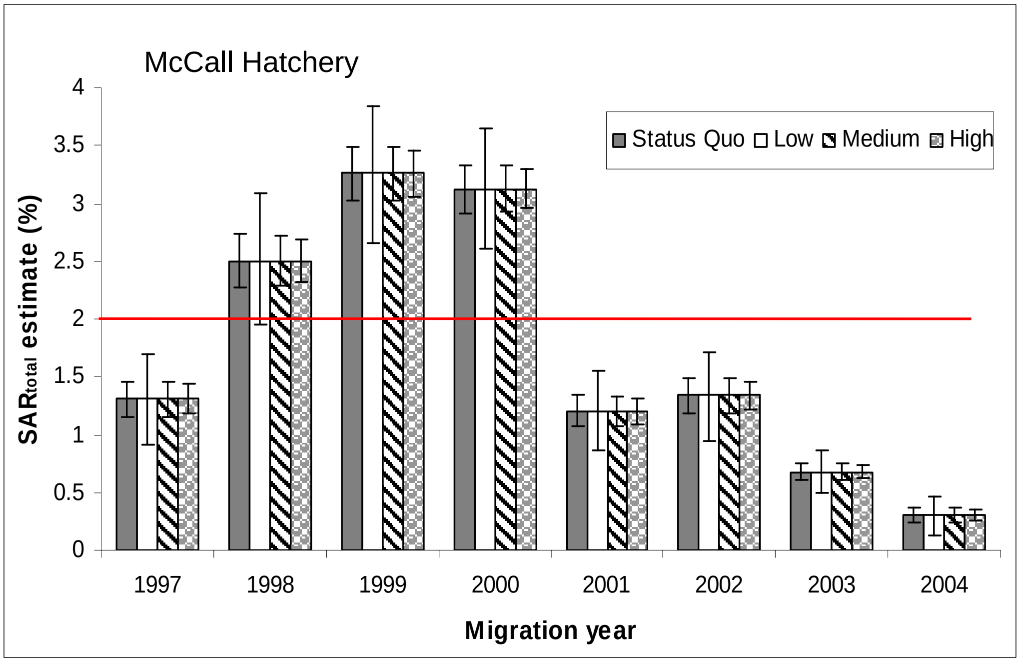

Figure 4.9. Estimated SAR$_{Totoal}$ for PIT-tagged hatchery chinook from the McCall facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

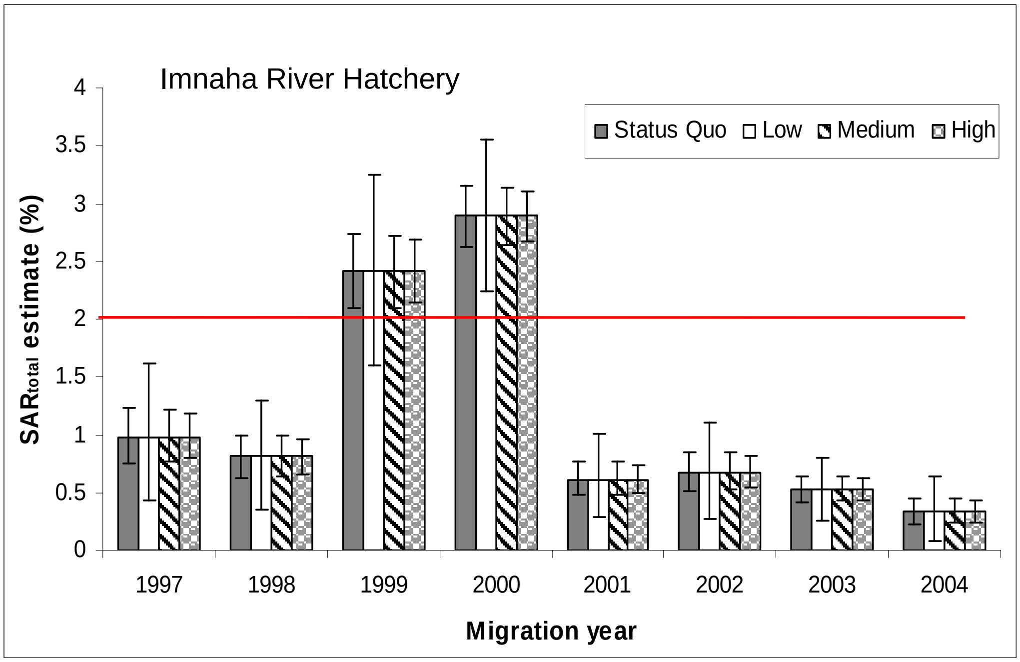

Figure 4.10. Estimated SAR_{Totoal} for PIT-tagged hatchery chinook from the Imnaha River facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

Annual TIR estimates and management targets

Wild spring/summer chinook

For transportation to be more effective than in-river passage, TIR values should be consistently greater than 1.0. The value of 1.0 can be considered as a threshold, and a situation where TIR values are definitively greater than 1.0 (i.e., lower 90% CI > 1.0) is an example management target.

Estimated TIR ratios for PIT-tagged wild spring/summer chinook are presented in the first column of Table 4.8. The lower limit of the 90% CI for TIR exceeded a value of 1.0 only in 2001, indicating a significantly higher SAR for transported wild chinook than in-river fish in that year (i.e., better to transport fish than allow them to migrated in-river).

The ability to determine whether it is more beneficial to transport fish than to allow them to migrate in-river does not significantly improve under any of the alternative designs for wild chinook at the Snake Basin level (Figure 4.11). Based on the example decision rule, a decision regarding the preferable river passage route (in-river vs. transport) can be clearly made in 3 of 10 years under the Status Quo, Low, Medium, and High designs. In the remaining 4 years the TIR CI interval crosses the value 1, suggesting that the SAR estimates between transported and in-river are not sufficiently different for a decision to be made with greater than 90 percent confidence.

Table 4.8. Estimated TIR ratios for wild and hatchery spring/summer chinook for 1994 to 2004 and 1997 to 2004, respectively (with 90% CIs). Estimates calculated using data collected under Status Quo. Modified from Schaller et al. 2007. Estimates from 2001 are not included in the geometric mean, as this was a highly unusual year.

	TIR Estimates					
		HATCHERIES				
Year	Wild	RAPH	DWOR	CATH	MCCA	IMNA
1994	1.62 (0.62–5.05)					
1995	0.95 (0.39-2.14)					
1996	1.92 (0.00-6.8)					
1997	0.74 (0.17-1.58)	1.73 (1.08-2.85)	1.75 (0.92-3.46)		1.38 (1.06-1.80)	1.36 (0.83-2.37)
1998	0.87 (0.50-1.35)	1.66 (1.32-2.16)	0.72 (0.59-0.88)		1.96 (1.54-2.56)	1.55 (0.93-3.15)
1999	1.14 (0.82-1.51)	1.28 (1.11-1.51)	0.99 (0.81-1.24)		1.49 (1.29-1.73)	1.89 (1.40-2.51)
2000	0.60 (0.32-0.92)	1.32 (1.13-1.55)	0.99 (0.82-1.19)		1.89 (1.67-2.15)	1.29 (1.06-1.58)
2002	0.65 (0.45-0.94)	1.5 (1.20-1.91)	1.24 (0.93-1.61)	1.81 (1.02-3.43)	1.44 (1.18-1.79)	1.75 (1.07-3.03)
2003	1.05 (0.69-1.67)	1.07 (0.70-1.60)	1.20 (0.82-1.80)	1.44 (0.60-3.56)	1.46 (1.17-1.81)	1.21 (0.79-1.89)
2004	0.97 (0.53-2.37)	1.79 (0.94-5.52)	0.95 (0.60-1.72)	1.75 (0.0-2.31)	1.23 (0.66-2.98)	1.50 (0.48-4.80)
Geometric mean	0.99	1.46	1.08	1.66	1.53	1.49
2001	8.96 (3.61-16.8)	21.7 (13.3-54.1)	8.76 (5.04-20.4)	5.33 (0.0-13.6)	31.9 (17.9-88.4)	10.8 (4.94-39.8)

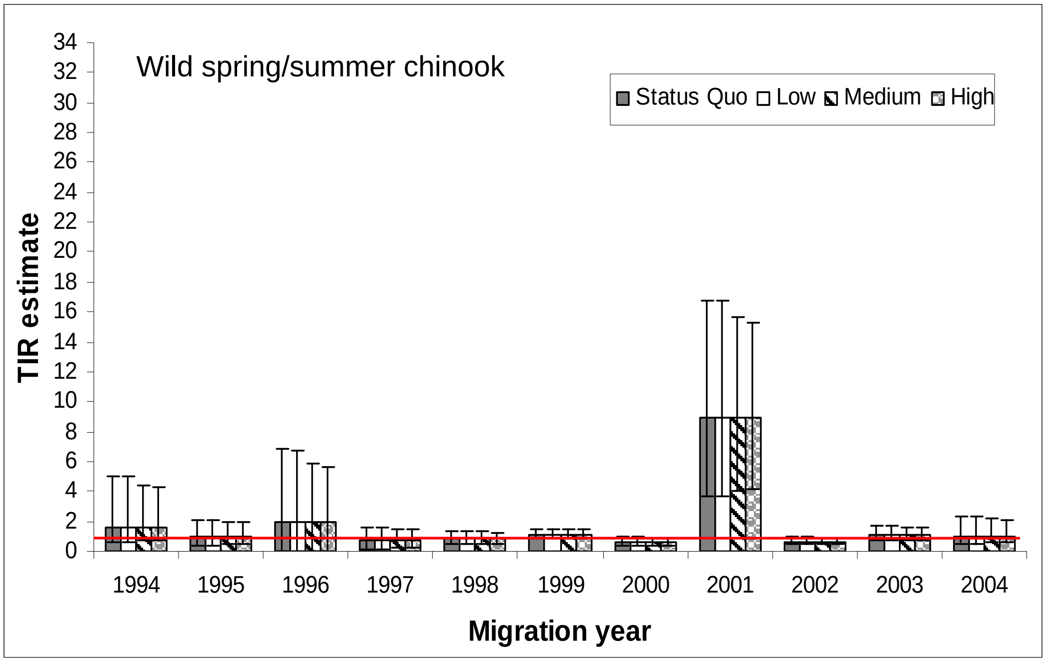

Figure 4.11. Estimated TIR for PIT-tagged wild chinook for migration years 1994 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

Inter-annual variation in TIR estimates for both wild and hatchery chinook may be large and can be expected to influence population viability, if a large portion of fish are transported. In addition, sampling variance may also be substantial in parameter estimates of chinook and for wild (ESA-listed) fish in particular since wild fish are opportunistically sampled and tend to be available for capture and tagging in much lower numbers than hatchery fish. Sampling variance is inversely related to the number of adult returns, suggesting that the number of tagged smolts in each group of interest is a limiting factor for statistical inference of the differences in annual estimates of survival between groups. The confounding effect of this combined variation on inferences about these parameters can be seen in annual TIR estimates, where annual confidence bounds on TIR are wide and overlap the threshold value of 1.0 in most years. Combining data from multiple years does appear to provide greater precision in the mean TIR estimate for wild chinook via smaller CIs (Figure 4.12), although, overlap the threshold value of 1.0 still occurs in all time periods.

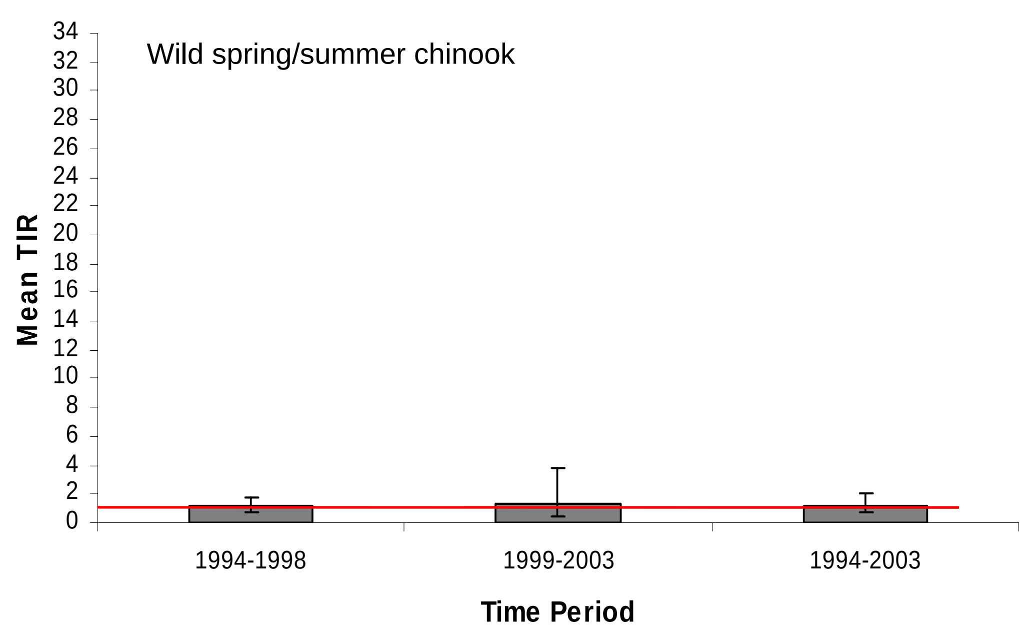

Figure 4.12. Five and ten year mean TIR estimates for PIT tagged wild chinook across migration years 1994 to 2003. The red horizontal line indicates threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

Excluding migration year 2001, which had TIR ratios exceeding 5 in all hatchery groups, geometric mean TIR ratios covering the seven years from 1997-2000 and 2002-2004 have been around 1.5 for Rapid River, Imnaha, and McCall Hatchery chinook (Table 4.8). For Dworshak Hatchery chinook, the 7-yr geometric mean TIR ratio was less than 1.1. Although Catherine Creek hatchery chinook have a shorter time series of data (Table 4.8), its TIR ratios tend to follow the former three hatcheries more closely than Dworshak Hatchery. Trends in hatchery TIR ratios are presented in Figure 4.13 to Figure 4.17 (leftmost bars). A significant increase in the transport SAR over the in-river SAR is found when the lower limit of the 90% CI of the TIR ratio estimates is greater than one. In general, transportation provided benefits in most years to Snake River hatchery spring/summer chinook from 1997-2004; however benefits varied among hatcheries. Prior to 2004, estimated TIR ratios significantly greater than one were observed in most years for Rapid River and McCall hatchery chinook, about half the time for Imnaha hatchery chinook, and once for Catherine Creek. Significant TIR ratios greater than one have not been observed for Dworshak Hatchery chinook.

Transportation effectiveness can be determined with decreasing frequency under the Low design for all hatchery facilities relative to the Status Quo. Based on non overlapping 90% CIs, the cumulative number of data years that transportation effectiveness can be determined for hatchery chinook is 20 / 30 under Status Quo, 9 / 30 under the Low design, 20 / 30 under the Medium design, and 22 / 30 under the High design (see Figure 4.13 to 16 for an annual breakdown by hatchery and Table 4.9 for hatchery summaries). In general, the width of CIs under Status Quo, Medium, and High are similar in size; however, under the Low scenario the CIs are significantly larger. The consequence of a large CI is highlighted by the fewer number of years in which transportation effectiveness can be assessed using the Low design compared to the other alternatives (Table 4.9).

Table 4.9. Proportion of years in which compliance with a transportation effectiveness threshold (i.e., TIR = 1) can be confidently determined for the five hatchery facilities (1997 to 2004).

	Existing Data	CSMEP M & E Alternatives		
Hatchery	Status Quo	Low	Medium	High
Dworshak	2 / 8	1 / 8	2 / 8	3 / 8
Rapid River	6 / 8	2 / 8	6 / 8	6 / 8
Catherine Creek	1 / 4	0 / 4	1 / 4	1 / 4
McCall	7 / 8	4 / 8	7 / 8	7 / 8
Imnaha River	4 / 8	2 / 8	4 / 8	5 / 8
Cumulative Data Years	20 / 36	9 / 36	20 / 36	22 / 36

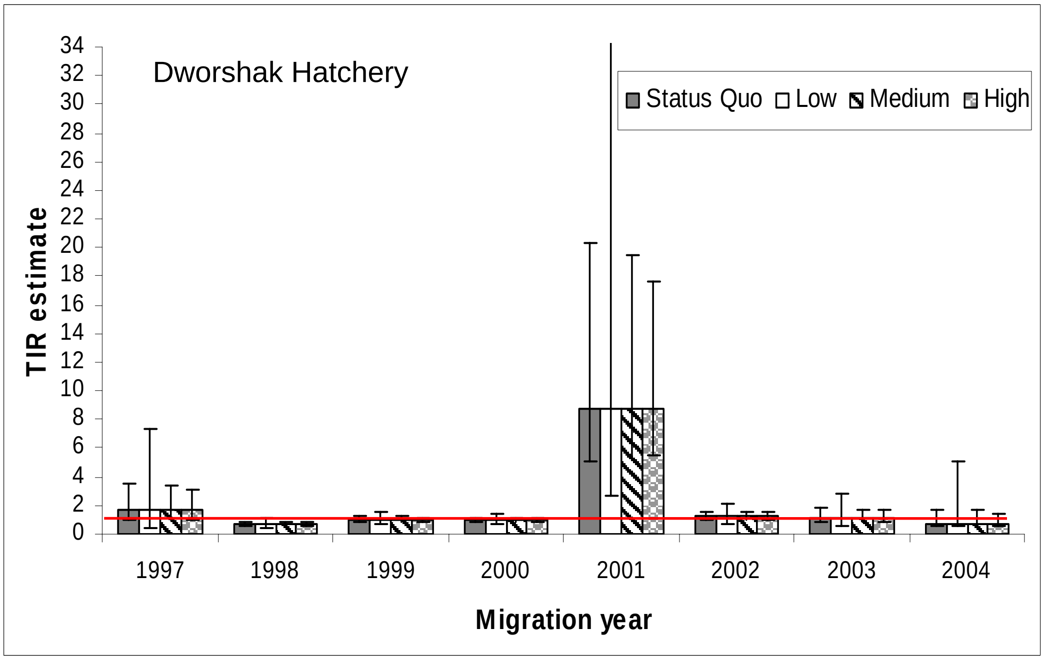

Figure 4.13. Estimated TIR for PIT-tagged hatchery chinook from the Dworshak facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

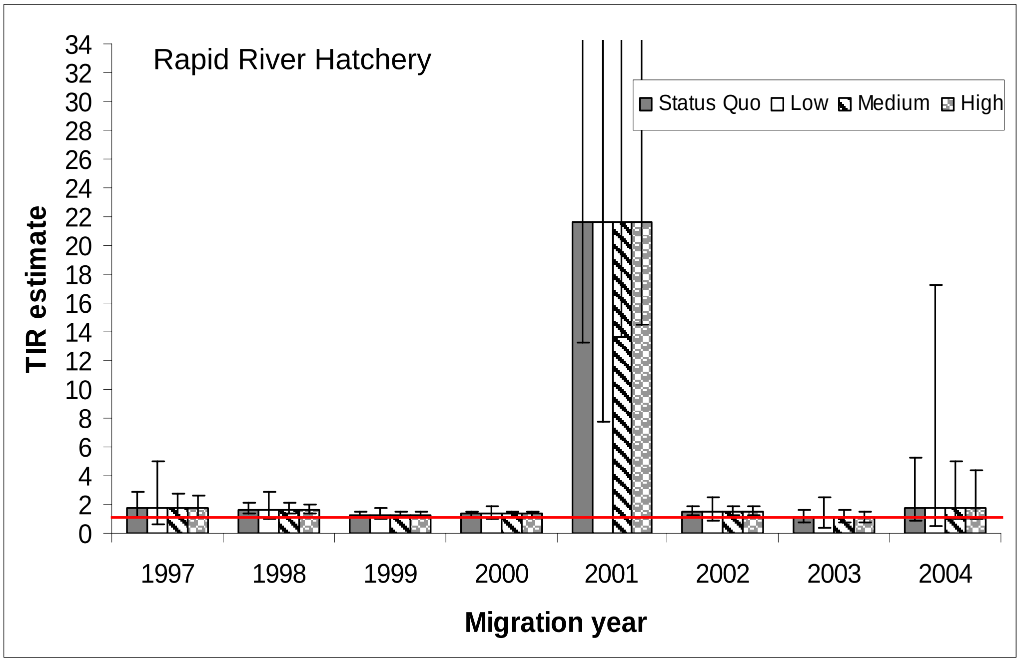

Figure 4.14. Estimated TIR for PIT-tagged hatchery chinook from the Rapid River facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

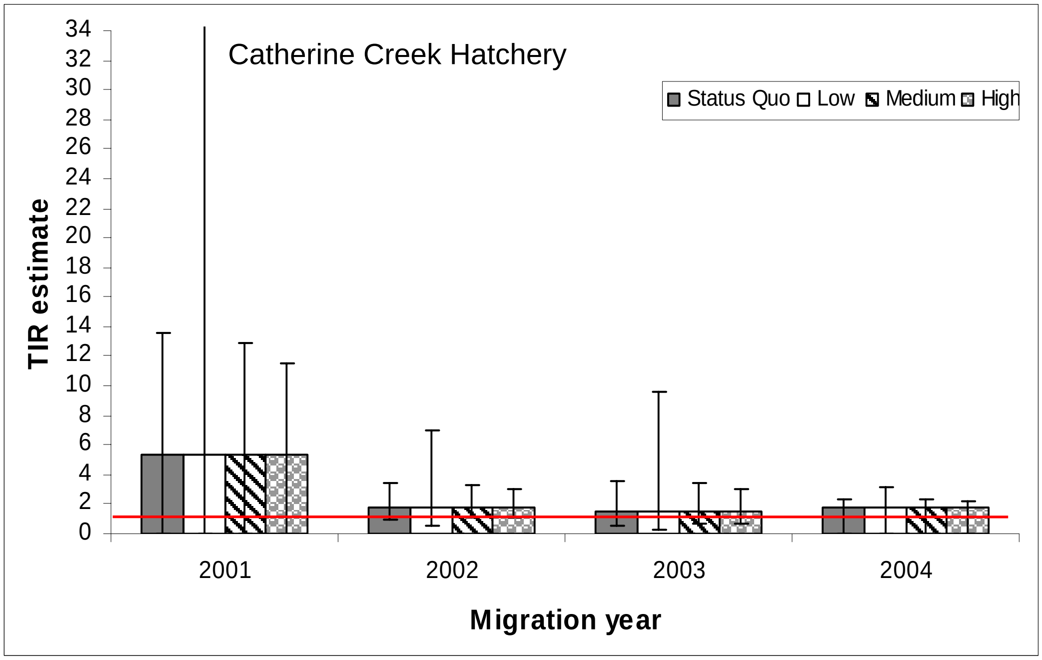

Figure 4.15. Estimated TIR for PIT-tagged hatchery chinook from the Catherine Creek facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

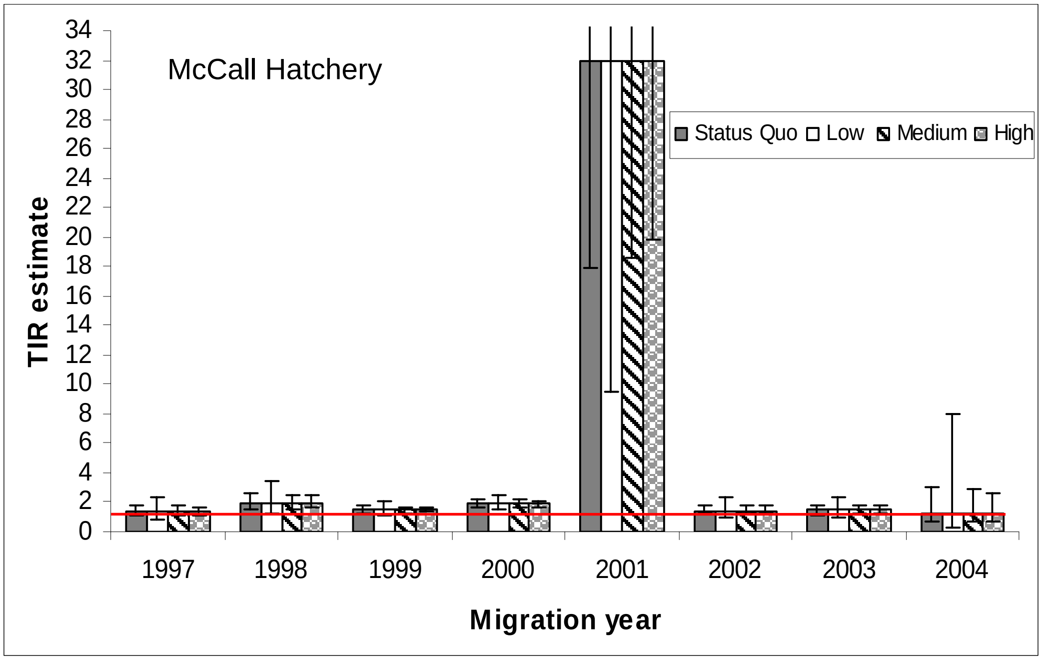

Figure 4.16. Estimated TIR for PIT-tagged hatchery chinook from the McCall facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

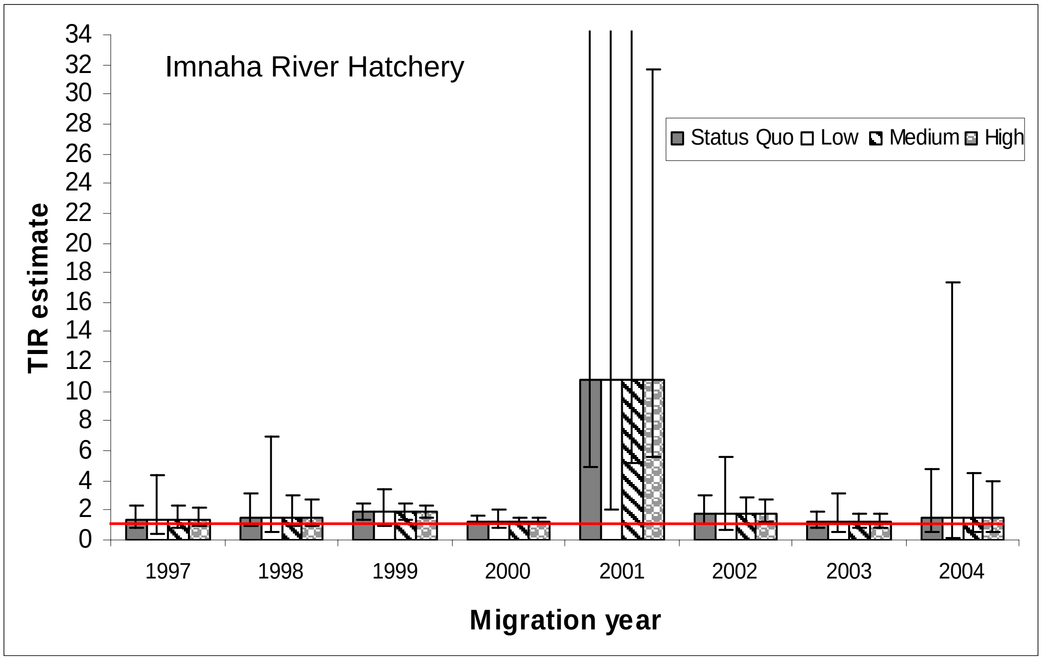

Figure 4.17. Estimated TIR for PIT-tagged hatchery chinook from the Imnaha River facility for migration years 1997 to 2004 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

Annual in river survival and management targets

Table 4.10. Estimated in-river survival from LGR to BON (S_R) of wild and hatchery PIT tagged chinook for 1994 to 2004 and 1997 to 2004, respectively (with 95% CIs). Estimates calculated using data collected under Status Quo. Modified from Schaller et al. 2007.

Year	Mean S_R Values		
	Wild	Hatchery	Combined
1998	0.59 (0.39-0.80)	0.69 (0.55-0.84)	0.66 (0.54-0.78)
1999	0.61 (0.48-0.73)	0.54 (0.48-0.60)	0.55 (0.50-0.61)
2000	0.48 (0.41-0.54)	0.42 (0.30-0.54)	0.45 (0.39-0.50)
2001	0.22 (0.18-0.26)	0.25 (0.22-0.28)	0.24 (0.22-0.26)
2002	0.58 (0.44-0.72)	0.53 (0.44-0.62)	0.55 (0.47-0.63)
2003	0.49 (0.44-0.55)	0.53 (0.43-0.63)	0.49 (0.44-0.54)
2004	0.37 (0.24-0.49)	0.43 (0.34-0.52)	0.42 (0.34-0.49)
2005	0.48 (0.29-0.67)	0.45 (0.39-0.50)	0.45 (0.40-0.50)
2006	0.42 (0.26-0.57)	0.62 (0.56-0.67)	0.61 (0.55-0.66)

Annual trends in S_R over the period 1998 to 2006, based on data collected under the Status Quo are presented in Table 4.10 and Figure 4.18. Using our example non-overlapping 90% CIs compliance criteria, compliance with the BiOp standard can be assessed in 2 of 9 years for wild chinook. With respect to hatchery chinook compliance can be determined in 4 of 9 years, and for hatchery and wild chinook combined compliance can be determined in 7 of 9 years.

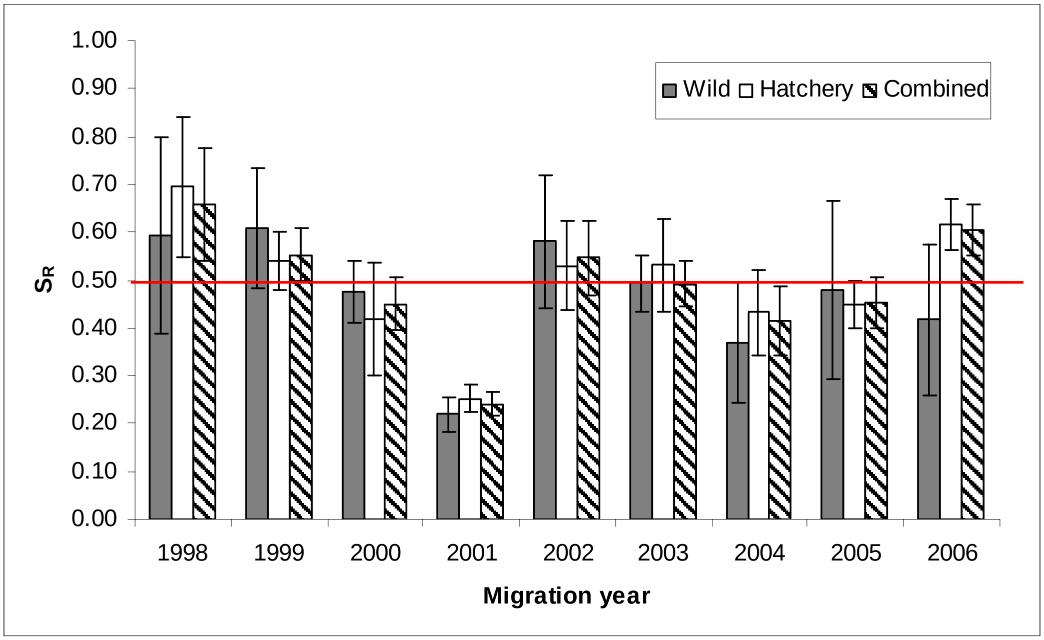

Figure 4.18. Trend in in-river survival (S_R) from LGR to BON for PIT tagged wild and hatchery spring / summer chinook in migration years 1998 to 2006. The horizontal dashed line represents the BiOp standard of 0.496 S_R. Error bars are 95% CIs.

The total number of in-river migrants does not vary substantially from the Status Quo for the alternative designs, with the exception of hatchery fish for the Low option (i.e., compliance can only be assessed in 2 of 9 years). Past work (Hinrichsen and Paulsen, unpublished manuscript; Chapter 3, Schaller et al. 2007) has not uncovered any systematic differences in in-river survival for hatchery and wild Chinook, and so we assume here that the two groups would be combined for any in-river survival analysis. Therefore, numbers on average are sufficiently close to the Status Quo that we do not expect substantial changes in the in-river survival sampling variance with any of the options. Only if numbers were to decrease dramatically would the sampling variance of annual estimates of in-river survival increase substantially.

Decreasing the sampling variance will require substantial increases in the number of tagged in-river migrants at LGR beyond any of the scenarios in Table 4.2. In general, the confidence bounds displayed in Figure 4.18 will decrease by $1/P$, where P is the factor by which sample size increases. For example, under Status Quo, roughly 70,000 in-river migrants leave LGR each year (43,000 hatchery and 27,000 wild). To halve the width of the confidence bounds, one would need to increase the sample size by a factor of 4, to about 280,000 tagged fish per year.

4.3.2 Results for supportive analyses

Simulation results for multiple-year estimates of SARS

Results from the simulations show that the relative width of the 95% CI on the multiple-year mean SAR declined with time for both mean SAR values examined (Figure 4.19). After 5 years of data, the width of the interval is close to the value of the mean of the distribution. After 20 years, the CI width has declined to about half this value (Figure 4.19). The CI's dependence on mean SAR is a consequence of the assumption of constant CV over different mean SARs. In addition, the width of the estimated interval was almost independent of the number of PIT-tagged fish (1000, 2500, 5000, and 10,000) used to estimate the value.

The estimated probability of the hypothesis that SAR is > 2.0%, when in fact the true SAR value is > 2.0%, increased with time and again was largely independent of the number of tagged fish used to estimate SARs (Figure 4.20). Because of the non-symmetrical distribution of probability estimates around the mean (since it's greater than 0.5), the median of the distribution of probability for both SAR values is greater than the means shown in Figure 4.20. This suggests that more than 50% of the time, we would expect the estimated probability to exceed the mean values shown for any of the time periods. Nevertheless, the results indicate that **the true average SAR will probably need to be close to 2.5% to be highly confident that true SAR is greater than 2.0 within 20 years**

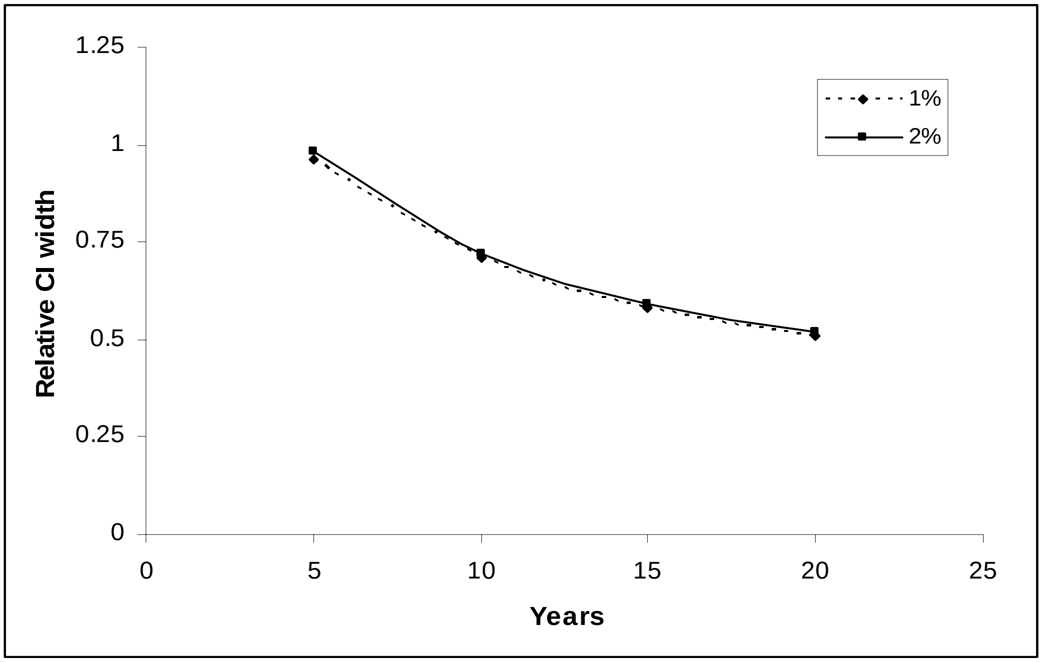

Figure 4.19. Relative width of 95% CI on SAR (CI width/mean SAR) for two values of estimated SAR (1 and 2%). A CV of 0.60 was assumed for environmental variance.

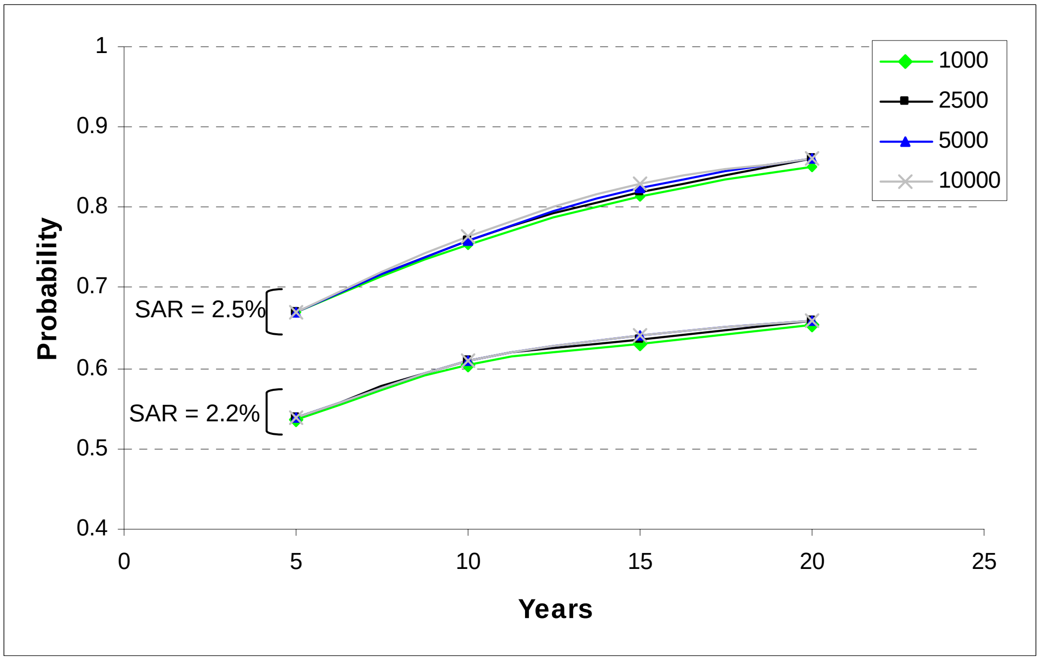

Figure 4.20. The expected (average) estimated probability (from beta distribution of mean of SAR) that the mean SAR is greater than 2.0% for two values of true SAR and for four values for annual PIT-tagged smolts. CV = 0.60 (from environmental variance).

The estimated mean 95% CIs of the geometric mean TIR are shown as a function of annual transport tag number and number of years monitored, for the simulation scenarios listed in Table 4.7 (see Figure 4.21. Modified from CSMEP 2006).

Simulations results suggest that increasing tag numbers leads to slightly narrowed TIR CIs for a given true TIR, but increasing the number of years has a much greater effect. In addition, comparing figures with the same TIR but different in-river SARs (e.g., Figure 4.21 – top two panels) for a given number of tagged smolts, suggests that a greater number of adult returns (i.e., higher SAR value) has the same effect on CI width as tagging more fish. The increase in precision about the mean TIR with increased number of tagged smolts in the two groups is likely due, at least in part, to the improvement in estimation of correlation coefficient between transport and in-river SARs.

These results also suggest that the absolute width of CIs is proportionally related to the underlying TIR, i.e., the greater the TIR, the greater the CI width. Overall, the relative benefit to TIR CIs of accumulating years is similar to that for SARs: at 20 years, the CI for a given annual number of tags is approximately half that at 5 years, for the same annual number of tags

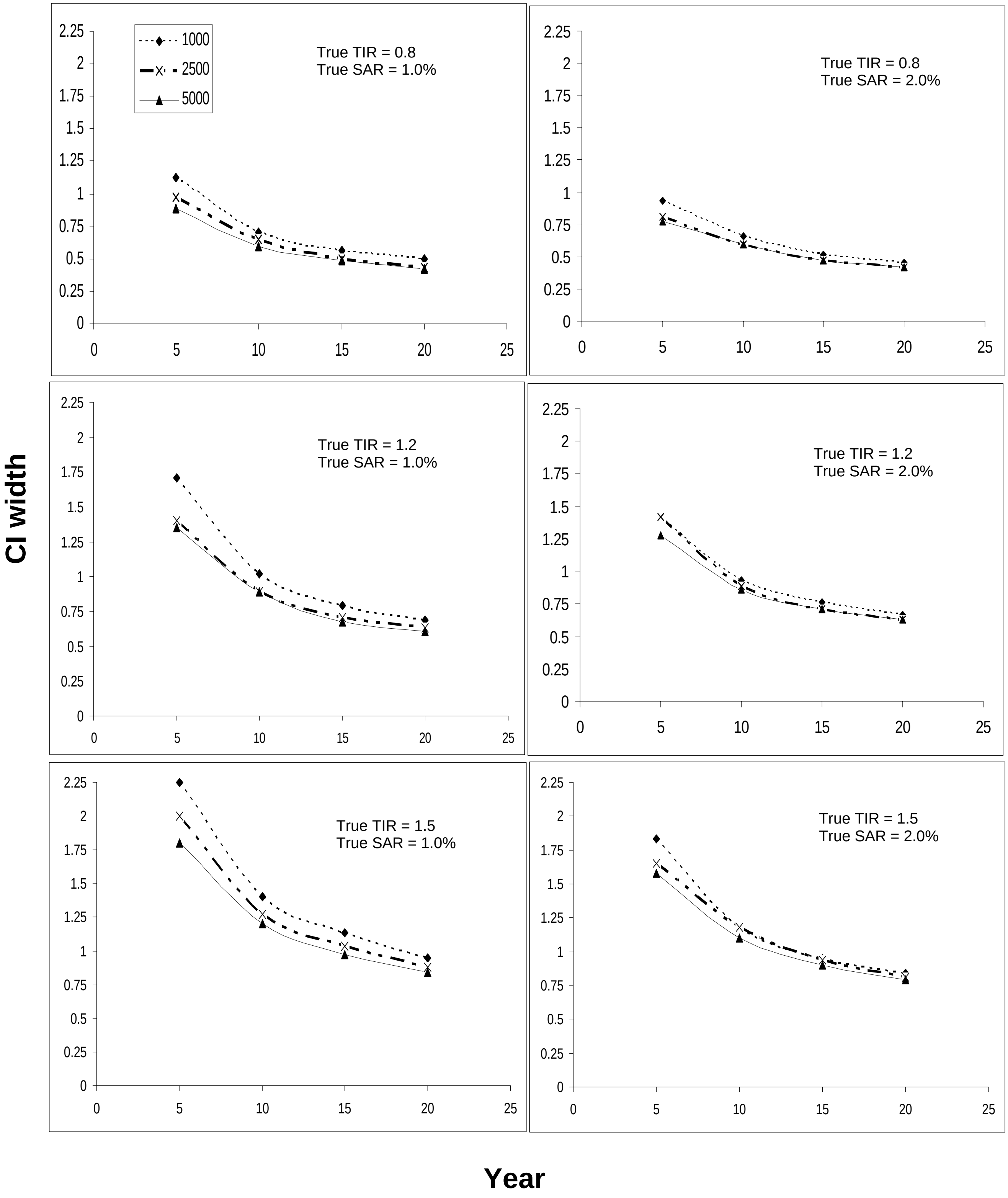

Figure 4.21. Average width of CI of geometric mean TIR for three levels of annual transport tags (100 simulations, 5000 replicates each). This is the actual CI width, not the relative width plotted in Figure 18. The ratio of number of in-river tags to transport tags = 1:1 for all scenarios.

Evaluation of TIR decision rules to estimates of TIR

The number of times where the correct decision is made regarding the estimated probability of TIR being greater 1 is tracked in five year intervals for a period of twenty years for each of the transportation decision rules (i.e., averse, tolerant, and neutral). The sensitivity of making a correct decision to various assumptions is explored for each of the scenarios in Table 4.7.

In general, our results suggest that accumulating more years of data leads to better decisions across decision rules and scenarios (for example see Figure 4.22. Modified from CSMEP 2006). However, if the initial decision rule chosen is the most appropriate one (e.g., for a true TIR of 0.8 the most appropriate rule is averse and for a true TIR of 1.5 the most appropriate rule is tolerant) the frequency of correct decisions increases to its maximum value more rapidly relative to using a less appropriate decision rule. Employing the inappropriate decision rule results in a less favorable outcome, where correct decisions are made less frequently. Interestingly, the wrong decision rule across all scenarios still yields correct decisions at least 50% of the time even after only five years. Under all scenarios, a neutral decision rule results in correct decisions being made at least 70% of the time after only five years.

Our results also suggest that greater annual numbers of tagged fish does not necessarily equate to a higher probability of making correct decision. In addition, the benefits in terms of increased correct decision frequency appear to be relatively small for scenarios where increased tags do yield increased correct decisions.

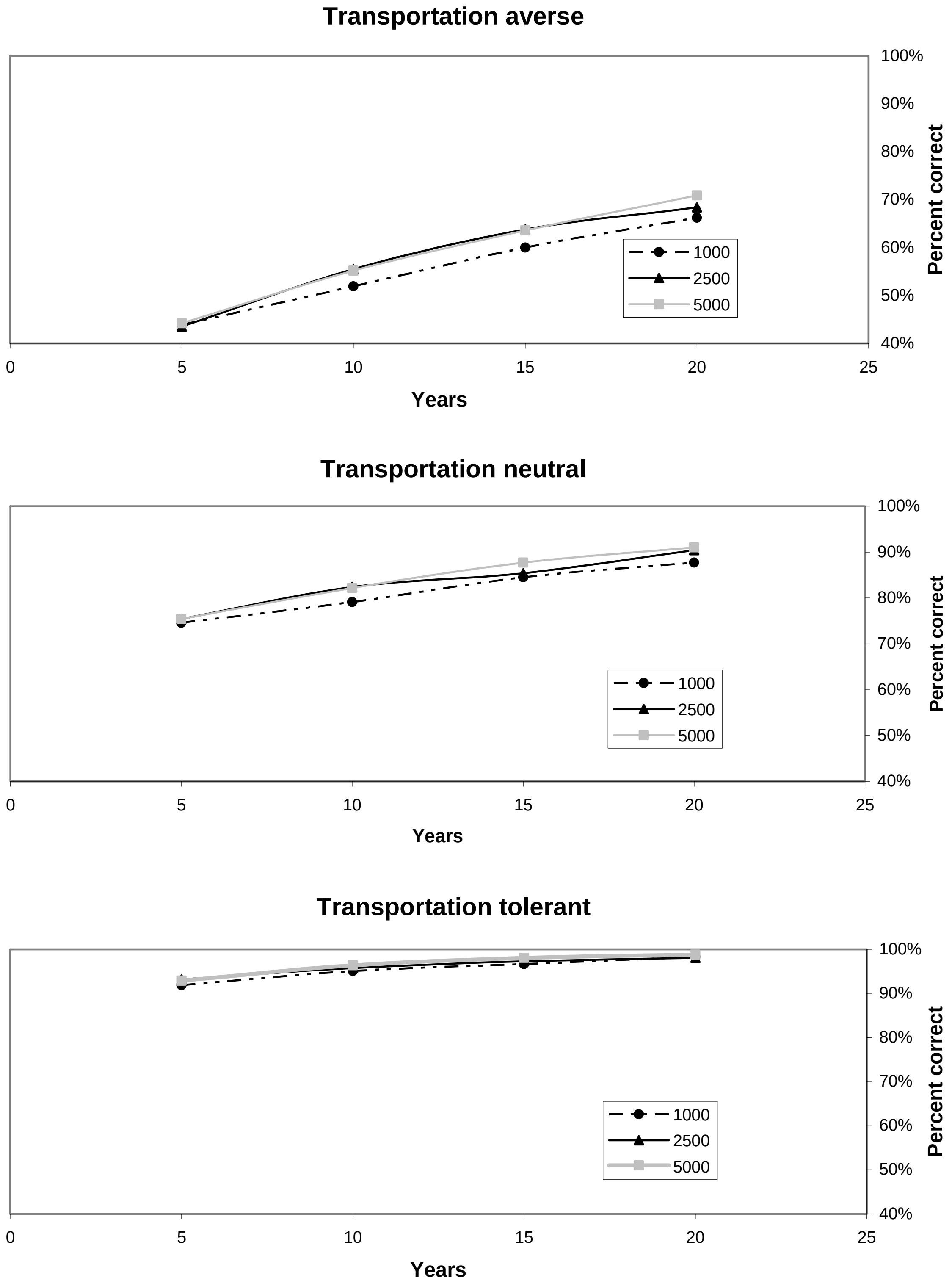

Figure 4.22. Frequency of correct decision about hypothesis that TIR > 1 for three decision rules, with three levels of annual transport tags. Runs 13-15: Mean in-river SAR = 2.0%; True expected TIR = 1.2; Ratio of number of in-river tags to transport tags = 1:1.

Within season variation in transportation of fish

TIRs can vary substantially over the season for both wild and hatchery chinook (Table 4.11). The quartile TIR estimates for wild chinook suggest that it is more beneficial to allow smolts to outmigrate in-river during the first half of the year (i.e., first and second quartile estimates are less than 1) and that transportation of smolts should begin during the latter half of the season (i.e., during quartiles 3 and 4 when TIR estimates greater than 1). However, with respect to hatchery chinook, quartile TIR estimates suggest that it is preferable to transport hatchery smolts year round rather than allow them to outmigrate in-river (i.e., TIR estimates are greater than 1 for all quartiles).

Table 4.11. Mean TIRs by quartiles for hatchery and wild spring/summer chinook during the period 1995 to 2004. Ninety-five percent CIs are shown in brackets

	Quartile			
	1	2	3	4
Wild chinook TIRs	0.53 (0.43 – 0.63)	0.78 (0.67 – 0.90)	1.10 (0.95 – 1.26)	1.83 (1.53 – 2.17)
Hatchery chinook TIRs	1.65 (1.51 – 1.79)	1.81 (1.68 – 1.95)	2.88 (2.69 – 3.10)	2.59 (2.41 – 2.78)

4.4 Discussion and recommendations

4.4.1 Determining compliance with SAR goals under different M & E designs

Over the period from 1994 to 2003, average SARs for wild spring/summer chinook have been well below the minimum 2% recommended in the NPCC Fish and Wildlife Program mainstem amendments (NPCC 2003). While this target is primarily for listed (i.e. wild) populations, we can also examine the performance of hatcheries against this same SAR goal. SARs for hatchery Snake River spring/summer chinook have shown similar patterns as wild Chinook during 1997-2004, although the actual survival rates have differed among hatcheries. Annual SAR_{Total} estimates for Dworshak and Catherine Creek hatcheries have not exceeded 2% in all years that the respective hatcheries have operated in the CSS study. Rapid River, McCall, and Imnaha hatcheries have faired marginally better with SAR_{Total} estimates above 2% SAR in 1, 3, and 2 of 8 years, respectively.

Determination of compliance with the 2% SAR level (with a high degree of confidence) does not appear to significantly improve under the Medium and High design alternatives relative to the Status Quo, for both wild and hatchery chinook. This result is a consequence of the annual SAR estimates being substantially less than the 2% SAR minimum, so much so that their upper 90% CIs generally fall well below 2% for the Status Quo. The benefit of a reduction in estimated uncertainty expected from an increase in tag numbers (i.e., narrower CIs on SAR estimates under Medium and High alternatives) is therefore not realized under the condition of very low SARs. However, when the value of the annual SAR estimate is such that its Status Quo CI straddle 2% SAR, moving to a High design would allow compliance to be determined with greater frequency because of the narrower CI (except when the estimated SAR is very close to 2%). The advantage of the High design is illustrated for wild chinook in years 1999 and 2001, where the CI overlaps 2% under Status Quo but not under the High design, thereby allowing compliance to be determined in the latter case (see Figure 4.4). Because the Low design proposes tagging the same number of wild fish as the Status Quo, the ability to determine compliance does not deteriorate under Low relative to the Status Quo because the CI width under the two remains the same. With respect to hatchery chinook, the Low design tags far fewer fish, resulting in wider CIs and thereby impeding the ability to determine compliance when the annual SAR estimate and respective CI are close to 2%.

Simulation results of annual SAR estimates and CIs under different tag number scenarios suggest that a longer time series, rather than increased annual tag numbers, is the primary driver behind narrowing CIs for long-term SAR mean values (Figure 4.19). This is likely because at the tagging rates simulated, sampling error is dwarfed by process error (true environmental variation) in SARs. However, true coverage of the underlying mean value of SAR of estimated confidence intervals is somewhat sensitive to tag numbers, with increasing annual number of tags improving coverage (up to 5000 tags, at least). On the other hand, the advantage of increased tag numbers is realized when examining SAR estimates for a single year (i.e., short-term SAR estimates), where for example annual compliance with 2% SAR cannot be assessed at a lower tag number (e.g., Status Quo) but can be determined at a higher tag number (e.g., High design). This raises the question of whether the increased precision in annual SAR estimates for a single year is worth the substantial additional cost of tagging more fish. Getting the best possible estimates of SAR in individual years (by marking large numbers of fish) is useful for other purposes (e.g., understanding which covariates affect SARs), but not necessary for estimating long-term mean values. The tradeoff between annual cost and the increased certainty in annual SAR estimates is one that managers need to be aware of and consider when making management decisions regarding short versus long-term recovery objectives for spring/summer chinook.

Taking multiple-year SAR estimates is an alternative method to decrease the uncertainty in SAR estimates. This particular method is valuable when it is not possible to increase tag numbers for budgeting or biological reasons (i.e., not enough funds or fish to tag). For multiple-year estimates, statistical precision improves up to the level of 5,000 PIT-tags annually, beyond this level there isn’t much benefit. However, using more years in multiple-year estimates can significantly improve precision and provide clearer answers. Comparing the CI interval width between the 5-year and 10-year estimates illustrates that uncertainty decreases with more years of information (Figure 4.5). Multiple-year estimates can provide insights on compliance with only a relatively small number of PIT-tags (e.g., 1,000 to 5,000 tags), which permits analyses on smaller spatial scales (e.g., MPGs, some large populations) and smaller temporal scales (in-season patterns). MPG and population-level SAR estimates can permit assessments of the extent to which improvements to spawning and rearing habitat (or supplementation actions) persist throughout the life cycle. This is one example of how PIT-tag data can be used to address hydro, habitat and hatchery questions.

4.4.2 Determining transportation effectiveness under different M &E designs

Due to the low number of adult returns, it is generally not possible to determine with a high degree of confidence whether in a given year transportation improved overall survival of wild spring/summer chinook, compared to leaving fish in-river. Over the period from 1994 to 2004, the TIR for wild spring/summer chinook was significantly greater than 1 only in 2001 (i.e., lower 90% CI > 1) and significantly less than 1 only in 2000 and 2002 (i.e., upper 90% CI < 1). Transportation appeared to provide little or no benefit to wild spring/summer chinook during the conditions experienced in most years from 1994 to 2004, except during the severe drought year 2001. The 10-year geometric mean (excluding 2001) TIR ratio was 0.99, while in 2001 the TIR was approximately 9-fold higher. This unweighted geometric mean does not take into account the magnitude of uncertainty of point estimates in the individual years. Unlike the case for SARs discussed above, multiple-year geometric means of TIRs have CIs which straddle the threshold of interest, making it difficult to determine conclusively that transportation was either beneficial or detrimental for spring/summer chinook.

In general, transportation provided benefits most years to Snake River hatchery spring/summer chinook from 1997 to 2004; however benefits varied among hatcheries. Omitting 2001 (when all TIRs exceeded 5), the 7-year geometric mean TIR was 1.08 at Dworshak, 1.46 at Rapid River, 1.50 at Imnaha and 1.54 at McCall hatcheries, indicating a higher transport benefit for the latter three hatcheries. Although based on a shorter time series, annual TIRs for Catherine Creek hatchery chinook have remained greater than one, with a geometric mean of 1.66.

The ability to definitively determine whether it is better to transport fish or allow them to migrate in-river is contingent on two things: 1) the degree of difference between the TIR estimate and the value of one (i.e., the closer the TIR estimate is to one, the harder it is to distinguish which is better); and 2) the width of the 90 percent CI on the TIR estimate, coupled with whether the CI straddles the value of one. For wild chinook the ability to assess which is preferable does not improve under the Medium or High designs relative to the Status Quo, nor does it deteriorate under the Low design. The reason for the lack of improvement under Medium and High designs in these instances is that the TIR estimates for wild chinook are generally quite close to one. Consequently, it is not possible to tell which is better using the example TIR evaluation criteria; even with the narrower confidence intervals experienced under the Medium and High designs. Under the Low design, the same number of wild fish are tagged as under the Status Quo, hence the reason the width of the CI interval remains the same to that of Status Quo.

With respect to hatchery chinook, the Medium design yields the same results across all hatcheries as the Status Quo for the similar reasons to those described for wild chinook TIRs. The High design on the other hand, improves the ability to ascertain the preferable down-river route relative to the Status Quo for both Imnaha and Dworshak hatchery chinook as a consequence of narrower CIs. An increased ability in the determination of preferable down river route is not realized for McCall, Rapid River, and Catherine Creek hatcheries for three reasons. First, with respect to McCall and Rapid River hatcheries, the number of years in which one can determine one transportation route to be preferable to the other is already quite high under Status Quo (i.e., little room for improvement). Second, it is not possible to distinguish which outmigration route is better for a couple of years because the TIR estimate is quite close to one, for both McCall and Rapid River. Last, with respect to Catherine Creek, substantial uncertainty in initial TIR estimates, as a result of fewer hatchery fish, has lead to wide CIs which straddle the value one under all design alternatives.

Under the Low design, the number of years in which it is possible to determine the beneficial mode of downriver movement for hatchery fished is roughly halved across all hatcheries relative to the Status Quo (Table 4.9). The deleterious consequence of tagging fewer fish, as proposed under the Low design, is felt quite strongly when trying to calculate reliable TIRs and makes it more difficult, if not impossible, to determine whether in-river or transported passage is preferential for hatchery chinook.

Simulation results of TIRs suggest that increasing annual tag numbers does result in narrowed CIs of long-term estimates of TIRs. The increase in precision about the TIR estimate is likely due, at least in part, to the improvement in estimation of the correlation coefficient between transport and in-river SARS due to more reliable point estimates of the SARs. Similar to simulation results for SARs, accumulating years (i.e., longer time series) also has the benefit of decreasing uncertainty in TIR estimates. Simulations of different transportation decision rules also suggest that increased tag numbers leads to a higher probability of making the correct decision in a shorter amount of time, even when using an inappropriate rule. However, simulation results show that in the long run improvements in decision making from increased tag number are minimal compared to improvements in decision making as a result of longer time series.

This raises similar questions to those posed regarding increasing tag numbers and associated costs to improve SAR estimates. Is the cost of increased tagging worth the improved inter-annual decision making ability with respect to transportation of fish? Again, this is something that managers need to be aware of and take into consideration when setting both short and long term objectives.

4.4.3 Determine whether in-river survival rates meet 2000 BiOp performance standards under different M & E designs

The FCRPS BiOp set a performance standard of 49.6 percent for smolt survival from LGR to BON dam. Status quo monitoring has PIT-tags on about 40,000 wild chinook, though numbers vary by year depending on the strength of the run. About 20 percent of the tagged wild chinook smolts die before they get to LGR, and only half of those which do get there are detected, leaving only about 16,000 tags for determining in-river survival for wild chinook.

During the period from 1998 to 2006, it is possible to determine whether the BiOp standard was complied with in 2 of 9 years for wild chinook. With respect to hatchery chinook, the BiOp standard was met in 4 of 9 years, and in 7 of 9 years for wild and hatchery spring/summer chinook combined. An improvement in the ability to detect compliance does not occur for any of the three groups. This is in part due to the S_R value in several years being quite close to the BiOp standard of 49.6 percent.

4.4.4 How does effectiveness of transportation change over the course of the season?

Hatchery chinook appear to benefit from transportation during all quartiles, whereas wild chinook appear to benefit from transportation during the latter two quartiles and not during the first two. Because it is not possible to only transport hatchery chinook during the first two quartiles and allow wild chinook to migrate in-river, the trade-offs around transportation of smolts during the first two quartiles should be evaluated. The relative value of a wild chinook to a hatchery chinook, coupled with the transportation benefits to the population as a whole and the cost of transporting fish will have to be taken into account by managers in the trade-off evaluation. Further, since effective separation of steelhead and chinook in the collection and transportation system hasn’t been achieved, the benefits to wild and hatchery steelhead of temporally-dependent transportation would need to be considered.

5. Habitat

5.1 Introduction

Habitat restoration actions designed to improve salmonid populations are considered a cornerstone of recovery strategies for Columbia River Basin fish stocks. However, there is a need to more clearly determine the effectiveness of these actions on salmonid survival rates and production. Monitoring programs designed for evaluating the effectiveness of habitat actions must be able to reliably detect two linked responses:

1. the effect of habitat actions on fish habitat; and
2. the effect of changes in fish habitat on fish populations.

CSMEP's Habitat Subgroup recognized serious challenges in developing a generic template for habitat effectiveness monitoring:

1. Habitat conditions vary greatly across subbasins. Examples of these differences can be expressed in terms of their natural biogeoclimatic regimes, the status of their fish populations, the degree of human impact and management, and the number and nature of restoration actions that have been implemented or are being considered for implementation within them.
2. Questions regarding the effectiveness of habitat improvement actions encompass different scales of inquiry, which imply different scales of monitoring.
3. Management objectives are often not clearly articulated and the results of habitat actions can therefore be difficult to quantitatively evaluate.[8]
4. The mechanistic linkages between habitat change and fish response are often poorly understood.

In the absence of explicit policy input, CSMEP's Habitat Subgroup endeavored to work beyond the development of a generic template design, and instead tried to provide decision-makers with practical examples of why particular types of information are so important for quantitative design and assessment. This compromise provides a way of moving beyond a general discussion of design considerations and avoids developing a generic design that provides a precise answer to the wrong question.

The Habitat Subgroup found that the Data Quality Objectives (DQO) process provided a good starting point for general framing of their monitoring strategy, but was too generalized for developing specific M&E habitat effectiveness designs. Instead, the Habitat Subgroup attempted to develop a consistent "Question Clarification" process that could be applied to create individual habitat-action effectiveness-monitoring designs, that took into account the unique situations found in particular subbasins or watersheds. Decision-makers can work their way through the "Question Clarification" process, provide the explicit information necessary to develop a monitoring question consistent with current policy, and guide a biologist / biometrician in the quantitative design of a monitoring program to address that question.

As part of a pilot evaluation to determine whether a feasible "Question Clarification" process could be developed, the Habitat Subgroup designed several alternative plans for monitoring the effectiveness of

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[8] For example many Habitat Conservation Plans (HCPs) lack specific biological criteria for success.

restoration actions in the lower Snake River Basin, specifically those prescribed within the Lemhi Habitat Conservation Plan (HCP) (see Figure 5.1 for location of Lemhi River within the Columbia Basin). Habitat actions planned for the Lemhi HCP are intended to restore and improve access to historical fish habitat areas within the watershed.

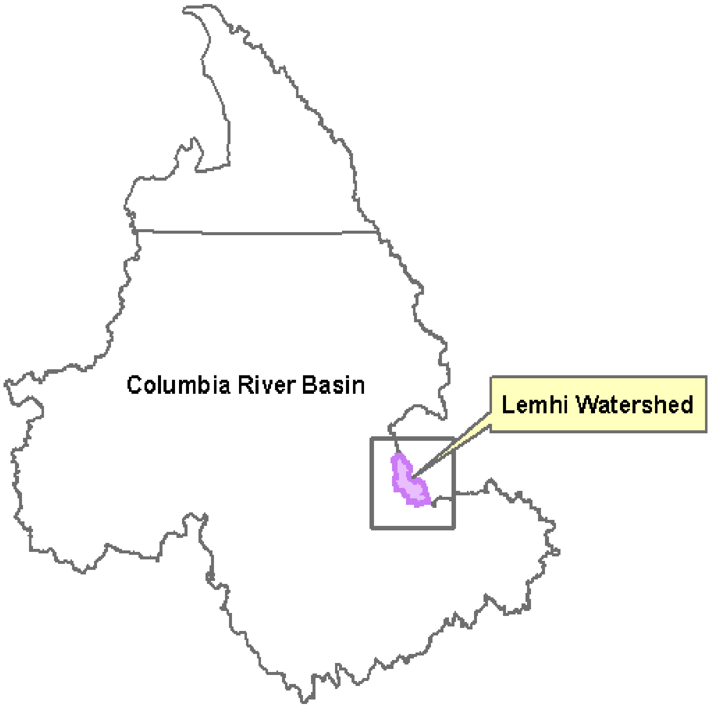

Figure 5.1. Location of Lemhi River watershed within the Columbia River Basin.

5.2 Data Quality Objectives (Habitat Effectiveness): Steps 1 to 5

Steps 1 to 5 of the DQO process undertaken by the CSMEP Habitat Subgroup described general policy needs and questions associated with habitat effectiveness monitoring in the Columbia River basin (Table 5.1) and the general components required for the quantitative design and evaluation of effectiveness monitoring programs (Marmorek et al. 2005). Table 5.2 provides a more detailed assessment of DQO steps 1to 5 that are considered specific to the Lemhi River watershed pilot area.

Table 5.1. Data quality objectives (DQO): Steps 1 through 5 as they pertain to general habitat effectiveness actions in the Snake River Basin.

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Habitat degradation and loss of connectivity are considered key factors in the decline of CRB anadromous and resident salmonid populations. Habitat improvement actions are considered a cornerstone of recovery strategies but there is a need to more clearly determine the effectiveness of these actions for increasing salmonid survival rates and production.	
Stakeholders:	States—Washington, Oregon, Idaho Tribes—NPT, SBT, CTUIR, CTWIR, YIN, CTCR Federal—NOAA, USFWS, BPA, USACOE Other—NPPC, CBFWA, conservation groups, Tribal, commercial, sport fishers, landowners & local soil conservation districts	
Non-technical Issues:	Lack of funding; Landowner Permission; Uncoordinated processes; Ill-defined scope and objectives; Jurisdictional overlap (e.g., state, tribal, federal, international boundaries, local regulations); Legal constraints and adjudication	
Conceptual Model:	Habitat actions will first increase the amount of usable habitat and/or improve habitat conditions. Improved conditions will lead to increased habitat use, improved fish condition, reach-scale abundance, and watershed scale fish survival and productivity. Thus the problem has three components: 1) detect the effect of habitat actions on habitat, 2) detect the effect of changes in habitat on fish populations, and 3) detect the overall effect of habitat actions on fish populations. The scale of effects of actions on habitat may vary, ranging from the local target action area up to the entire watershed. Effects of actions on fish populations could range from individual fish up to the larger population, the extent of which may be dependent upon the life history characteristics of individual species.	
2. Identify the Decision		
Principal Questions:	1. Have specific habitat improvement projects affected local habitat condition and local fish distribution, population survival, abundance or condition? 2. On aggregate, did clusters of habitat projects within a sub watershed or targeted at a specific subpopulation affect fish survival, abundance or condition in a larger demographic unit? 3. Are particular classes of habitat projects more effective or ineffective than others? 4. What are the mechanistic connections between habitat actions and fish population responses? 5. Have habitat projects achieved the expected improvements in habitat conditions or fish population responses?	✓
Alternative Actions:	Maintain the current program and designs of habitat actions Make adaptive management changes to the design of current habitat actions in order to improve the performance and increase the benefits to fish populations. Discontinue habitat actions as currently designed and adopt a different strategy for restoring fish populations	✓
Decision Statement:	Is the current program of habitat actions achieving the objectives for improving fish habitat and fish population performance measures so that program modifications, expansions or elimination are not required?	✓
3. Identify the Inputs		
Action Levels (critical effect sizes):	Quantitative performance standards need to be specified by which the results of future monitoring can be compared. At this time, there are few examples of such quantitative values available for the evaluation of habitat actions in the Columbia River basin. These performance standards will vary with the scale of the monitoring question (e.g., project level, subbasin, ESU). The minimum detectable effect at different scales will often not be known and may need to be hypothesized by analysts until verified by field data.	✓
Information Required:	Data/inventories of past, ongoing, and planned habitat restoration activities (and their hypothesized effects and sequencing) Data/Inventories of past, ongoing, and planned fish and habitat monitoring.	

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
Sources of Data:	State, tribal and federal programs and NGOs identified in CSMEP meta-data inventories (which may include information from the following sources: AA & NOAA habitat action inventories; IAC/SRFB; IDEQ; USFS (AREMP and PIBO); USFWS	
Quality of Existing Data:	Available data generally apply only to Snake River spring-summer Chinook, and only to actions affecting parr-to-smolt or parr-per-spawner life stages. Additionally, these data were collected through programs that were not designed to evaluate habitat project effectiveness. CSMEP data inventories found little information on programs that specifically collected data to assess the effectiveness of habitat actions in the Snake River (a situation likely common throughout the Columbia Basin)	
New Data Required:	New data and sampling approaches are required. There is a need for statistically valid sampling of both fish populations and habitat conditions. Better spawner and smolt enumeration may be necessary to detect changes in these metrics due to habitat actions. It appears feasible to obtain this in many locations in the Snake (but not everywhere).	
Analytical Methods:	B-A, or BACI designs, where differences between before and after treatment values of performance measures, may be compared to Action Levels using a t-test or confidence intervals. To account for important covariates and confounding factors, it may be necessary to apply more complex analytical models. Examples from recent work include linear regression models, non-linear neural networks, and multivariate models. However, because these applications are quite novel, with few published analyses completed to date, it is difficult to predict exactly what methods will be required, especially for detection of habitat action effects on fish survival and productivity.	
4. Define the Boundaries		
Target Populations:	Snake River spring and summer Chinook (current focus of Lemhi example) (with linkages to Upper Columbia summer Chinook due to lower river harvest) Redfish Lake sockeye Snake River steelhead Bull trout (also addressed in the Lemhi example)	
Spatial Boundaries (study):	Watersheds within the lower Snake River ESU (Lemhi subbasin as focal example)	
Temporal Boundaries (study):	Monitoring duration: Until actions shown to be effective or not Update schedule: example - beginning in year X at 3, 5, 7, 12, and 15 year intervals, and each 4 year period subsequent Time scale over which the data vary: 3-12 years	
Practical Constraints:	Funding Access to sample site, project locations, or data. Statistical constraints such as feasibility of acquiring required data	
Spatial Boundaries (decisions):	Watersheds/ESUs within the lower Snake River	
Temporal Boundaries (decisions):	Federal Recovery Plan is scheduled to be completed in April 2006 Adaptive Management schedule (plan check-ins are recurring intervals) 2004 FCRPS BiOp is a 15 (?) year plan with milestone and check-in State Recovery Plans have 25 year planning cycle Subbasin Plans have 15 year planning cycle HCP is a 30 year plan	

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
5. Decision Rules		
Critical Components and Population Parameters:	1) Changes in habitat quantity 2) Changes in habitat conditions (quality) 3) Change in smolts per spawner resulting from habitat actions 4) Changes in parr-to-smolt survival rates from actions	✓
Critical Action Levels (Effect Sizes): - these need to be clearly defined	1) Changes in habitat quantity - X% increase 2) Changes in habitat conditions – X% goes from poor to good? 3) Change in smolts per spawner must be at least X%? 4) Changes in parr-to-smolt survival rates must be at least X%?	✓
If-Then Decision Rules:	If the observed change in the critical population components between treatment (project) locations and control areas before and after the implementation of the project is positive, and greater than or equal to the critical action level, then do more of these project types in similar locations. If an effect is not detected, then the process moves through the adaptive management sequence to assess whether the monitoring and evaluation program was sufficient to be able to detect such a change, or whether the management action, or Action Level criteria need to be changed.	✓
Consequences of Decision Errors:	May continue/expand actions that have little beneficial effect (Type I error); May discontinue actions that really do work (Type II error); Undue or increased cost; Continued loss of fisheries; Negative impacts to state and local economies; Federal trust responsibilities not met; Adjudicated requirements not met	✓

[1] Policy Inputs - indicates with a check steps where group needs greater policy level feedback, presentation will elaborate on what feedback is required

Table 5.2. Data quality objectives (DQO): Steps 1 through 5 as they pertain to specific habitat effectiveness actions within the Lemhi River watershed.

DQO STEPS	LEMHI BASIN EXAMPLE	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	The Lemhi River in east-central Idaho has experienced extensive agriculture and grazing, with many irrigation diversions and returns of irrigated water resulting in increased temperatures and sedimentation. During the irrigation season, fish passage in the lower river is difficult and the channel has become de-watered in dry years. There has been channelization in the lower river, resulting in habitat homogenization. A Lemhi Habitat Conservation Plan (HCP) is being formalized to address ESA issues in the watershed until 2035. The goal of the HCP is "…to provide within-basin habitat conditions in the Lemhi River basin necessary to produce fish in numbers adequate to sustain or increase their populations". In practical terms, the HCP goal is to meet Viable Salmonid Population (VSP) criteria for abundance, productivity, spatial structure and diversity.	
Stakeholders:	IDFG, Shoshone Bannock Tribes, Local landowners, Office of Species Conservation, Upper Salmon Basin Watershed Project, NOAA Fisheries, USFWS	
Non-technical Issues:	Landowner relationships, lack of funding, interagency coordination	
Conceptual Model:	The underlying assumption of the HCP is that as habitat conditions are improved, fish populations will respond and desired biological effects will be achieved. The conservation objectives are 1) to provide adequate flow to remove or reduce migration barriers, 2) maintain or enhance riparian conditions, and 3) improve instream conditions with respect to cover, temperature, flow, and sedimentation. The desired actions are: 1) reconnect tributaries to the Lemhi River, 2) alter channel morphology to address fish passage, 3) minimize fish entrainment in bypass diversions, 4) enhance spawning and rearing habitat, 5) maintain minimum flows, 6) improve riparian corridors, 7) mimic the natural hydrograph. Some are these actions will be site-specific, while others will address the entire Lemhi watershed.	
2. Identify the Decision		
Principal Questions	Have the actions implemented under the Lemhi HCP: • Expanded the distribution of rearing juvenile salmonids? • Increased the density of juvenile salmonids rearing in the system? • Increased parr-smolt survival of juvenile Chinook in the Lemhi? • Increased the number of Chinook smolts leaving the Lemhi River? • Caused any changes in seasonal migration pulses and size distribution of Chinook smolts leaving the Lemhi River? • Increased abundance of bull trout in reconnected tributaries? • Increased escapement of adult Chinook salmon to the Lemhi basin?	✓
Alternative Actions:	Maintain current Lemhi HCP program of habitat actions Make adaptive management changes to design of current habitat actions to improve performance of HCP habitat actions and increase benefits to fish populations. Discontinue plans for HCP habitat actions as currently designed and adopt a different strategy for restoring fish populations	✓
Decision Statement:	Is the current program of habitat actions achieving the objectives for improved fish habitat and fish population performance measures so that program modifications, reductions/expansions, or elimination are not required?	✓

DQO STEPS	LEMHI BASIN EXAMPLE	Policy Inputs[1] (✓)
3. Identify the Inputs		
Information Required:	*Habitat Performance Measures:* 1. Temperature – reconnect tributaries to provide cold-water refugia during summer months 2. Flow – increased ease of passage & survival of adults & juveniles 3. Substrate & channel characteristics – increase amount of optimal spawning/rearing habitat *Fish Performance Measures:* 1. Spatial distribution (Chinook parr, steelhead parr/smolts, all bull trout) 2. Parr density (Chinook) 3. Smolts per redd (Chinook) 4. Migratory timing & size (Chinook) 5. Population abundance (bull trout) 6. Parr-to-smolt survival (Chinook) 7. Redd counts (Chinook) – to account for effect of seeding level and changes in spawning distribution. 8. Spawning adults (Chinook) – weir counts, to account for effect of seeding level	
Sources of Data:	IDFG Chinook redd counts, IDFG snorkel surveys, IDFG juvenile screw traps, IDFG tributary surveys (bull trout redd counts, electrofishing surveys, tissue sampling), IDFG PIT tag detectors at diversion bypasses in Lower Lemhi, Idaho State University telemetry tracking of bull trout in upper Lemhi and Hayden Creek, IDWR flow and temperature gauges at several sites, USGS flow gauges, flow modeling by BoR and University of Idaho, IDEQ FLIR flight of Lemhi mainstem, IDFG water temperature monitoring at remote sites in mainstem and tributaries, baseline instream and riparian habitat inventory (1994) by multi-agency group, PIBO reach inventories.	
Quality of Existing Data:	Long time-series of consistent, single-pass Chinook redd counts Datasets consist of information on (mostly) native fish (no hatcheries on Lemhi) Estimates of outmigrating juveniles available from traps	
New Data Required:	Adult weir is needed on Big Timber Creek tributary to evaluate movements of fluvial trout Expanded telemetry tracking of trout in Upper Lemhi Increase in the number and frequency of parr density surveys Systematic steelhead abundance estimates More information in general is required for other areas of the Lemhi watershed, particularly Hayden Creek and the lower mainstem	
Analytical Methods:	B-A, or BACI designs, where differences between before and after treatment values of performance measures may be compared to Action Levels using a t-test and confidence intervals. To account for important covariates and confounding factors, it may be necessary to apply more complex analytical models. Preliminary designs divide the Lemhi into three Sections: • Section A – mainstem Lemhi and tribs below Hayden Creek. Tentatively an additional control area. • Section B – mainstem Lemhi and tribs above Hayden Creek. Tentatively the Treatment area. • Section C – Hayden Creek and tribs. Tentatively the Control area.	

DQO STEPS	LEMHI BASIN EXAMPLE	Policy Inputs[1] (✓)
4. Define the Boundaries		
Target Populations:	Spring/Summer Chinook Bull Trout	
Spatial and Temporal Boundaries (study):	The sampling design (where, when, and for how long the protocols are activated) is dependent on the spatial contrast and protocol of interest. For example, if a snorkeling protocol were implemented to address the effects of channel reconnection in the Lemhi watershed, randomly selected sites could be snorkeled in treatment and control areas of the Lemhi inter- and intra-annually for a period of 20 years. Five-year check-ins could be included for progress evaluation. Alternatively, if a snorkeling protocol were implemented to address the effects of channel reconnection in tributary/mainstem junctions, snorkeling would occur at fixed and random sites only within the treatment areas on an inter- and intra-annual basis for a period of 20 years. For either question, sampling intensity (number and size of the sample units) will be determined based on desired statistical attributes (accuracy, precision, and power)	
Practical Constraints:	Funding Access to sample sites, project locations, or data. Statistical constraints such as feasibility of acquiring required data Inherent variability of the Lemhi system	
Spatial Boundaries (decisions):	Lemhi Basin	
Temporal Boundaries (decisions):	Habitat Conservation Plan (HCP) for Lemhi Basin is 30 years duration	
5. Decision Rules		
Critical Components and Population Parameters (key examples):	Have the actions implemented under the Lemhi HCP **expanded the distribution** of rearing juvenile salmonids within the basin and **increased the density** of rearing juvenile salmonids relative to average mainstem densities by X% over 30 years (with some precision) when the number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for? Have the actions implemented under the Lemhi HCP produced at least a 100% **increase in the number** of juvenile **spring Chinook** salmon leaving the Lemhi River in 30 years (+/- X%) when the number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for? Have the relative **magnitudes of the seasonal migration pulses** and **size distribution** of migrating **Chinook juveniles** leaving the Lemhi River **changed** over the life of the Lemhi HCP? Have the actions implemented under the Lemhi HCP **increased the abundance of bull trout** in reconnected tributaries relative to unconnected tributaries by X% over 30 years (with some precision)? Have the actions implemented under the Lemhi HCP **increased parr-smolt survival** (X% +/-specified precision) of juvenile **spring Chinook** salmon leaving the Lemhi River in 30 years when the number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for? Have the **returns of adult Chinook salmon to the Lemhi basin increased** X% (+/-specified precision, see VSP criteria developed by ICTRT) of the life of the Lemhi HCP?	✓
Critical Effect Sizes:	These threshold levels have not been defined for the Lemhi HCP	✓
If –Then Decision Statements:	These statements have not yet been defined for the Lemhi HCP (i.e., what would be the appropriate response if the actions do/do not result in expected improvements in habitat/fish performance measures)	✓
Consequences of Decision Errors:	• May continue/expand actions that have little beneficial effect (Type I error); • May discontinue actions that really do work (Type II error); • Undue or increased cost	✓

After completing DQO steps 1 to 5, CSMEP's Habitat Subgroup moved beyond general policy description towards quantitative designs.

5.3 Methods

The Habitat Subgroup selected the Lemhi River Habitat Conservation Plan (HCP) as a real world example for testing and demonstrating their "Question Clarification" process. This required first developing a set of questions designed to allow biologists/biometricians to both inform decision-makers about the quantitative needs for monitoring design and to help extract this information from them. While these questions address the same information needs touched upon in Steps 1 to 5 of the DQO, they also address a general concern of the design group that the DQO template is not clear enough about why this information is required, or the implications for the design process when it is not provided.

5.3.1 Lemhi River Habitat Conservation Plan (HCP)

A Habitat Conservation Plan (HCP) is being prepared jointly by IDFG, NOAA and USFWS that addresses Endangered Species Act (ESA) issues in the Lemhi River watershed; an overview is presented in Appendix 5. The duration of the Lemhi HCP is 30 years, during which time a number of water conservation projects will be implemented. The main projects will be a series of approximately 10 to 16 actions to reconnect isolated tributaries to the mainstem Lemhi River. The channel reconnections will occur in phases staggered over the duration of the HCP. The reconnection of these tributaries and the reestablishment of the historical hydrograph (in terms of timing, not quantity of water) while ensuring minimum flows is expected to provide access to historical habitat for Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and bull trout (*Salvelinus confluentus*).

The Lemhi River watershed has three distinct sections (Figure 5.2):

A. Section A – The lower main stem Lemhi is primarily utilized as migration corridor with very little high quality spawning and rearing habitat. Much of this reach has been straightened and channelized, which has increased gradient and created long stretches of shallow water. It is still a valley stream, but there is no known Chinook spawning in this section. Tributary reconnections are being contemplated for this reach with a focus on fish passage.

B. Section B – The upper main stem Lemhi is where the majority of channel reconnections will occur with the focus on spawning and rearing conditions.

C. Section C – Hayden Creek is a large tributary of the Lemhi that will not be directly affected by channel reconnection, thus potentially serving as a reference system for activities occurring in Section B.

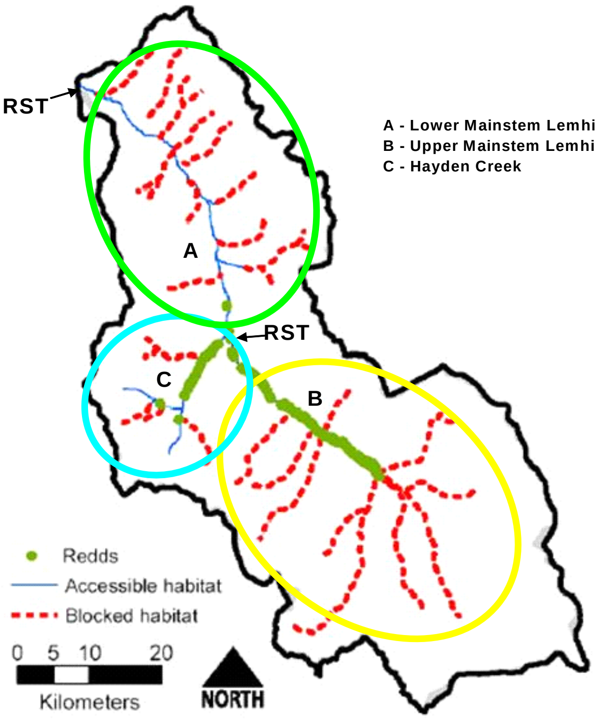

Figure 5.2. Map of the Lemhi River watershed denoting Sections A (migration corridor), B (action area), and C (potential reference area). RST indicates the approximate location of existing rotary screw traps.

5.3.2 Priority questions and the question clarification process

The CSMEP's Habitat Subgroup identified a number of priority M&E questions for the Lemhi HCP. Have reconnection projects:

1. increased the distribution and density of Chinook juveniles?
2. increased number and size of juvenile Chinook outmigrants?
3. changed timing of Chinook outmigration?
4. increased Chinook parr-smolt survival?
5. increased Chinook adult returns?
6. increased distribution and abundance of bull trout?
7. improved bull trout survival?

As these initial questions were considered far too generic to adequately address the specific responses to tributary reconnections, the Habitat Subgroup created a series of nested sub-questions that could further clarify the information needs. Although intended for policy makers, the Habitat Subgroup applied this "Question Clarification" process to their interpretation of the intent of the LCP. This process produced a suite of clarified questions (Table 5.3) for the Lemhi HCP around which the Habitat subgroup could develop their designs.

Table 5.3. Clarified management questions for the Lemhi HCP as developed by CSMEP's Habitat effectiveness design subgroup.

Lemhi HCP Clarified Question
Chinook Juvenile Density and Distribution:
1a. Have the actions implemented under the Lemhi HCP expanded the distribution of rearing juvenile salmonids within the basin and increased the density of rearing juvenile salmonids relative to average mainstem densities by X% over 30 years (with some precision) after number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for?
1b and 1c are more explicit variations on 1a:
1b. Have the tributary reconnection projects expanded the distribution of rearing juvenile salmonids and increased the density of rearing juvenile salmonids in the Lemhi watershed of the Salmon River relative to average mainstem densities by X% over 30 years (with some precision) after number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for?
1c. Have the tributary reconnection projects expanded the distribution of rearing juvenile salmonids and increased the density of rearing juvenile salmonids in the tributary mainstem junctions of the Lemhi watershed of the Salmon River relative to average mainstem densities by X% over 30 years (with some precision) after the number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for?
Chinook Juvenile Production:
2. Have the actions implemented under the Lemhi HCP produced at least a X% increase (e.g. 100%) in the number juvenile spring Chinook salmon leaving the Lemhi River in 30 years (+/- X%) after number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for?
Chinook Migration timing:
3. Have relative magnitudes of seasonal migration pulses and size distribution of migrating Chinook juveniles leaving the Lemhi River changed over the life of the Lemhi HCP?
Chinook Juvenile survival:
4. Have the actions implemented under the Lemhi HCP increased parr-smolt survival (X% +/-specified precision) of juvenile spring Chinook salmon leaving the Lemhi River in 30 years after number of spawners, natural disturbances, climate indicators, and habitat conditions not-impacted by the actions have been accounted for?
Chinook Adult returns:
5. Have the returns of adult Chinook salmon to the Lemhi basin increased X% (+/-specified precision, see VSP criteria developed by ICTRT) over the life of the Lemhi HCP?
Bull trout abundance:
6. Have the actions implemented under the Lemhi HCP increased the distribution & abundance of reproductive adults in the reconnected tributaries when confounding factors, including presence of non-native brook trout (*Salvelinus fontinalis*), natural disturbances, habitat conditions (i.e., complexity), and climate indicators been accounted for?
Bull trout survival:
7. Have the actions implemented under the Lemhi HCP increased the survival of juvenile and adult bull trout exhibiting fluvial life-history expression when confounding factors, including presence of non-native brook trout (*Salvelinus fontinalis*), natural disturbances, habitat conditions (i.e., complexity), and climate indicators been accounted for?

5.3.3 Performance measures

Several performance measures were identified for addressing the fish performance questions in Table 5.3.

Fish population performance measures:

1. Spatial distribution (Chinook parr, steelhead parr/smolts, all bull trout)
2. Parr density (Chinook)
3. Smolts per redd (Chinook)
4. Migratory timing & size (Chinook)
5. Population abundance (bull trout)
6. Parr-to-smolt survival (Chinook)
7. Redd counts (Chinook) – This performance measure and the number of spawners (8) are also used as covariates to account for changes in parr density and distribution, smolt size and abundance, egg to parr survival, parr to smolt survival, and spawner distribution that may occur from density dependent interactions.
8. Spawning adults (Chinook)

Fish habitat performance measures:

The focus of CSMEP is on developing fish monitoring programs and therefore does not describe what and how habitat information will be collected. Other collaborative groups such as PNAMP are focusing on how habitat information might be monitored and collected. This document only provides a short description of the type of information that may be useful to collect.

Three types of habitat performance measures of fundamental importance for evaluating Lemhi River channel reconnection actions have been identified. They are:

1. temperature – creation of cold-water refugia in reconnected tributaries & adjacent main stem during summer months;
2. flow – increased ease of passage & survival of adults & juveniles; and
3. substrate & channel characteristics – increase in the amount of optimal spawning/rearing habitat.

These are only a subset of the following longer list:

> ***Basin/subbasin landscape and land use patterns:*** This information may include variables such as: soil and geology types, precipitation, hydrology, stream temperatures, air temperatures, climatic factors (longer term), fire (size, frequency and intensity), landslides, flood events, land-use activities (e.g. mining, timber harvest, grazing, etc.), ownership boundaries, road density, water use (points of use and return), diversions and barriers, culverts, and agricultural and urban development. These potentially important factors may be collected directly at this large scale (remote sensing), or collected on-site at smaller scales and summarized or aggregated to the appropriate sub-basin or basin scale.

Reach scale information: Reach scale habitat and land use information may include:

- Mesohabitat: physical dimensions and instream habitat characteristics (e.g., gradient, depth and area of pools, riffles, structure and substrate),
- Channel type, valley type, springs,
- Riparian characteristics (e.g. vegetation type and extent, density, canopy cover),
- Water quality parameters such as temperature and dissolved oxygen,
- Primary and secondary production,
- Water use (points of use and return), diversions and barriers, culverts, grazing, and pollutants.

The number of different types of habitat information collected during monitoring will depend on the intensity of the monitoring design selected.

Explanatory variables

Not all monitored variables need to be direct measures of response to habitat actions. In some cases they will serve an “explanatory” purpose. Such explanatory variables can be used to reduce the variability of the effects of the actions and/or enable us to infer whether a failure to detect changes in parr distribution and abundance can be attributed to a specific cause. As an example, a failure to detect any increase in parr density within a reconnected tributary could be related to water temperatures within the reconnected habitat that are not conducive to spawning or rearing. The temperature information is unnecessary to determine the direct effectiveness of the project (a failure for this example); however the explanatory variable enables us to determine the cause of the failure. This enables project sponsors to either choose more appropriate candidates for future reconnection projects, or implement additional actions within reconnected channels to address the newly identified limiting factor. Thus, establishing mechanistic, causal links between habitat actions and fish population responses will be important for the adaptive management of the Lemhi HCP.

Data collected to address particular performance measures can also serve as data to inform explanatory variables. For example, parr density information will be collected to address the parr distribution and abundance question, while an estimate of egg-to-parr or parr-to-smolt survival may be used as an explanatory variable to understand why parr distribution or abundance might not have increased following channel reconnection actions.

5.3.4 Spatial and temporal contrasts

Designing a monitoring strategy that incorporates spatial and temporal contrasts into data collection and analysis can strengthen inferences about the effectiveness of habitat actions. Their importance, however, will depend on the question that the monitoring program is being designed to address. For example, determining the effects of channel reconnections within the affected areas of the Lemhi River would require that measures of parr density and distribution be collected solely within Section B of the watershed (see Figure 5.2). Alternatively, determining the effects of channel reconnection on the Lemhi River watershed as a whole would require that data be collected also within Sections A and C.

Ideally, a time-series of comparable information from pre- and post-implementation of the Lemhi HCP would be available on the above performance measures and potential explanatory variables from watershed Sections A, B, and C to determine if the HCP achieved its goals. If so, Before-After-Control-Impact (BACI) (e.g. Stewart-Oaten et al. 1986) or Randomized Intervention Analysis (RIA) designs

(Carpenter et al. 1989) could be used to evaluate this information. BACI and RIA designs are similar, but BACI analyses must conform to the assumptions for parametric statistics. One advantage of these designs is the use of a control, which for the Lemhi River watershed would be Hayden Creek (Section C), where tributary reconnections will not occur. Because of the geographic proximity of Section C to Sections A and B, these sections are likely to have similar climatic experiences and habitat characteristics (e.g., geology and vegetation). In addition, similar sampling protocols can likely be undertaken in all these sections.

5.3.5 Sampling and response designs

The ***sampling*** design (where, when, and for how long monitoring takes place) selected will depend both on the spatial contrast of interest and the desired level of precision in results. For each of the M&E questions, the sampling intensity (number and size of sample units) should be determined based on desired statistical attributes (accuracy, precision, and power) relative to the size of the effect that is important to detect.

The ***response*** design (what and how data are collected) determines which sampling protocols will be used. For the selection of a response design it will be necessary to explore how different performance measures and potential data collection methods vary in accuracy and precision, spatial and temporal resolution, and cost. Sampling protocols may also serve multiple functions. For example, if electrofishing has been selected as the protocol for sampling parr density and spatial distribution, then using electrofishing to address explanatory variable needs (e.g., parr-to-smolt survival) would increase sampling efficiencies while also maintaining the same sampling biases.

5.3.6 Data needs

There are several sources of data available for the Lemhi River watershed that could be used to frame sampling and response designs for the Lemhi monitoring questions. CSMEP's Habitat Subgroup gathered data on past Lemhi habitat actions (Figure 5.3), as well as existing fish monitoring sites. Existing monitoring for the Lemhi River includes adult weirs, screw traps, redd count areas, parr density sites, and parr-to-smolt survival estimates (Figure 5.4). Additional information detailing current monitoring programs in the Lemhi River watershed is provided in Appendix 5.

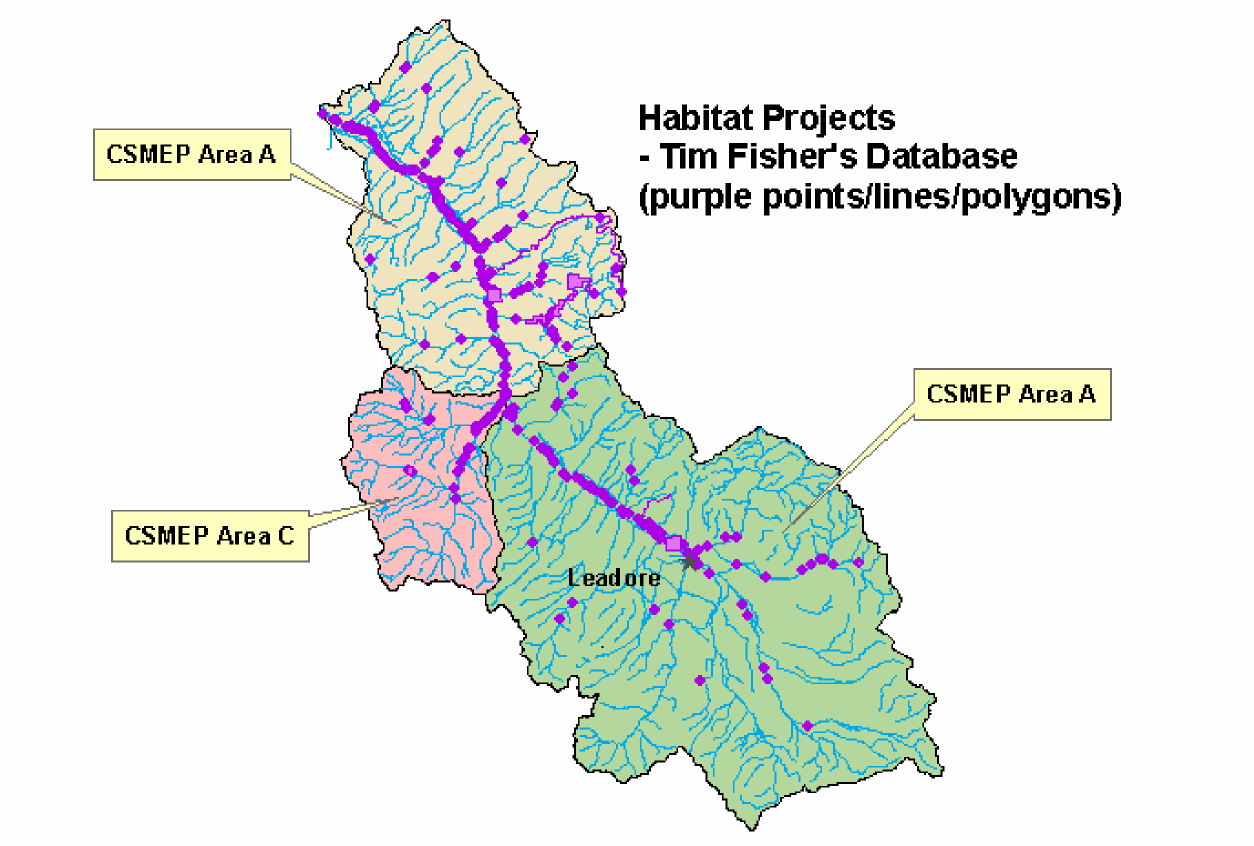

Figure 5.3. Lemhi River watershed with CSMEP areas and locations of past habitat actions. Habitat action data courtesy of Tim Fisher, Fisher Fisheries Ltd.

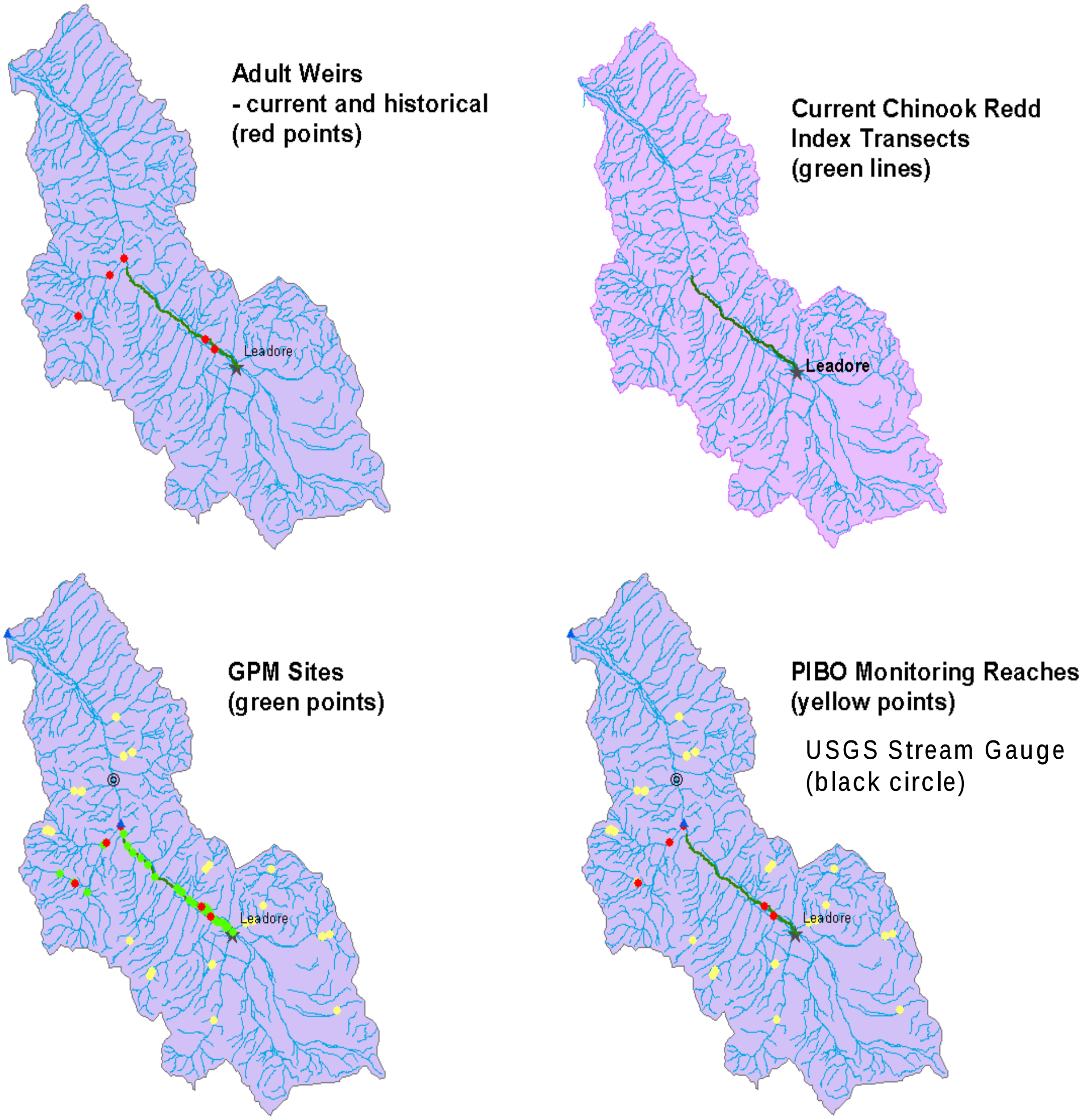

Figure 5.4. Type and location of existing fish monitoring activities in the Lemhi River watershed.

5.3.7 Design alternatives

“Low”, “Medium”, and “High” intensity monitoring alternatives were developed to address the clarified habitat effectiveness questions (Figure 5.3) for the Lemhi HCP. Within the context of the CSMEP habitat designs, “intensity” refers to the relative density and distribution of sampling areas within Sections A, B and C of the Lemhi River watershed. Table 5.4 compares the Lemhi ‘Status Quo’ monitoring design with the CSMEP “Low-”, “Medium-”, and “High-intensity” effectiveness monitoring design alternatives for addressing the Lemhi HCP. Table 5.5 presents clarified habitat restoration effectiveness questions. Full descriptions of the **alternative CSMEP designs** are available as appendices in CSMEP's FY06 Annual Report.

CSMEP's ***"Status Quo" design*** alternative is a restatement of the monitoring programs that are currently operational in the Lemhi River watershed (Section 5.3.6 and Appendix 5).

The ***"Low" design*** alternative builds on the monitoring programs that are currently operational in the Lemhi River watershed (Section 5.3.6 and Appendix 5) and suggests some relatively minor changes to improve spatial and temporal contrast (Table 5.5). These additions to the "Status Quo" include:

1. adding a rotary screw trap to Hayden Creek before the implementation of habitat reconnection actions, and
2. expanding the distribution and frequency of within-year redd and parr surveys.

The "Low" design contends that most of the Lemhi questions can be answered with a fairly moderate increase in habitat monitoring (temperature and flow) and additional fish monitoring, given that certain assumptions hold true about the independence of fish populations within Sections A, B and C, and fish sampling efforts remain consistent over time. The fastest payoff within this design will be through extensive snorkeling, which will describe fish use in previously unpopulated areas as long as detection probabilities are high.

The ***"Medium" design*** alternative builds on the core structure of the "Low" alternative, but adds several monitoring components that increase spatial coverage (Figure 5.6) and expand the data set. These additions include:

1. Increased numbers of fixed snorkel sites adjacent to reconnection sites in the tributaries and adjacent to tributary confluences on the mainstem.
2. Data collection in additional, random "extended" snorkel sites. Snorkel sites would be located in connected, reconnected and disconnected areas and would be chosen using EPA's GRTS sampling protocol to gather data on fluvial and resident bull trout populations.
3. The addition of annual habitat surveys (i.e., collection of data on temperature, flow, riparian conditions and biologics (e.g., Oregon Habitat Inventory methods)), at both fixed and extensive snorkel sites to provide a broader set of explanatory variables;
4. The addition of penta-annual habitat surveys to gather data on geomorphic, landscape and watershed processes.
5. An increased level of seining and PIT tagging in the mainstem and tributaries above rotary screw traps for improved parr-smolt survival estimates and SARs. Tagging of all bull trout captured to allow estimates of bull trout population abundance.

The ***"High" design*** alternative builds still further on the template of the "Medium" alternative. It is meant to provide estimates with the greatest statistical reliability, allow inferences with the greatest confidence, and also provide more detailed explanatory information to address unexpected results and improve future management actions. The High design incorporates greater replication, with more fixed and random sites than either the "Low" or "Medium" designs (Figure 5.7). It also has the broadest data set, and provides more explanatory variables and greater potential for learning about the mechanistic links between actions and responses. The changes incorporated under the "High" design relative to the "Medium" design include:

1. The use of multiple methods for sampling juvenile distribution and abundance (e.g., snorkeling, seining, electrofishing - whichever is the most appropriate at a particular site).
2. Use of classification systems, or models, to project the impacts of reconnection actions on stream temperatures so as to focus the monitoring effort.
3. A new adult weir below the junction of Hayden Creek (Section C) with Upper Mainstem (Section B).
4. More extensive PIT tagging, especially within tributaries of Section B where habitat reconnection actions are taking place.
5. The placement of PIT tag detectors at the weir and rotary screw traps in the mainstem, both above and below tributary confluences and within tributaries, including those with and without channel reconnection actions.

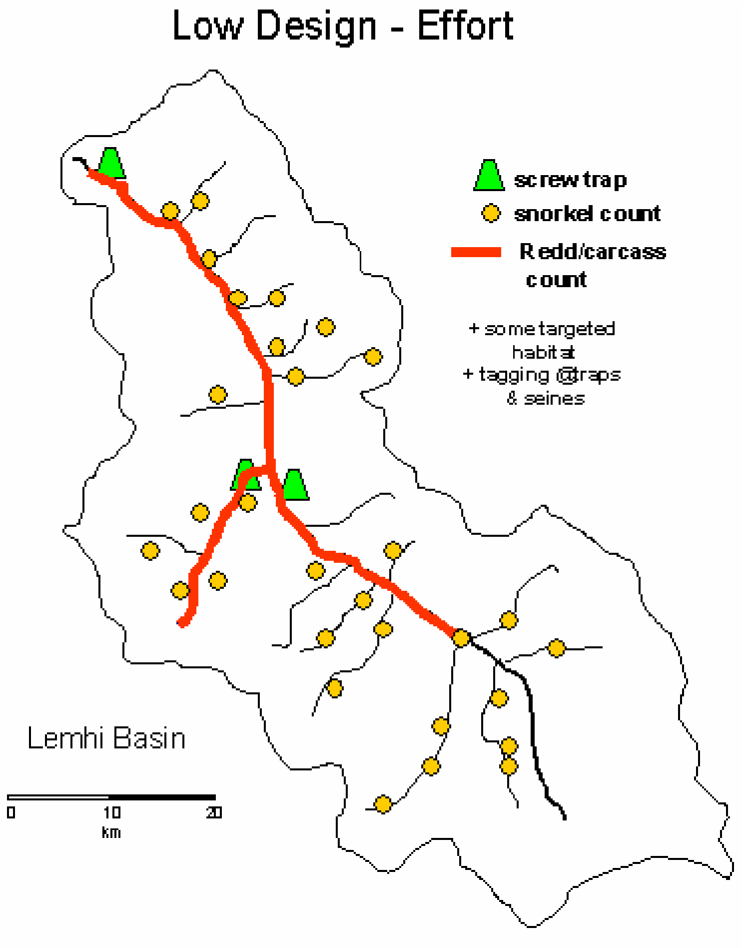

Figure 5.5. CSMEP's low design for the Lemhi River Habitat Conservation Plan (HCP).

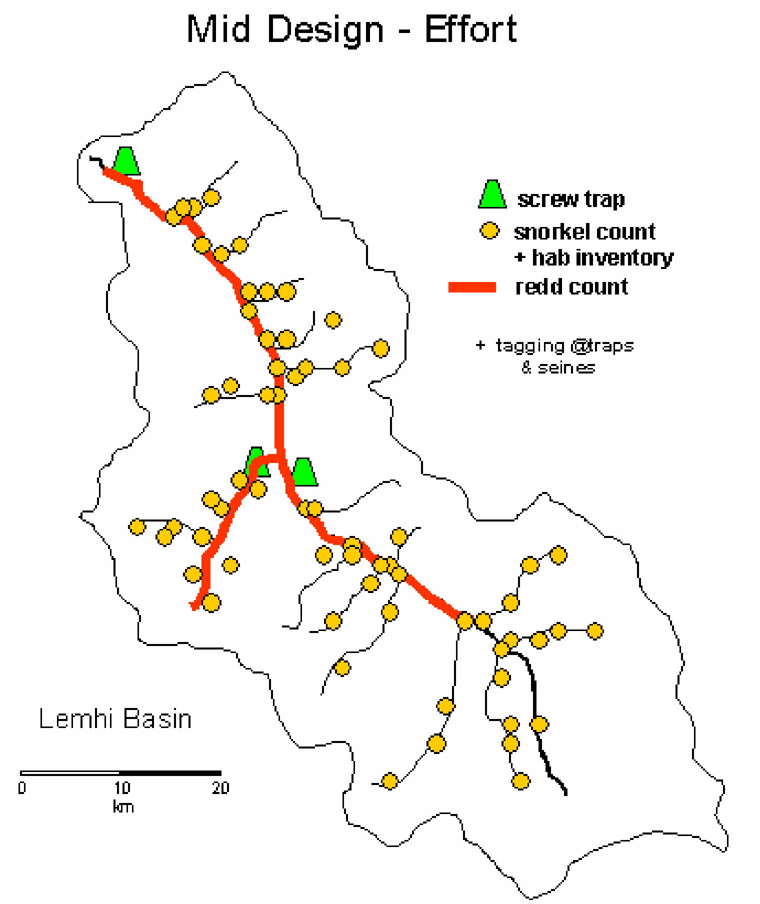

Figure 5.6. CSMEP's medium design for the Lemhi River Habitat Conservation Plan (HCP).

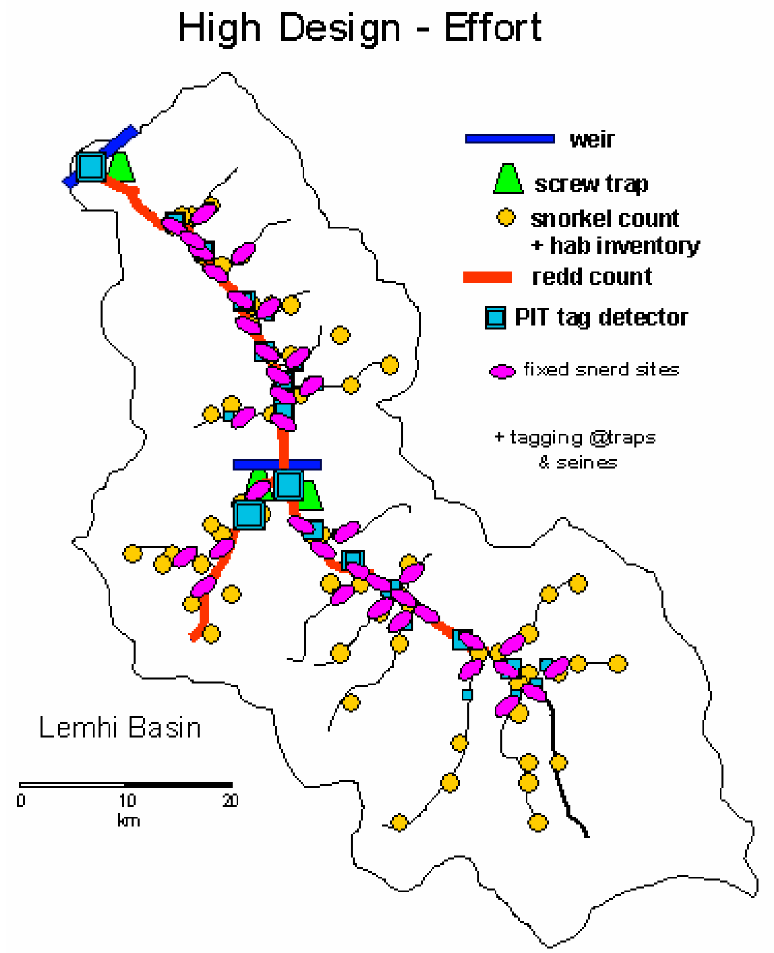

Figure 5.7. CSMEP's high design for the Lemhi River Habitat Conservation Plan (HCP).

5.3.8 Design costs

Differences in design structure are associated with differing design costs. Cost models were estimated for each of the "Low", "Medium" and "High" designs using both a "Top down" and a "Bottom-up" approach. The "Top down" approach is based on per project costs and contracting history for previous projects. The "Bottom-up" approach is based on unit costs (e.g., costs per sample) times the number of units (e.g., number of samples) and is thus explicitly linked to the differences in sample size and monitoring protocol. While the "Bottom-up" cost model begins the process of developing the detailed cost models required for thorough exploration of alternative designs, the "Top down" approach is valuable because it captures the costs of monitoring components that are not easily expressed in a unit cost basis such as the costs of reporting and training crews. Using the two approaches provides a means of "bounding" the annual costs of each alternative and a useful cross-check between practical experience and design driven costs.

5.4 Results

5.4.1 Overview of design alternatives

There are broad similarities between the three CSMEP design alternatives. All three have monitoring activities within Sections A, B, and C, and in Section B tributaries are monitored before and after implementation of channel reconnection actions. In addition, all three consider Section C as a potential control system. As such, they can all accommodate “Before-After”, or “Before-After-Control-Impact” type monitoring designs to get at broad scale changes in abundance and distribution. They also provide some ability to compare tributaries with and without reconnection actions. However, the range of data types and the intensity with which those data are monitored varies between alternatives (see Table 5.4 for comparison of design elements). For example, the “High” design includes carcass surveys, while neither the “Medium” nor “Low” alternatives do. The “High” and “Medium” alternatives both include fixed and random parr density/habitat survey components, while the “Low” alternative only includes fixed-site parr density surveys, and fewer of them. The High design includes PIT tag detectors at the weir, at rotary screw traps (RSTs) in the mainstem, mainstem above and below tributaries, and within the tributaries; neither the “Medium” nor “Low” alternative include the use of PIT-tag detectors anywhere within the Lemhi River watershed.

Although all three CSMEP design alternatives involve using Hayden Creek as a control, there is some concern that this may not be a good control system. Due to very low numbers of Chinook redds counted and short time series for some data types (e.g., parr densities) in Hayden Creek, a suitable control system may need to be found outside of the Lemhi River watershed. Potential candidates might include the Pahsimeroi, Big Lost or Little Lost Rivers.

Differences in sampling protocol, structure and intensity between each of the alternatives are the primary cause for differences in the quality of design inferences (Table 5.5). While all alternatives allow for inference with respect to the clarified questions for the Lemhi HCP, the “Medium” and “High” alternatives provide inferences in which biologists will have greater confidence. For example, the “Medium” and “High” alternatives increase both the density of sampling and the allocation of samples to fixed and random sites. This will allow for more rigorous statistical assessments of fish population responses to the actions and status and trends over time within the Lemhi River watershed. The “Low” design may be able tell managers if the fish population has increased, but not whether it was due to the HCP actions. The addition of the adult weir and the higher level of PIT-tagging under the “High” alternative will provide the most precise estimates of egg-to-parr and parr-to-smolt survival rates, and smolt-to-adult return rates (SARs). The practical implication of this higher precision is greater power to assess effectiveness of HCP actions in a shorter period of time. This shorter duration for the restoration experiment could potentially offset the higher implementation and annual operating costs of the “High” alternative relative to the “Low” or ”Medium” designs.

Table 5.4. Alternative sampling and response designs for evaluating Lemhi River subbasin habitat actions (what, how, where data are collected).

Performance Measures	Status Quo (SQ)	Low	Medium	High
1. Spatial distribution (Chinook par, steelhead parr/smolts, all bull trout)	Snorkel counts conducted in (A) and (C)	SQ + Hayden Creek	'Low' + snorkel counts in all tribs with higher intensity.	'Medium' + and in mainstem below all trib junctions for abundance estimates.
2. Parr density (Chinook)	Snorkel counts conducted in (A) and (C)	SQ + Hayden Creek	'Low' + snorkel counts in all tribs with higher intensity.	'Medium' + fixed sites within tribs, and in mainstem below all trib junctions for abundance estimates.
3. Smolts per redd (Chinook)	One screw trap located in (A).	Screw traps in (A), (B) and (C).	Same as 'Low'	'Medium' + PIT tag detectors at the mouths of (B) (A) and (C).
4. Migratory timing & size (Chinook)	One screw trap located in (A).	Screw traps in (A), (B) and (C).	Same as 'Low'.	'Medium' + PIT tag detectors at the mouths of (B) (A) and (C).
5. Parr-to-smolt survival (Chinook)	Survival from trap in Lower Lemhi to LGR.	Some tagging from fish captured through seining throughout drainage. Screw trap at mouth of (B) (A) and (C).	'Low' + more extensive tagging from fish captured through seining throughout drainage.	'Medium' + PIT tag detector in all reconnected tribs and in mainstem below all tribs.
6. Redd counts (Chinook)	Redd counts conducted in upper Lemhi.	Full (A+B+C) redd surveys.	Same as 'Low'	Same as 'Low'.
7. Spawning adults (Chinook)	Inferred from redd counts	Full mainstem (A+B+C) carcass surveys.	Same as 'Low'	'Low' + weirs at (B) and just below confluence of (A) and (B). PIT tag adults and recapture with carcass surveys and PIT tag antenna.
8. Population abundance (bull trout)	Redd counts conducted in some tribs in (C) and (A).	Redd counts in paired tribs containing bull trout in the lower (B) and upper (A) Lemhi, and control tribs in Hayden Creek (C).		Extensive mark-recapture data collected in paired tribs throughout the Lemhi Basin and control tribs in Hayden (C) to estimate abundance and bias in redd counts. Use of PIT-tag detectors at key migration points
9. Survival of juvenile and adult migratory bull trout	N/A	N/A	N/A	Extensive mark-recapture data collected in paired tribs throughout the Lemhi Basin and control tribs in (C) to estimate survival across life stages. Use of PIT-tag detectors, weirs, and screw traps at key migration points to provide additional recapture events.

Table 5.5. Overall effectiveness monitoring designs for evaluating effectiveness of Lemhi River watershed habitat restoration actions, and qualitative assessment of design alternatives. Quality of information: 5 = excellent; 4 = very good; 3= good; 2= fair; 1=poor; N/A = not applicable.

Questions evaluated	Status Quo (SQ)	Low	Medium	High
1. Have projects increased the distribution and density of Chinook juveniles?	(1) Presence/absence only, area limited	(3) Qualitative differences in density, limited habitat information	(4) Detect effects, Improved spatial resolution vs. 'Low'	(5) Most powerful design. Mark-recapture estimates of density. Should demonstrate project effects.
2. Have projects increased number and size of juvenile Chinook outmigrants?	(1) Area limited, cannot detect effects	(3) Improved design, but still limited ability to detect effects	(3) Detect effects, habitat surveys increase likelihood of identifying cause/effect relationship	(4) Detect effects, screw trap and PIT tag antennas will increase accuracy & precision of population estimates.
3. Have projects changed timing of Chinook outmigration?	(2) Same as Question 2	(2) Same as Question 2	(2) Same as Question 2	(2) Same as Question 2
4. Have the projects increased Chinook parr-smolt survival?	(1) Before/after possible, unlikely to detect effects	(2) Same as Question 2	(2) Same as Question 2	(2) Same as Question 2
5. Have the projects increased Chinook adult returns?	(1) Area limited, cannot detect effect	(3) Better design, but still unlikely to detect effect.	(4) Detect effects, habitat surveys increase likelihood of identifying cause/effect relationship	(5) Weirs, carcass surveys and PIT tag antennas increases precision & accuracy.
6. Have projects increased distribution and abundance of bull trout?	(1) Area limited, no pre-project data exists for treatment tribs	(3) Improved design, some pre-treatment data, migratory bull trout only	N/A	(5) Abundance for resident & migratory bull trout, evaluation of redd count bias
7. Have the projects improved bull trout survival?	NA	NA	NA	(5) Good design, estimates of density. Should demonstrate project effects.

5.4.2 Alternative design costs

Preliminary cost results generated by the two approaches were similar across the CSMEP design alternatives (Table 5.6) although the "Top down" estimates were all lower than the "Bottom-up" estimates. The greatest cost difference was seen for the "Medium" alternative. Slight differences in cost estimates between the two approaches will need to be reconciled to ensure that the alternatives match in their assumed monitoring components. For example, the "Bottom-up" costs for the "High" alternative include PIT-tag detectors, while the "Top down" approach does not include the cost of PIT tag detectors. These differences are partly due to the iterative nature of the design process in that the cost estimation was done at different stages, thus these costs should be considered examples. Ultimately these cost estimates would be adjusted as the statistical designs and analytical methods are further refined during the evaluation process.

Table 5.6. Relative top-down and bottom-up annual costs for the Lemhi Status Quo (SQ), Low (L), Medium (M) and High (H) monitoring design alternatives. Note that the Habitat group needs to reconcile these differences and that the cost estimates will change as the designs are refined during the evaluation process.

Design	Top-Down*	Bottom-Up†
Status Quo	$125,000	$125,000
Low	$323,000	$354,000
Mid	$377,000	$493,400
High	$580,000	$643,600

* Top–down is based on per project costs and contracting history for previous projects.

† Bottom-up is based on cost per unit time per person multiplied by the sample sizes identified in the plans.

5.5 Conclusions and recommendations

CSMEP's "Low" alternative was intended to build on existing monitoring programs and data. This alternative makes minor adjustments to status quo monitoring in the Lemhi River watershed and provides only a basic design for detecting the effects of the Lemhi River, channel-reconnection habitat actions. It is not intended to provide information about the cause-effect relationships that drive observed changes in fish populations. Consequently, the "Low" design cannot provide information to inform adaptive management within the Lemhi HCP. The "Low" design will answer only the question, "Did the fish population parameter change?", but will not reveal causality. CSMEP's "High" design alternative is an "ideal" design that should be capable of precisely answering question as well as providing feedback to managers for improving implementation and monitoring of habitat actions. The "Medium" alternative falls between the High and Low design alternatives with respect to precision, cost, and the ability to provide adaptive feedback.

A preliminary set of "High, "Medium" and "Low" intensity design alternatives for evaluating the Lemhi HCP has now been sketched out by CSMEP. Although some comparison is possible between these design alternatives, there is still additional work that must be completed before the alternatives can be quantitatively compared using a formal trade-off analysis. For example, CSMEP's design process to this point has focused on specifying the structure of annual sampling operations, not on the pattern of sampling over the period of the HCP. This is an important consideration because for some of the analyses, the between-year variation in performance measures is likely to be more limiting for detecting effects that are within-year variation. Thus, a next step is to establish the pattern of temporal monitoring within which the alternatives will operate. Should sampling occur every year from year 0 to year 30 of the HCP? Or should it proceed from year 0 to some check-in point (e.g., 5-years), at which time the status of the system and monitoring program are assessed?

A formal trade-off analysis of the CSMEP designs for the Lemhi HCP will require the use of:

1. *Statistical models* to calculate the consequences of the "High", "Medium", and "Low" designs in terms of the precision and bias of parameter estimates, the statistical power of hypothesis tests to detect effects of importance, These models will require estimates of process, sampling and measurement error for the different types of performance measures from different monitoring protocols in the Lemhi River watershed. This information is needed to establish the range of variation in performance measures expected for each of the designs and determine the minimum detectable effect size.
2. *Cost models* to more precisely calculate the implementation and annual costs associated with each design permutation. Ideally, these models will eventually be linked to the design parameters of the statistical model (e.g., linked so that costs vary with the number of sites monitored and sampling protocol). CSMEP's Integrated Costs Database Tool will be able to assist this effort.
3. *Standard methods for summarizing and presenting the results of these analyses to decision-makers*. The statistical models used for analyses of the relative precision of information obtained under alternative designs can be difficult to explain to non-technical audiences. A standard method for presenting these results should be developed to facilitate quick interpretation of results and communication of results to decision-makers.

CSMEP's design work for the Lemhi River pilot study has identified broader habitat monitoring issues of interest to regional managers. The comments below summarize these issues as a starting point for more focused cross-scale discussions in future.

1. *Explore broader-scale evaluation of habitat restoration effectiveness questions and monitoring alternatives.*

   <u>Additional Control system for the Lemhi River watershed:</u>

   - What needs to be considered when selecting locations to use for contrasts (control, another treatment). Is it possible to identify replicates for a whole basin? This could be assessed by looking for similar patterns in smolt/spawner across basins. What would adding a control like this add to Lemhi HCP designs? This is important to evaluate *a priori* as recent work (e.g., Bradford et al. 2005) suggests that BACI is not always that powerful because benefits of this design will only be apparent when there is a high correlation in freshwater survival rates between systems.
   - For nested designs, new questions will emerge such as should projects in different watersheds be initiated at the same time, or staggered?

   <u>Across basin comparisons:</u>

   - Develop background information on the distribution of potential projects in different subbasins.
   - Look for different basins with similar channel reconnection actions as are being proposed for the Lemhi.

- Independently study the flow-temperature-fish distribution relationships in each subbasin monitored. For example, learn from observations in Lemhi in order to adapt implementation and monitoring work in the other areas – a “phase and refine” approach.
- Recognize that it will be difficult to address action-specific questions in watersheds where many confounding projects are ongoing. Identification of individual responses will be masked in such cases, especially where baseline information is lacking.

2. *Consider weighted allocation of sampling to collect Before-data.*

Restoration actions are often opportunistic, thus there is little opportunity to collect much Before-data. It would be useful to address this weakness by using EMAP-style status and trend monitoring weighted towards areas where restoration actions are anticipated to take place. Weighting factors could be developed through approaches such as limiting factor analysis to anticipate where actions may occur, and then weight sample allocation by the likelihood of restoration actions taking place in a particular area. This could be part of an effectiveness monitoring program integrated at a broader basin-wide scale.

3. *Consider how the Lemhi design alternatives might change for different types of restoration actions.*

Monitoring techniques within designs will have to vary dependent of the restoration actions evaluated. For example, undertaking more riparian actions might require more snorkel survey work for monitoring, but would probably not radically change the design. It would, however, change where and for how long to monitor since changes may take longer to manifest. For example, it could take thirty years for riparian vegetation to establish after restoration activities.

4. *Be realistic about where the Lemhi pilot designs can be applied more broadly.*

The Lemhi pilot design alternatives will be very specific to the Lemhi River watershed. At the broader scale, more general advice is supposed to be provided through the Federal RME pilot projects. Their purpose is to see what can be learned that is broadly applicable to design elsewhere. The “process” applied within CSMEP’s Lemhi pilot is important, even though the specifics of the Lemhi designs will not be easily transferable. For the Lemhi River watershed, the designs could take advantage of Sections A, B and C and a specific break in the distribution of proposed actions; the ability to form these contrasts makes this effectiveness monitoring. Thus, while BACI designs are applicable to the Lemhi River watershed, they won’t be applicable everywhere (e.g., with no control available, a Before-After (BA) design might be the best possible).

CSMEP used the Lemhi River watershed as a pilot area to test the use of the DQO process and identify refinements as necessary for developing useable habitat action effectiveness designs. The CSMEP work was thus a learning exercise, with no expectation that CSMEP designs need actually be applied to the Lemhi River HCP. The Lemhi River is, however, a designated NOAA Pilot Project area, for which an independent design has been developed and will be implemented as part of the Integrated Status and Effectiveness Monitoring Program (ISEMP).

Both the CSMEP group and NOAA Pilot Project drafted monitoring plans were intended to enable a robust evaluation of the effectiveness of proposed and ongoing habitat actions in the Lemhi. The CSMEP group primarily focused on the effects of tributary reconnections. Alternatively, the NOAA Pilot Project design focused on a larger set of questions, pertaining to all of the habitat actions proposed for the Lemhi (see Appendix 5). In addition, the NOAA Pilot Project includes the following features:

1. an adaptive management component to assist in the selection of habitat actions and the selection of tributaries to be reconnected.
2. a life-cycle based approach, enabling identification of which life history stages are limiting population growth.

Because the CSMEP and NOAA Pilot Project shared some common questions, the CSMEP plan – especially the high-end design - and the monitoring aspects of the HCP have both substantial overlap and several major differences (see CSMEP FY06 Annual Report (Marmorek et al. 2006) for an in-depth comparison of the two approaches). They overlap in that both plans include monitoring of both habitat changes and changes in fish distribution expected to result from tributary reconnections. Both the CSMEP DQO and the draft HCP evaluate whether juveniles move into newly reconnected tributaries, and whether increased productivity – survival rates and rearing capacity – result from the reconnections. For both plans, the species of interest are resident and anadromous salmonids with concurrent monitoring of both localized project effectiveness and habitat condition, and somewhat larger-scale monitoring of juvenile production and survival. Note, however, that the CSMEP DQO example is just that – an example to illustrate design methods. Finally, it is important to note that a number of similarities exist between the designs. NOAA’s Pilot Project design benefited greatly from the design alternatives that CSMEP evaluated prior to the beginning of the Lemhi Pilot work. For example, NOAA’s Pilot Project has elected to implement the tandem extended-length PIT tag arrays first discussed within the CSMEP Habitat Subgroup. Likewise, the clarified questions formulated by the CSMEP subgroup have been adopted in large part by NOAA’s Pilot Project in the Lemhi.

CSMEP’s Habitat Subgroup identified a number of pragmatic issues regarding the Lemhi River HCP that must be resolved in any technical “template” for habitat action effectiveness monitoring. Practical action effectiveness monitoring designs must first incorporate sufficient analytical flexibility to compensate for less than complete control over action implementation. Second, it is likely that existing, but disparate, sampling efforts cannot provide adequate information at the temporal and spatial scales required for efficient implementation of action effectiveness evaluations. Thus, it is likely that the efficient implementation of action effectiveness evaluations will necessitate both a new sampling effort and the modification of existing sampling efforts. Third, it is clear that targeted research for illuminating the mechanistic linkages between habitat restoration actions and fish population responses is still needed. As one moves to other subbasins where habitat management issues are diverse, there are likely to be potentially large differences in design elements; in particular, where and when to deploy monitoring resources. It will be impossible to predict ahead of consideration of the mature scientifically questions specific to those locations. Consideration of those questions will in turn require a unique rather than template process that is informed by the management history and management plans in those new locations.

6. Hatchery

6.1 Introduction

CSMEP's Hatchery Subgroup was charged with improving designs for hatchery M&E. As critical questions related to hatcheries can broad-scale in nature, CSMEP hatchery designs consequently needed to extend beyond the boundaries of CSMEP's Snake River Basin pilot area and focus on a broader evaluation of the "effectiveness" of hatchery programs across the Columbia River Basin. Problematically, policy level guidance was insufficient to initially focus the hatchery subgroup on a subset of relevant hatchery effectiveness questions. Lack of a formalized definition of "effectiveness" resulted in the identification of 41 questions over a range of spatial scales (i.e., from individual programs to regional assessments) (Appendix 6A), requiring information on up to 65 performance measures, each with an unspecified degree of precision.

Internal CSMEP evaluation of these 41 hatchery questions concluded that many of the questions were likely to be adequately addressed by existing and proposed hatchery monitoring (if funded) at the scale of individual hatcheries. Given this, additional development of alternative M&E hatchery designs by CSMEP at the scale of individual hatcheries was felt to be redundant. This conclusion was supported by policy input from a joint Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and CSMEP meeting in 2006. CSMEP's Hatchery Subgroup therefore refocused their design efforts on identifying/evaluating pertinent regional-scale questions relating to hatchery strategies and management actions that were not currently being representatively addressed through existing or proposed hatchery monitoring projects.

6.1.1 Data Quality Objectives Steps 1-5

CSMEP applied EPA's Data Quality Objectives (DQO) process to guide the development and evaluation of alternative hatchery designs. This led to a smaller subset of questions based on a regional evaluation of hatcheries that were carried forward through the first five steps of the DQO (Table 6.1) Specific M&E questions identified for harvest augmentation and supplementation hatchery programs are summarized in Table 6.2 and Table 6.3 respectively.

Table 6.1. Data quality objectives: Steps 1 through 5 as they pertain to hatchery actions. From CSMEP 2005 Annual Report.

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Artificial propagation is used extensively as a management tool for Pacific salmon in the Snake River Basin. Hatchery programs are operated to contribute to three general management goals: 1. Harvest Augmentation: to provide fish for tribal, commercial, and recreational opportunity while keeping impacts to natural populations within acceptable limits. 2. Supplementation: the use of hatchery fish to increase abundance and decrease the extinction risk of natural populations while keeping impacts to non-target populations within acceptable limits. 3. Genetic Conservation: maintain genetic resources of imperiled populations to allow for reintroduction of supplementation in the future. Considerable uncertainty remains, however, regarding benefits and risks of hatchery programs, to targeted non-target populations.	
Stakeholders:	States—Washington, Oregon, Idaho Tribes—NPT, SBT, CTUIR, CTWIR, YIN Federal—NOAA, USFWS, BPA, USACOE Other—NPPC, CBFWA, conservation groups, Tribal, commercial, sport fishers	
Non-technical Issues:	Appropriate people with enough time to assess ongoing M & E programs, adequate long-term funding to develop integrated study plans, and assess if uncertainties are being adequately addressed. Lack of adequate funding for data collection for supplementation program M & E projects	
2. Identify the Decision		
Principal Questions:	There is a large suite of monitoring questions required in evaluation of hatchery programs (the group identified 11 questions for harvest augmentation, 25 for supplementation and 5 for conservation hatcheries) **Examples** of some principal questions include: Harvest Augmentation: • To what degree does the hatchery program meet harvest objectives? • What is the magnitude and distribution of hatchery strays into natural populations Supplementation • What is the ratio of R/S for hatchery produced and naturally produced fish • What is the relative reproductive success of natural spawning hatchery and natural fish? Conservation • None of the existing hatchery programs within the Columbia River Basin were categorized as "conservation" programs under the CSEMP definition, thus questions/designs were not developed for this category. For the purpose of CSMEP analyses we will focus only on the subset of Harvest and Supplementation hatchery questions that will require broadly-based, integrated multi-program designs to address	✓
Alternative Actions:	Make management and facility changes to hatchery programs to improve performance and reduce impacts on natural populations. Reduce the magnitude of reliance on hatcheries, including elimination of some hatchery programs. Decide that benefits of production outweigh risks of to natural populations (i.e., do nothing).	✓

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
Decision Statements:	Is the harvest augmentation hatchery program achieving harvest contribution objectives and keeping impacts to natural populations at acceptable levels so that program modifications, reductions, or elimination are not required? Is the supplementation hatchery program increasing abundance and decreasing the extinction risk for the target natural population and keeping the impacts to non-target populations at acceptable levels so that program modifications, reductions, or elimination are not required?	✓
3. Identify the Inputs		
Action Levels (critical effect sizes)	The level of change that would trigger an adaptive management action varies considerably between each hatchery objective and the associated metrics. Unfortunately, the vast majority of hatchery programs do not identify quantitatively "acceptable limits". It would be difficult to describe generic action levels for each metric that would trigger an adaptive change in a specific hatchery program or groups of programs. Instead, decisions must be framed around two general factors, the perceived value of the particular metric monitored as well as the variance or degree of confidence in this value.	✓
Information Required:	The range of information required to address the full suite of hatchery questions is extensive. We identified a need for information from 65 performance measures across hatchery, supplementation and conservation hatcheries. Examples of <u>some</u> of the information needs include: <u>Harvest Augmentation Hatcheries</u>: • Commercial, recreational, and tribal harvest contributions by fishery • Smolt-to-adult survival • Progeny-to-parent ratios • Stray rates • Proportion of natural spawners that are hatchery strays <u>Supplementation Hatcheries</u>: • Recruits per spawner for hatchery/natural fish • relative reproductive success of naturally spawning hatchery/natural fish • Hatchery/Natural fish abundance • Hatchery/Natural fish harvest rates • Hatchery/Natural fish spawning distribution • Smolt to adult survival for natural/hatchery fish • Maintenance of genetic diversity	
Sources of Data:	Data resides in a variety of sources. Each hatchery program has some data for some metrics. No programs have data for all metrics. The temporal and spatial scales, as well as, the number of metrics for which there are data varies considerably among programs.	
Quality of Existing Data:	<u>Harvest augmentation hatcheries</u>: catch contribution, catch distribution, and smolt-to-adult survival data is available. In some cases, however, specific harvest objectives are not well defined. The data available for stray rates, and particularly for stray impacts to natural populations, is limited. <u>Supplementation hatcheries</u>: data available but in some cases for a limited number of years. In addition, most supplementation hatchery programs are not collecting data for all the important metrics that would be useful for informing broad questions related to regional effectiveness. There is also a lack of data from control or reference streams that can be used for comparisons.	
New Data Required:	There is a need to better understand how hatchery data are collected, how comparable data are among hatchery programs, and the extent, accuracy and precision of this data (as well as what fraction of a population the data represent).	

DQO STEPS	SNAKE RIVER BASIN PILOT	Policy Inputs[1] (✓)
Analytical Methods:	Given the wide range of hatchery objectives and associated metrics, a suite of analytical approaches may be required, including: • Pre-post/control comparisons (BA, BACI) • Relative performance comparisons between hatchery/natural fish • Standard parametric and non-parametric tests • Genetic analyses • Time series analyses • Stock recruitment analyses	
4. Define the Boundaries		
Target Populations:	Interior CRB stream-type Chinook salmon populations.	
Spatial Boundaries (study)	The focus area is the geographical boundary of interior CRB stream-type Chinook salmon. However, ocean and in-river harvest downstream from the Snake are included in the boundary, as are the locations of populations where Snake River fish stray.	
Temporal Boundaries (study)	There will be variable temporal boundaries dependent on the specific question and associated metrics. Temporal durations include life-stage specific, annual, generational, and multi-generational.	
Practical Constraints:	There are financial, logistical, and technical constraints. In addition, there is a general lack of pre-treatment or control system data available around which to frame analyses.	
Spatial Boundaries (decisions):	The first level of assessment is hatchery program-specific, the second level is the target natural population, the third level is at the major population grouping, the fourth level is at the ESU, and the fifth level will be outside the ESU.	
Temporal Boundaries (decisions):	Some adaptive management decisions can be made annually for some program; however, in most cases management decisions must be made on the temporal scale of salmon generations. The temporal scale is linked to the timeframe for availability of adequate data. Adequate data, in some cases, is many salmon generations out in the future.	
5. Decision Rules		
Critical Components and Population Parameters; Critical Action Levels: If-Then Decision Statements;	While the group was successful at defining hatchery monitoring questions and associated information needs, they were less successful at defining appropriate "decision rules." Very few hatchery programs provide quantitative guidance for the use of data in an adaptive management framework. For example, many hatchery programs communicate their goals as "supplement natural populations while keeping impacts to non-target populations within acceptable limits." The vast majority of programs do not identify quantitatively what "acceptable limits" are or define what their response would be if these acceptable limits were exceeded. This is a complex issue, primarily for three reasons: 1) acceptable limits are not purely scientific, since hatcheries have legal mandates and a complex societal basis; 2) the long and short-term biological affects of impacts at various levels are largely unknown and are unlikely to manifest uniformly across all hatchery programs; and 3) decisions regarding hatchery management are typically made based on the interaction of multiple questions rather than the result of a single question, thus creating a difficult decision matrix.	✓
Consequences of Decision Errors	May continue/expand hatchery actions with little beneficial effect or even detrimental effects on fish populations; May discontinue hatchery actions that do have beneficial effects on fish populations; Unnecessary costs; Negative impacts to fisheries harvest; Continued loss of fisheries	

6.1.1.1 Harvest augmentation hatchery questions

Questions relevant to harvest augmentation hatcheries are presented in Table 6.2. Assuming that these programs are intended to augment harvest, presumably lost as a result of habitat modification (e.g., hydropower development), they should provide a demonstrable contribution to harvest (questions HA1 and HA2). The contribution to harvest must be large enough to offset the potentially deleterious effects of the operation of such facilities. This requires an assessment of the effects of harvest augmentation hatcheries on the viability of natural populations. The degree to which harvest augmentation hatcheries are expected to affect natural populations is assessed at a coarse scale by the distribution (question HA3) and magnitude (question HA4) of hatchery strays. Given an understanding of stray ratios, the impacts of hatchery strays on the viability of natural populations (question HA7) is a function of their reproductive success (question HA5, which then dictates the magnitude of expected ecological interactions between naturally spawned juveniles with hatchery ancestry and natural origin juveniles as well as the genetic impacts of introgression) and the potential for disease transfer (question HA6). A recognized shortcoming of the refined questions is a lack of information regarding direct ecological interactions that may result from straying (e.g., competition, predation, etc.). The group agreed that such studies, while important, were likely to be most efficiently addressed via dedicated research at individual facilities, rather than through a large-scale regional evaluation.

Table 6.2. Harvest augmentation questions developed during the first five steps of the DQO process.

	Regional Question	Priority
HA1	What are annual harvest contributions and catch distribution of hatchery produced fish?	H
HA2	To what degree do hatchery programs meet harvest objectives?	H
HA3	What is the distribution of hatchery strays in natural populations?	H
HA4	What are the proportions of stray hatchery fish in non-target natural populations?	H
HA5	What is the relative reproductive success of hatchery origin adults relative to natural origin adults?	H
HA6	What are the disease agents and pathogens in hatchery fish, and to what degree are these agents transmitted to natural fish. What are the impacts of such transmissions?	H
HA7	What are the impacts of hatchery strays on non-target populations?	H

6.1.1.2 Supplementation hatchery questions

Supplementation hatcheries act as refuges to offset mortality in early life-history stages. The ability of hatcheries to decrease early life-history mortality, though not ubiquitous (Miller 1990), is well supported (Hard et al. 1992). Comparisons of adult to juvenile productivity are becoming more commonplace as a means to assess this issue. Juveniles from supplementation programs are typically released into habitats to which they are expected to return and spawn, thereby potentially increasing natural production. Thus a common metric of supplementation hatcheries is a comparison of the progeny per parent ratios of the hatchery relative to natural production. Because this has been a key metric of numerous monitoring and evaluation projects, the ability of hatcheries to achieve a higher adult to adult return rate, relative to natural production, although again not ubiquitous, is well established (Waples et al. 2001). Given that supplementation programs can successfully increase escapement relative to natural spawning alone, it follows that targeted habitat must be capable of supporting increased escapement. Monitoring and evaluation activities that accompany numerous supplementation projects have illustrated that targeted streams are underseeded, suggesting that "excess capacity" is available for production (e.g., Arnsberg et al. 1992). It has also been shown that spawning and early rearing (i.e., egg to emigrant) habitat is not the limiting factor for many populations that are supplemented (Petrosky et al. 2001), and the status and trends of habitat at the life-history stages that limit survival may or may not be known (e.g., mainstem, estuary, and marine). Thus, question S1 (Table 6.3) seeks to determine which habitats limit productivity, the life history stages that are expressed in those habitats, and the status and trends of habitat(s) that limit productivity. In short, this question places bounds on the expectations that should accompany supplementation.

Assuming that supplementation programs increase survival from the juvenile to adult life-history stages, achieving the goal of increasing natural production requires that hatchery origin adults successfully reproduce and that their progeny are viable and survive at rates similar to their conspecifics that do not have hatchery ancestry. Assuming that their natural origin conspecifics might be expected to exhibit optimal reproductive success, it is reasonable to compare the reproductive success of hatchery origin adults to their natural origin conspecifics (question S2). Designs to address this question should include similar performance measures in reference streams to determine whether variance in reproductive success increases in supplemented streams and whether productivity changes as a result of supplementation (which may not be apparent solely from measures of relative reproductive success). Likewise, the survival of juveniles with hatchery ancestry can be meaningfully compared to their conspecifics that lack hatchery ancestry.

Assuming that supplementation provides a demographic benefit from the perspective of productivity (as measured by question S2), hatchery origin juveniles have the potential to serve as disease vectors, potentially offsetting otherwise positive demographic benefits (question S3). These impacts are unlikely to be limited solely to targeted populations, thus this question should be addressed at a regional scale, wherein the distribution and prevalence of diseases are monitored in supplemented and reference locations.

Broodstock collection, mortality within the hatchery, and post-release mortality can potentially decrease genetic diversity of targeted populations (Hard et al. 1992); likewise, the implementation of specific breeding protocols, decreased genetic drift owing to reduced random mortality, and increased abundance potentially resulting from supplementation can maintain or increase genetic diversity (Hedrick and Hedgecock 1994). Question S4 evaluates the variance among the effective population sizes of hatchery and conspecific natural populations to evaluate whether supplementation, as a class of recovery actions, is most likely to have a positive or negative effect on the maintenance of genetic variation. Because supplementation often targets declining populations, genetic variation within supplemented populations should be compared to reference populations with similar population dynamics.

Despite the fact that supplementation programs generally endeavor to produce juveniles that are genetically, behaviorally, and functionally identical to their natural origin conspecifics, the fact remains that straying of hatchery origin adults can potentially have deleterious consequences for natural origin populations (e.g., Grant 1997). Therefore, the distribution and magnitude of straying of hatchery origin adults originating from supplementation programs is of interest (question S5). Because supplementation is a key component of multiple recovery plans it is also meaningful to determine whether the stray rates of adults originating from supplementation programs is greater than their natural origin conspecifics (question S6); particularly given that changes in the life-history stage of released juveniles, release timing, and method of release can potentially decrease stray rates (Quinn1993; Unwin and Quinn 1993; Hard and Heard 1999). At a coarse scale, the impacts of hatchery strays is a function of the magnitude of straying (question S7), the reproductive success of strays (question S8), and the resulting effects on the viability of non-target populations (question S9).

Table 6.3. Supplementation hatchery questions developed during the first five steps of the DQO.

Regional Question		Priority
S1	What are the status and trends of habitat targeted by supplementation projects and what is/are the life-stage specific factors that limit productivity?	H
S2	What is the reproductive success of naturally spawning hatchery fish relative to natural origin fish in target populations?	H
S3	What are the disease agents and pathogens in hatchery fish, to what degree are these agents transmitted to natural fish, and what are the impacts of such transmissions?	H
S4	What are the relative effective population sizes and genetic diversity of hatchery supplemented vs. un-supplemented populations before, during, and after supplementation?	H
S5	What proportion of hatchery origin juveniles return as adults to target versus non-target populations?	H
S6	Do hatchery origin juveniles from supplementation programs stray at a greater rate than their natural origin conspecifics?	H
S7	What are the proportions of natural spawning stray hatchery fish in non-target natural populations and their impact on the viability of natural populations?	H
S8	What is the reproductive success of naturally spawning hatchery fish relative to natural origin fish in non-target populations?	H
S9	What are the effects of hatchery supplementation on the productivity, abundance, and viability of non-target natural and hatchery-influenced populations?	H

Note: Question 9, while applicable to target populations, focuses on non-target populations owing to the fact that designs to assess impacts to target populations are well developed. In general, it was agreed that impacts to non-target populations remain largely unknown, thus requiring the development of designs specific to that question.

6.1.1.3 Data Quality Objectives Steps 1-5 Conclusions

Despite the fact that the number of questions carried through the first five steps of the DQO decreased from 41 to 16, it was apparent that this was still too large an initial list of questions to be tackled by the CSMEP Hatchery Subgroup. In addition, it became clear that design products would be most useful if they viewed harvest augmentation and supplementation as the extremes of a continuum of hatchery management. This approach was anticipated to improve the efficiency of sampling and to provide better management guidance.

Of the 16 remaining questions, the Hatchery Subgroup identified the following as the highest priority integrated question:

> **What is the distribution and relative reproductive success of hatchery origin adults in target and non-target Columbia River Basin populations?**

Target populations were defined as those that are deliberately supplemented by hatchery production, and non-target populations as those that are not deliberately supplemented but may receive *de facto* supplementation in the form of stray hatchery origin adults. Strays were defined as any hatchery origin adult from a supplementation program that returns to a population other than its target. Conversely, any adult from a harvest augmentation hatchery was defined as a stray if it is not harvested or collected for broodstock but instead attempts to spawn in any stream (supplemented or otherwise).

6.2 Methods

Monitoring and evaluating the distribution and relative reproductive success of hatchery origin adults in target and non-target Columbia River basin populations requires two types of information:

1. estimates of the relative abundance of strays in a “representative” group of Columbia River Basin populations; and
2. estimates of the reproductive success of hatchery origin adults relative to natural origin adults in target and non-target populations.

Although this information is most meaningful when utilized simultaneously, it was found that sampling challenges precluded the formulation of a single design to generate representative estimates for both. The next two sections therefore develop proposed low, medium, and high level designs separately for each type of information.

Although the primary focus of CSMEP activities in 2007 was the Snake River Basin, the question identified for the hatchery subgroup necessarily required a larger spatial scale. The hatchery subgroup did not include the entire Columbia River Basin in design efforts, rather the designs described in this document evaluated Interior Columbia River Basin stream-type Chinook salmon populations and major population groups (MPGs), as delineated by the Interior Columbia Technical Recovery Team (ICTRT 2005). However, the designs could easily be applied to all stream-type Chinook salmon populations and MPGs within the Columbia River Basin. Of the interior Columbia River MPGs and constituent populations, we evaluated only the eight MPGs and 45 populations that reside in accessible habitat (Table 6.4); and excluded seven MPGs and 32 populations (including the upper and lower North Fork Clearwater) whose habitat exists above impassable barriers (Table 6.5).

Table 6.4. Interior Columbia River Basin MPGs and populations included in CSMEP design efforts.

MPG	Population	
Lower Snake	Tucannon River	Asotin Creek
Grande Ronde/Imnaha Rivers	Wenaha River Lostine River Minam River Catherine Creek	Grande Ronde River upper mainstem Imnaha River mainstem Big Sheep Creek Lookinglass Creek
South Fork Salmon River	Little Salmon River South Fork Salmon River mainstem	Secesh River East Fork South Fork Salmon River
Middle Fork Salmon River	Chamberlain Creek Middle Fork Salmon River below Indian Creek Big Creek Camas Creek	Loon Creek Middle Fork Salmon River above Indian Creek Sulphur Creek Bear Valley Creek Marsh Creek
Upper Salmon River	North Fork Salmon River Lemhi River Salmon River lower mainstem below Redfish Pahsimeroi River	East Fork Salmon River Yankee Fork Valley Creek Salmon River upper mainstem above Redfish Panther Creek
Dry Clearwater (Lower)	Lapwai/Big Canyon Creeks Potlatch River	Lawyer Creek Upper S. Fork Clearwater
Wet Clearwater (Upper)	Lolo Creek Lochsa River Meadow Creek	Moose Creek Upper Selway River
Wenatchee/Methow	Wenatchee River Entiat River	Methow River Okanogan River

Table 6.5. Interior Columbia River Basin MPGs and populations excluded in CSMEP design efforts.

MPG	Population	
Middle Snake (Pine to Weiser)	Pine Creek Wildhorse Creek Eagle Creek Powder River	Burnt River Crane Creek /lower Weiser Little Weiser Upper Weiser
Payette/Boise	Big/Little Willow Creeks Squaw Creek South Fork Payette	North Fork Payette Boise
Malheur	Willow Cr./lower Malheur North Fork Malheur	Upper Malheur
Owyhee	Lower Owyhee Little Owyhee	S. Fk. Owyhee Upper Owyhee
Upper Snake (Snake Tributaries to Rock Creek)	Canyon Creek Lower Bruneau Upper Bruneau	Salmon Falls Rock Creek (Upper Salmon)
Kettle/Colville	Sanpoil River Kettle/Colville	Kootenay River
Spokane	Spokane River	Hangman Creek
Wet Clearwater (Upper)	Lower N. Fork Clearwater	Upper N. Fork Clearwater

6.2.1 Stray ratios

The relative abundance of strays within a population, hereafter "stray ratio", is calculated as the number of stray hatchery origin adults within a population divided by total adult abundance in that population. Estimates can be obtained either by direct total counts, or as estimated total counts. Secondarily, information on the origin of strays is useful in identifying the spatial extent of straying and the types of hatcheries and/or individual facilities that contribute to observed stray ratios to the greatest degree. The primary source of data for calculation of stray ratios are coded wire tags (CWTs) and external marks such as fin clips. While marking rates are very high for some hatchery programs, they are not always 100 percent therefore requiring estimates of the proportion of marked fish to account for unmarked hatchery origin fish within the population. Data to calculate the proportion of hatchery origin fish is obtained from either direct counts at traps/weirs, from sub-samples of fish at a trap/weir, or from carcass surveys. For supplemented populations, the proportion of stray hatchery fish must be estimated by further examination of the mark/tag information. The estimated number of strays is then divided by the corresponding escapement estimate, to obtain the stray ratio.

As a first step in design development we evaluated the strengths and weaknesses of CWT information (section 6.2.1.1–6.2.1.3). Secondly we evaluated the precision of stray ratio estimates under a range of assumptions (6.2.1.4–6.2.1.7).

6.2.1.1 Strengths and weaknesses of existing CWT Data

The external mark most widely used to identify hatchery origin fish is removal (clip) of the adipose fin. To obtain specific information for each adult (hatchery/release location and year class), with which to differentiate stray from non-stray hatchery origin fish, fisheries managers exploit data obtained from coded wire tags (CWTs). A CWT is a small (0.25 x 1.1 mm) length of steel wire on which a digital code is printed (PSC 2005, and www.rmpc.org/cwt-program-overview.html). The CWT is implanted in the nasal cartilage of a juvenile fish, typically just prior to release. Nearly all salmon hatchery programs in the Pacific Northwest apply CWTs (and in almost all cases, an adipose fin clip as an external mark to indicate the presence of the internal CWT) to some portion of their annual production, with the CWT code for each release group being unique (Appendix 6B).

The practice of tagging hatchery origin salmon with CWTs was initiated in the Pacific Northwest in the 1970s, and was developed into a coordinated region-wide program by the early 1980s. The tagging program was created for the purpose of determining rates at which the different hatchery stocks are captured within the various ocean and in-river fisheries. Within regional fisheries a sample of fish is screened for individuals with an adipose fin clip. The snout of all adipose clipped fish is removed and shipped to a participating laboratory where they are electronically scanned for presence of a CWT. CWTs are then dissected out, and the binary code recorded for each. By agreement between essentially all federal, state, tribal and private fisheries agencies in the Pacific Northwest, from both the US and Canada, tag code information and the associated capture metadata is then reported to the Regional Mark Processing Center (RMPC), administered by the Pacific States Marine Fisheries Commission, for inclusion in the Regional Mark Information System (RMIS) database (Pacific Salmon Commission 2005, and www.rmpc.org). This publicly accessible database can be queried and the information used to estimate exploitation rates for releases from a given hatchery, as well as to provide estimates of stock composition within a given fishery (PSC 2005).

Subsequent to establishment of the CWT program for estimating distribution and fishery impacts among salmon stocks, fisheries managers decided to extend the sampling and recovery procedures to screen all adults returning to the region's hatcheries, and to the inspection of carcasses observed during spawning ground surveys. The carcasses are enumerated and the number with adipose fin clips recorded. The snouts of adipose-clipped fish are removed (possibly after electronic detection in the field for presence of a CWT) and sent to a laboratory for CWT recovery and identification. The CWT data, along with the associated survey and population escapement metadata – number of carcasses screened, estimate of total escapement (calculated from expanded redd counts or weir counts), etc. – are reported to RMPC for inclusion in RMIS. The database can then be queried and the information can potentially be used to estimate stray and non-stray ratios within escapement to streams/rivers of interest, as well as to identify the source hatcheries of these fish, and their relative proportions (PSC 2005).

6.2.1.2 Querying RMIS for stray rate information

Having identified the need to estimate ratios of stray and non-stray hatchery origin adults as part of a greater effort to assess the impacts of hatchery programs in the basin, CSMEP's Hatchery Subgroup examined the relative reliability of the stray ratio estimates obtained from the currently available information in RMIS. It was decided to limit the exercise to information to stream-type Chinook salmon. We were already aware that the database is most rich for information on these stocks. In contrast, much less information for fall Chinook and for steelhead is available in RMIS, as carcass surveys are logistically much more difficult to perform for these stocks. RMIS was queried on a "population-by-population" basis for information on each interior Columbia River Basin stream/river for which spawning ground recovery information has been reported. Individual tag data was separated into that for strays (both, in-basin stray and out-of-basin) and non-strays, and proportions of each were calculated using the associated metadata.

Detailed step-by-step query procedures used for this exercise are described in Appendix 6C. Briefly, the procedure involved logging into the RMIS Standard Reporting database, and performing a series of queries within each of the three sections within the database – "Recoveries", "Releases" and "Other":

a) the Recoveries data were queried to obtain CWT spawning ground recovery information for a specific Species, Run (e.g., spring, summer or fall) and Recovery Location (a specified stream/river). The data were copy-pasted into the first sheet within a spreadsheet file - labeled Releases.

b) data under the "Tag_Code" column was copy-pasted into a second sheet – labeled Tag Code – and a unique tag code list created.

c) the unique tag code list was pasted into the "Tag Code or Release ID" window in the "All Releases" query within the Releases section. This query returned all of the metadata associated with the release group for each tag code, and the information was copy-pasted into a third sheet within the spreadsheet - labeled Releases.

d) Data in the Recoveries and Releases tables were then merged into a new table created in a fourth sheet – labeled Merged. This combined data set was then sorted by Run Year, Release Location, and Tag Code, and summary estimates within each run year were calculated for the number of CWT recoveries per type of hatchery origin fish: in-basin non-stray, in-basin stray, and out-of-basin stray.

e) A Catch_Sample query (within the Other section) was then performed to obtain run year specific metadata for specific Species and Recovery Location, which includes the Number_Sampled. The summary estimates for numbers of hatchery origin fish (by type) are then divided by Number_Sampled to calculate the corresponding stray/non-stray ratios.

6.2.1.3. Summary Observations on CWT/RMIS Data

Results of our analyses indicate that the CWT/RMIS program has the potential to provide reliable estimates of the rates at which Columbia basin hatchery origin fish return to their stream of release, or stray into other river systems. The reliability of these estimates is dependent, however, on four conditions:

1) CWTs are applied to hatchery origin fish at relatively high rates;
2) carcasses are randomly sampled during spawning ground surveys and with sufficient intensity;
3) recovery effort is distributed in a representative manner across supplemented and un-supplemented populations; and
4) CWT data collected from the snouts is faithfully reported to RMPC along with appropriate metadata for inclusion in RMIS.

A prerequisite to these analyses, of course, is a clear definition of the conditions which define a hatchery origin fish as a stray or non-stray. Prior to calculating stray and non-stray ratios, it was essential that we define how hatchery origin fish are classified into one or the other category. In our analyses we classified supplementation hatchery origin fish returning as adults to the spawning grounds of the stream/river into which they were released, as “non-strays.” “Strays” were classified as either “in-basin strays” – fish released from a harvest augmentation hatchery operated within the stream/river of concern - or as “out-of-basin strays” – returns from a hatchery program, supplementation or harvest augmentation program, located outside the subbasin of concern. Of note, we do recognize that our definitions might differ from those of other agencies.

A population-by-population summary of stray ratios is provided in Appendix 6D. Summary observations from our survey of data for Columbia/Snake basin Chinook populations include:

a) Definition of returning hatchery origin adults as strays or non-strays must be well described to avoid use of the terms in comparisons which might not be operating with the same definitions and presumptions.
b) Supplementation hatchery programs generally apply CWTs at very high rates (>95%), while tagging rate for harvest augmentation programs is much lower (generally, 10% to 50%) – see Appendix 6B.
c) With the exception of the Yakima River, data in RMIS for ocean and stream-type Upper Columbia Chinook salmon, is relatively abundant, and annual estimates for stray and non-stray ratios appear relatively reliable. Likewise, data for stream-type Chinook salmon in the Tucannon River is abundant and provides relatively good estimates. However, in all other rivers (which comprise the majority of stream-type Chinook salmon populations within the Columbia/Snake basin), there are substantial deficiencies in the sampling and/or reporting of CWT recovery information, which preclude valid estimates of stray and non-stray ratios over consecutive years.
d) Where data are available, analysis indicates that stream-type Chinook salmon populations generally do not experience a high rate of out-of-basin straying - typically, the rate is well below 5% – a level sometimes cited as one which should not be exceeded (e.g., Grant 1997).
e) Out-of-basin strays of Upper Columbia ocean-type Chinook salmon to the Wenatchee River occur at a very low rate, while out-of-basin strays to the Methow and Okanogan rivers are much more frequent.

To estimate the number and proportion of hatchery origin fish within the natural spawning population in a given stream/river, the RMIS database can be queried for data on CWTs recovered from carcasses in spawning ground surveys ("Fishery" = #54 – "Spawning Ground"). The value of each recovery is expanded (#/recovery) according to the tagging rate for that particular hatchery release group, and the recoveries are categorized as in-basin non-strays, in-basin strays or out-of-basin strays. The expanded values are then summed within categories, and divided by the total number of carcasses screened for adipose clips/CWTs (Number_Sampled) to obtain the different stray/non-stray ratios. Validity of this procedure rests on the assumption that screening for CWTs among the carcasses is a random process – an assumption which should be confirmed through an inquiry addressed to the associated management agency. For example, in the case of Umatilla stream-type Chinook salmon, *post facto* to our analysis, we learned that surveying of carcasses during spawning ground surveys was not random - that it was biased in a manner which underrepresented out-of-basin hatchery strays - and therefore invalidated our estimates of stray ratios for this population.

As a reminder, the stray/non-stray ratios calculated in this manner, must not be construed to represent escapement rates to the river, but of the naturally spawning population. In some systems, in-river mark selective fisheries occur, as well as broodstock collection and culling of hatchery origin fish at a downstream trap/weir. These activities may substantially decrease the number of hatchery origin fish. Also, one must remember to take into consideration changes which occur over time in these in-river management practices, when assessing trends in historical stray/non-stray ratio data.

Availability of CWT and survey metadata in RMIS varies substantially across the Columbia basin. While data sets in RMIS for Upper Columbia spring and summer Chinook appear relatively regular and complete, such is generally not the case for the Mid-Columbia and the Snake River regions. In some cases, substantial recovery data are available in RMIS, but the associated Catch/Sample data is missing or incomplete (e.g., for the Imnaha, Grande Ronde, Clearwater and Salmon rivers). In other cases, both recovery and catch/sample data are essentially non-existent (e.g., for the Wind, Deschutes, and John Day rivers). Likely, some of the missing metadata is available in agency technical reports, however, obtaining it will require additional effort. In addition, it may be necessary to query agency personnel for additional information which may not be explicitly stated in reports (e.g., descriptions of carcass survey and sampling procedures). Lastly, data in RMIS tends to be 2-3 years "out-of-date". For example, the analyses reported here were performed in early 2007, however, very few rivers had recovery data more recent than 2004.

6.2.1.4 Precision of Stray Ratio Estimates Using CWT Data

We developed a model to estimate the fraction of stray and non-stray hatchery origin adults in a section of spawning habitat, based on examining a sample of n carcasses for existence of CWTs. The model depends on the number of hatchery fish found with CWT, the probability of finding a CWT given that a fish has one, and the probability of CWT retention.

Model parameters are defined as:

m = proportion of hatchery fish marked with CWT (Coded Wire Tag) before release.

n = sample size consists of n carcasses.

x = number of fish found to have CWT. These individuals are known to be hatchery fish.

f = probability of finding CWT given that the fish has one.

r = probability of CWT retention.

The sensitivity analysis allowed f to vary from 0.75 to 1 and r varied from 0.95 to 1, both with uniform distributions on the respective intervals.

Given that a fish is from the hatchery, the estimated probability of observing that the hatchery fish has a CWT is $\hat{p}_h$ = m*r*f.

Estimated number of hatchery fish in the sample of size n is $\hat{X}$ = x / $\hat{p}_h$.

Estimated stray ratio (proportion of hatchery fish on the spawning ground) is $\hat{S} = \hat{X} / n$.

Let S be the proportion of hatchery fish on the spawning ground or stray ratio. The simulation is started with an initial value of S. The expected number of hatchery fish in the sample of n is n*S. If X is the random variable associated with the event of observing a CWT in n*S hatchery fish, then X has a binomial distribution with number of trials equal to n*S and probability of 'success' equal to $\hat{p}_h$. The distribution of X is denoted by X~ Bin (n*S, $\hat{p}_h$).

The sensitivity analysis studies the properties of the estimator, $\hat{S} = \hat{X} / n$, with different values of S, m and n. As the 'true' value of S is known, we can also compute the Bias and Mean Square Error related to $\hat{S} = \hat{X} / n$.

The simulation is started by assigning some known value to S, m and n. For each replication, a random number is assigned to f from 0.75 to 1 and to r from 0.95 to 1. Using these numbers we can calculate $\hat{p}_h$ for each replication. Next, randomly generate one number for X~ Bin (n*S, $\hat{p}_h$). The value of the random variable, x, is a realization of the number of hatchery fish found to have a CWT. Compute $\hat{X}$ = x / $\hat{p}_h$ and $\hat{S} = \hat{X} / n$. For fixed values of S, m and n, repeat 1000 replications of the simulation. Finally, compute the Mean, Standard Error (standard deviation of the 1000 values), Bias, Mean Square Error (= bias squared + variance), and Coefficient of Variation of $\hat{S} = \hat{X} / n$.

6.2.1.5 Results of CWT model

Tables 6.6a through 6.6f summarize the statistics for $\hat{S} = \hat{X} / n$: Mean, Standard Error, Mean square Error, Bias and Coefficient of variation. As n (sample size) and m are increased, the mean of $\hat{S} = \hat{X} / n$ is approximately equal to the 'true' value of S. The Mean square error, Bias and Coefficient of variation decrease with increases in n and m.

Table 6.6a. Properties of the estimated proportion of the hatchery strays when the **true stray proportion is 0.05**. Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.048082	0.05115647	0.050003
marked fish	0.5	0.05079	0.04991963	0.049547
	0.75	0.050435	0.04955408	0.050194
	1	0.050244	0.04969326	0.050008
SD	0.25	0.066319	0.04349887	0.030781
marked fish	0.5	0.041365	0.02679111	0.018178
	0.75	0.026286	0.01668259	0.011923
	1	0.014554	0.00912574	0.006672
MSE	0.25	0.004402	0.00189349	0.000947
marked fish	0.5	0.001712	0.00071777	0.000331
	0.75	0.000691	0.00027851	0.000142
	1	0.000212	8.34E-05	4.45E-05
Bias	0.25	-0.00192	0.00115647	2.61E-06
marked fish	0.5	0.00079	-8.04E-05	-0.00045
	0.75	0.000435	-0.0004459	0.000194
	1	0.000244	-0.0003067	8.07E-06
CV	0.25	1.379289	0.8503103	0.615587
marked fish	0.5	0.814428	0.5366849	0.366888
	0.75	0.521189	0.3366542	0.237535
	1	0.289663	0.1836413	0.13341

Table 6.6b. Properties of the estimated proportion of the hatchery strays when **the true stray proportion is 0.1.** Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.094123	0.099543	0.100074
marked fish	0.5	0.101089	0.1008553	0.1009
	0.75	0.100654	0.09879863	0.099235
	1	0.100124	0.100988	0.099804
SD	0.25	0.093685	0.06012909	0.040862
marked fish	0.5	0.059851	0.03598012	0.025552
	0.75	0.039183	0.02363033	0.016601
	1	0.021755	0.01276224	0.0094
MSE	0.25	0.008811	0.00361572	0.00167
marked fish	0.5	0.003583	0.0012953	0.000654
	0.75	0.001536	0.00055984	0.000276
	1	0.000473	1.64E-04	8.84E-05
Bias	0.25	-0.00588	-0.00045701	7.44E-05
marked fish	0.5	0.001089	8.55E-04	0.0009
	0.75	0.000654	-0.00120137	-0.00077
	1	0.000124	0.00098795	-1.96E-04
CV	0.25	0.995345	0.6040515	0.408315
marked fish	0.5	0.592064	0.3567498	0.253237
	0.75	0.389283	0.2391767	0.167292
	1	0.21728	0.1263739	0.09419

Table 6.6c. Properties of the estimated proportion of the hatchery strays when **the true stray proportion is 0.2**. Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.2086341	0.200575	0.200624
marked fish	0.5	0.1986315	0.198314	0.199892
	0.75	0.1999828	0.197439	0.200544
	1	0.1996726	0.199046	0.199848
SD	0.25	0.1408767	0.088226	0.059995
marked fish	0.5	0.08392496	0.054	0.037997
	0.75	0.05513883	0.033576	0.023766
	1	0.02928507	0.019237	0.013215
MSE	0.25	0.01992081	0.007784	0.0036
marked fish	0.5	0.00704527	0.002919	0.001444
	0.75	0.00304029	0.001134	0.000565
	1	0.00085772	3.71E-04	1.75E-04
Bias	0.25	0.00863408	0.000574	6.24E-04
marked fish	0.5	-0.0013685	-1.69E-03	-0.00011
	0.75	-1.72E-05	-0.00256	0.000544
	1	-0.0003274	-0.00095	-1.52E-04
CV	0.25	0.6752337	0.439869	0.299043
marked fish	0.5	0.4225157	0.272298	0.190087
	0.75	0.2757178	0.170055	0.11851
	1	0.1466655	0.096643	0.066126

Table 6.6d. Properties of the estimated proportion of the hatchery strays when the **true stray proportion is 0.5.** Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.504373	0.5008964	0.496363
marked fish	0.5	0.494172	0.5006415	0.50023
	0.75	0.502199	0.4984381	0.499182
	1	0.502048	0.4997899	0.500444
SD	0.25	0.215355	0.1347637	0.093429
marked fish	0.5	0.131841	0.08011274	0.056757
	0.75	0.085806	0.05152929	0.036993
	1	0.047138	0.02935578	0.020966
MSE	0.25	0.046397	0.01816207	0.008742
marked fish	0.5	0.017416	0.00641846	0.003221
	0.75	0.007368	0.00265771	0.001369
	1	0.002226	8.62E-04	4.40E-04
Bias	0.25	0.004373	0.00089637	-3.64E-03
marked fish	0.5	-0.00583	6.42E-04	0.00023
	0.75	0.002199	-0.00156191	-0.00082
	1	0.002048	-0.00021012	4.44E-04
CV	0.25	0.426976	0.2690451	0.188228
marked fish	0.5	0.266792	0.1600202	0.113461
	0.75	0.170861	0.1033815	0.074107
	1	0.093891	0.05873625	0.041895

Table 6.6e. Properties of the estimated proportion of the hatchery strays when the true stray proportion is 0.75. Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.7549724	0.750431	0.750732
marked fish	0.5	0.7480057	0.748793	0.749309
	0.75	0.7542716	0.747206	0.751619
	1	0.7522773	0.748127	0.750485
SD	0.25	0.2662436	0.162867	0.116597
marked fish	0.5	0.1589439	0.101139	0.070813
	0.75	0.100038	0.064827	0.047107
	1	0.06004453	0.037211	0.027395
MSE	0.25	0.07091038	0.026526	0.013595
marked fish	0.5	0.02526715	0.010231	0.005015
	0.75	0.01002584	0.00421	0.002222
	1	0.00361053	1.39E-03	7.51E-04
Bias	0.25	0.00497244	0.000431	7.32E-04
marked fish	0.5	-0.0019943	-1.21E-03	-0.00069
	0.75	0.00427157	-0.00279	0.001619
	1	0.00227726	-0.00187	4.85E-04
CV	0.25	0.3526534	0.217031	0.155312
marked fish	0.5	0.2124903	0.135069	0.094504
	0.75	0.1326286	0.08676	0.062674
	1	0.07981702	0.049739	0.036503

Table 6.6f. Properties of the estimated proportion of the hatchery strays when the true stray proportion is 1.0. Proportions of hatchery fish marked are 0.25, 0.5, 0.75 and 1.0. The proportion of tagged fish retaining the CWT is uniform on the interval 0.95 to 1.0 and the proportion of the tags detected given that CWT is present is uniform in the interval 0.75 to 1.0. Results are based on 1000 parametric simulations of the estimator

$\hat{S} = \frac{\hat{X}}{n} = \frac{x/n}{\hat{p}_h}$, where $\hat{X}$ is estimated number of hatchery fish in the sample of size n and $\hat{p}_h$ is estimated probability that hatchery fish in the sample of size n will be observed.

		Sample size		
		40	100	200
Mean	0.25	0.9929	0.996685	1.003169
marked fish	0.5	1.011694	1.004613	0.998173
	0.75	0.999599	1.001111	1.000279
	1	1.000483	1.00317	0.998719
SD	0.25	0.316374	0.1955638	0.135731
marked fish	0.5	0.182412	0.118516	0.083254
	0.75	0.120745	0.07534261	0.054482
	1	0.067418	0.04193428	0.029635
MSE	0.25	0.100143	0.03825617	0.018433
marked fish	0.5	0.033411	0.01406732	0.006935
	0.75	0.014579	0.00567774	0.002968
	1	0.004545	1.77E-03	8.80E-04
Bias	0.25	-0.0071	-0.00331507	3.17E-03
marked fish	0.5	0.011694	4.61E-03	-0.00183
	0.75	-0.0004	0.00111122	0.000279
	1	0.000483	0.00317006	-1.28E-03
CV	0.25	0.318637	0.1962142	0.135302
marked fish	0.5	0.180303	0.1179718	0.083406
	0.75	0.120793	0.07525898	0.054467
	1	0.067385	0.04180177	0.029673

6.2.1.6 Finite Population Correction Factor

The simulation did not have a correction for the variance of $\hat{S} = \hat{X}/n$, when the proportion of carcasses examined, n, is 'large' compared to the total number of spawners on the spawning ground. Let N denote the total number of spawners on the spawning ground. In general the value of N will be unknown, however if N can be estimated then the variance of $\hat{S} = \hat{X}/n$ should be multiplied by the approximate finite population correction factor $(1-n/N)$, The CV should be reduced by approximately the multiplication factor equal to the square root of $\sqrt{(1-n/N)}$. For example if N = 100 and n = 40, then the finite population correction factor is (1 – 0.4) = 0.6. The estimated variance of $\hat{S} = \hat{X} / n$ should be multiplied by 0.6 (approximately), and the CV should be multiplied by 0.77 (approximately).

6.2.1.7 Conclusions Regarding Sufficiency of Existing Information for Stray Ratio Calculations

Existing CWT information was demonstrated to suffer from four weaknesses:

1) When CWTs are applied to less than 100% of hatchery origin juveniles, recovered tags must be "expanded" based on the mark rate, adding uncertainty to stray ratio estimates;
2) In many cases, it appears that mark recovery effort is either unrepresentative or insufficient to estimate stray ratios;
3) Recovery effort appears to be focused in supplemented populations, and thus may not represent stray ratios in un-supplemented populations;
4) CWT recovery data are not reported in a consistent fashion, and in most locations sufficient descriptions are not available to enable stray ratio estimates.

Very little information is available to inform decisions regarding "acceptable" stray ratios. Grant (1997) suggests that stray ratios should not exceed approximately 0.05. Predictably, the precision of stray ratio estimates decreased as the actual stray ratio decreased, as mark rates decreased, and as recovery effort decreased. Our sensitivity analysis suggested that the CV of stray ratio estimates might be expected to range from 1.38 to 0.13 when the "true" stray ratio is 0.05. Notably, the CV estimates were generated under the assumption that recovery data were accurately reported, a condition that appears unrealistic from our review.

6.2.2 Reproductive success of naturally spawning hatchery origin fish

Both supplementation and harvest augmentation hatcheries are intended to increase the abundance of adults, most commonly by using the protected environment of the hatchery to increase survival from the adult to juvenile life history stage, and less commonly by "captive rearing" wherein juveniles are reared in captivity until maturity and either spawned in captivity or released into targeted habitat for spawning. In the case of supplementation hatcheries, juveniles are released in targeted habitat in hopes that upon return as hatchery origin "non-strays" they will contribute to natural production; and in some cases provide harvest opportunities. However, numerous mechanisms have been proposed that suggest hatchery rearing may decrease the reproductive potential of hatchery origin adults and that losses in fitness owing to hatchery rearing may be transferable to natural populations when hatchery origin adults are allowed to spawn naturally. Thus, for supplementation programs, it is of interest to know whether *per capita* productivity of the naturally spawning component of the population increases, decreases, or remains unchanged during and following supplementation. For example, a possible result of supplementation is that the benefits of increased abundance might be offset by a loss of *per capita* productivity within the targeted natural population, or increased risk of extinction owing to increased variance in individual reproductive success. Alternatively, in the case of harvest augmentation hatcheries, adults in excess of broodstock requirements are intended strictly for harvest and not natural spawning. For both types of hatcheries, it is of interest to know whether progeny that stray into non-target populations negatively influence productivity of the non-target population. At a coarse level, the reproductive success of hatchery origin fish, and their frequency in non-target populations, could be indicators of the magnitude of risk posed by hatcheries to non-target populations.

The greatest uncertainty accompanying the operation of hatcheries regards the impacts of hatchery origin adults on the productivity of target and non-target populations. Numerous existing and proposed hatchery research, monitoring, and evaluation (RME) projects have been designed to assess long-term changes in productivity, however these efforts typically focus only on the target population(s), and thus provide little information to evaluate potential impacts on non-target populations. Likewise, an observed change in productivity when assessed using common performance metrics such as juveniles per adult or adult per adult ratios is only sufficient to indicate that a change occurred, but may yield very little information with which to determine why the change occurred. For example, if a decrease in *per capita* productivity were observed, it might be difficult or impossible to determine whether that result was a function of some deleterious impact accompanying supplementation, or any number of other alternatives such as a reduction in habitat quality or density dependence. Molecular genetic techniques can be employed to directly estimate the amount of production that can be attributed to individual naturally spawning hatchery origin adults relative to individual natural origin adults (relative reproductive success; RRS), thus enabling a direct evaluation of the impacts of hatchery origin adults on *per capita* productivity. Although some evidence suggests that the RRS of hatchery origin adults may decrease as the density of natural origin spawners increases (Fleming and Gross 1993), the ability to decompose reproductive output using genetic methods limits the number of factors that might otherwise confound the interpretation of results. For example, any change in habitat conditions, either positive or negative, would be assumed to equally impact the reproductive success of all adults utilizing that habitat, regardless of their origin. Thus, a decrease in habitat quality might lower total productivity, but would not be expected to change RRS. In the absence of genetically-based measures of RRS, a change in productivity resulting from a decrease in habitat quality might otherwise be wrongly attributed to supplementation. Likewise, if no change or an increase in productivity was observed following an improvement in habitat, deleterious impacts that might accompany supplementation could go unnoticed. In short, we elected to use genetically-based estimates of RRS to limit the impacts of environmental factors that might otherwise confound our analyses.

As described previously, populations of stream-type Chinook salmon in the Columbia River Basin exist as a continuum, ranging from populations that are heavily hatchery influenced to those that have relatively minor hatchery influence. A given population may be targeted by a supplementation program and/or receive *de facto* supplementation in the form of stray hatchery origin adults arising from harvest augmentation and/or supplementation programs. A quick review of available information showed that:

1. stray hatchery origin adults have been identified in nearly every population that is routinely surveyed;
2. populations that are targeted for supplementation also receive stray hatchery origin adults;
3. supplementation programs exhibit exceptional variance in the guiding principles and assumptions that underlie their operation; and
4. very little quantitative data appears to exist regarding the reproductive success of hatchery origin adults either when they return to their target population or when they stray.

These conclusions suggest that information relating to the impacts of hatchery origin adults on receiving populations is lacking and remains a critical uncertainty. In addition, it is possible that the impacts of strays vary based on the management of the hatchery where they originated.

Aside from the impacts of strays on receiving populations, the basic premise of supplementation rests on three critical assumptions:

1. that the hatchery program increases the abundance of naturally spawning adults by reducing early life history mortality;

2. that the reproductive success of returning hatchery origin adults, when they spawn under natural conditions, is similar to their natural origin conspecifics (e.g., *per capita* productivity is not reduced); and
3. that losses in reproductive contribution resulting from hatchery rearing, if manifested, are not cumulative.

Although not ubiquitous, the potential for hatcheries to return a greater number of adults than natural production alone is well established. However, quantified measures of the contribution of hatchery origin adults to natural production, and the subsequent survival of their naturally spawned progeny are rare, with the exception of a limited number of projects for which parentage analyses based on molecular genetics techniques have been employed to determine whether natural origin adults are themselves the progeny of hatchery or natural origin adults, or a cross. Thus, even in circumstances where supplementation is associated with increases in adult abundance, one cannot assume that pre-supplemented rates of productivity are maintained. The effectiveness of supplementation hatcheries as a means to decrease extinction risk by providing short term increases in abundance must therefore be evaluated relative to possible long term deleterious effects on productivity of the natural population. This evaluation requires information on the relative reproductive success of hatchery versus natural origin individuals. For example, if an improvement in survival is realized by hatchery rearing and the reproductive success of hatchery origin individuals is similar to or slightly lower than natural origin individuals, supplementation might be considered beneficial owing to its ability to quickly decrease demographic risk and limit the loss of genetic diversity of natural populations that suffer from low abundance. Alternatively, if the reproductive success of hatchery origin individuals is so low that it offsets demographic or genetic benefits; and/or variance in reproductive success contributes significantly to extinction risk, supplementation would be considered counter-productive.

Not surprisingly, numerous attempts have been made to identify the features associated with hatchery rearing that might contribute to a loss of fitness. These attempts have led to changes in hatchery management ranging from alteration of the physical environment of hatcheries to more closely resemble natural conditions (Maynard *et al.* 2003) to changes in broodstock collection and escapement management as a means to limit artificial selection (HSRG 2004). While most of the recommendations to improve hatchery practices have been non-uniformly implemented, in recent years, most hatchery programs have adopted policies that dictate the fraction of natural origin adults used for broodstock and place limits on the escapement of hatchery origin adults to natural spawning areas. These broodstock management and escapement policies thus provide a means to categorize hatchery programs.

6.2.2.1 Categorizing Columbia River Basin Populations

Given the diversity of broodstock management and escapement protocols utilized by Columbia River Basin hatchery programs, we propose to categorize populations using mean “proportion natural influence” (PNI) scores. PNI is calculated as (HSRG 2004):

$$PNI = \frac{pNOB}{pNOB + pHOS}$$

where, pNOB is the proportion of naturally produced fish used as broodstock, and pHOS is the proportion of first generation hatchery origin fish on the spawning grounds.

Populations influenced by hatchery programs that use a smaller proportion of natural origin fish in the broodstock (low pNOB), and experience a large number of hatchery origin adults in the spawning escapement (high pHOS), will have smaller PNI scores, and vice-versa. Through collaboration with the

Ad Hoc Supplementation Workgroup (AHSWG), we have summarized mean PNI scores for the interior Columbia River Basin populations (Table 6.7) as delineated by the Interior Columbia River Basin Technical Recovery Team (ICTRT 2005) for which data are available.

Table 6.7. Summary PNI statistics for targeted stream-type Chinook populations of the interior Columbia River Basin.

Population	Proportion Natural Influence*				
	Mean	Max	Min	Std. Dev.	CV (%)
Northeast Oregon					
Lostine (Carcass)	0.74	0.93	0.47	0.16	28
Lostine (Escapment Est.)	0.74	0.80	0.52	0.11	23
Lostine/Wallowa	0.75	0.93	0.49	0.16	27
Imnaha (Carcass)	0.42	0.86	0.16	0.18	54
Imnaha (Escapment Est.)	0.34	0.68	0.08	0.17	57
Upper Grande Ronde (Carcass)	0.77	1.00	0.22	0.34	40
Upper Grande Ronde (Escapement Est.)	0.78	1.00	0.36	0.29	36
Catherine Creek (Carcass)	0.75	0.89	0.53	0.14	29
Catherine Creek (Escapement Est.)	0.76	0.82	0.56	0.09	25
Lower Snake					
Tucannon	0.64	1.00	0.01	0.25	44
Salmon					
Pahsimeroi River	0.17	0.53	0.00	0.18	114
Upper Salmon -above Redfish Lake Creek	0.43	0.88	0.00	0.38	84
South Fork Salmon above weir	0.15	0.29	0.00	0.11	73
Johnson Creek	0.78	0.81	0.64	0.06	15
Clearwater (Wet)					
South Fork Clearwater	0.00	0.01	0.00	0.00	189
Lochsa	0.00	0.00	0.00	0.00	0
Upper Columbia					
Chiwawa	0.57	1.00	0.28	0.25	54
Twisp	0.50	0.67	0.00	0.31	80
Chewuch	0.28	0.42	0.00	0.14	130
Methow	0.10	0.34	0.00	0.12	167

*Note: PNI estimates for Northeast Oregon streams varied depending on whether calculations were based on carcass recoveries, redd count expansions, or adult counts.

6.2.2.2 Conclusions regarding the sufficiency of available information to assess RRS of hatchery origin adults in target and non-target populations

Within the stream-type Chinook salmon populations that we surveyed, several populations have completed or ongoing RRS studies (Table 6.8). The range of mean PNI values across Columbia River Basin hatcheries appears to be represented by these programs, however the specifics of these studies will be evaluated by CSMEP in 2008 to further evaluate the sufficiency of information that they might provide for a regional analysis.

Table 6.8. Summary PNI statistics for targeted stream-type Chinook populations of the interior Columbia River Basin with completed or ongoing RSS studies.

Population	Proportion Natural Influence				
	Mean	Max	Min	Std. Dev.	CV (%)
Northeast Oregon					
Lostine	0.74	0.93	0.47	0.16	28
Upper Grande Ronde	0.77	1.00	0.22	0.34	40
Lower Snake					
Tucannon	0.64	1.00	0.01	0.25	44
Salmon					
Pahsimeroi River	0.17	0.53	0.00	0.18	114
Upper Salmon -above Redfish Lake Creek	0.43	0.88	0.00	0.38	84
Upper Columbia					
Methow	0.10	0.34	0.00	0.12	167

6.3 Results

In order to generate information on stray ratios and reproductive success of hatchery origin adults for stream-type Chinook salmon populations of the interior Columbia River Basin, with which to evaluate effectiveness of the hatchery programs, we developed three alternative monitoring and evaluation designs– low, medium, and high. Each of the proposed design alternatives was required to meet the following objectives:

1. sampling must be representative of the diversity of Columbia River Basin stream-type Chinook salmon populations and/or hatchery programs;
2. designs must enable strong and statistically valid inferences for un-sampled populations/hatcheries;
3. designs must be logistically feasible; and
4. designs must use existing sampling effort to the greatest possible degree.

6.3.1 Stray ratio designs

Following interim guidance from NOAA Fisheries, our designs target the ability to detect a stray ratio as small as 5% (Grant 1997) with a coefficient of variation equal to or less than 10% in all populations (Jordan et al. 2003 page 100). If we assume that all hatchery origin adults are 100% externally marked with an adipose fin clip and that 50% of hatchery origin adults are marked with a CWT and that recovery data are perfect (e.g., CWT detection is 100%), simulations suggest that existing (*status quo*) recovery efforts will return stray ratio estimates with a coefficient of variation between 13% and 81%, depending on survey effort, when the true stray ratio is 5% (see section 6.2.1.5). If the total number of carcasses can be estimated (e.g., via sight/re-sight methods) the CV improves slightly, potentially yielding CVs in the range of 10% to 79%. Nonetheless, once all sources of error are accounted for, the precision accompanying stray ratio estimates based on *status quo* sampling is unlikely to meet the precision criterion developed by Jordan et al. (2003) to make sound management decisions.

CSMEP design alternatives to estimate stray proportions at the population and basin scale will utilize a rotating panel design that will distribute effort in a systematic-random fashion both spatially and temporally in all major population groups. Each of the designs (Figure 6.1) estimate stray ratios for all populations in the interior Columbia Basin, but differ with regard to the frequency of sampling. The low design estimates stray-ratios in one population within each MPG annually using carcass surveys, with the remaining populations sampled approximately every third year using a rotating panel design. The medium design maintains annual sampling in one population and increases the frequency of sampling to approximately every two years in the remaining populations. Additionally, from among the populations sampled annually, the medium design requires bi-directional weirs to be operated on three of the populations in order to estimate precision and bias in carcass survey techniques. The high design builds on the medium design by employing one bi-directional weir in each of the eight interior Columbia River Basin MPGs. Objectives by alternatives evaluations for these CMSEP stray ratio designs are presented in Table 6.9.

Table 6.9. Objectives by alternatives matrix for stray ratio design alternatives. For the purposes of cost estimation, the study is assumed to have a ten year duration. Cost estimates include total annual cost, percentage of total annual cost covered by existing programs (e.g., weirs currently operated under other projects), and total annual cost adjusted for existing effort (i.e., net "new" expenditures). Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3 = good; 2 = fair; 1= poor; ?= Unknown; n.a. not applicable.

		Design Alternatives			
Design objectives	Performance measures	Status Quo	Low	Med	High
Inferential ability (Qualitative)	Ability to representatively estimate stray ratios and origin of strays	(1)	(3) provides only ratios	(4)	(4)
	Frequency of sampling	Varies	(3)	(4)	(4)
Cost (x $1,000)	Average total annual cost	n.a.	$357,000	$551,000	$873,000
	(% of cost covered by existing operations)		(85%)	(60%)	(50%)
	Adjusted total annual cost		$54,000	$220,000	$437,000
Statistical Reliability (N)	Bias estimation	(1)	(3)	(4)	(5)
	Maintain coefficient of variation < 0.2	(1)	(3)	(4)	(4)

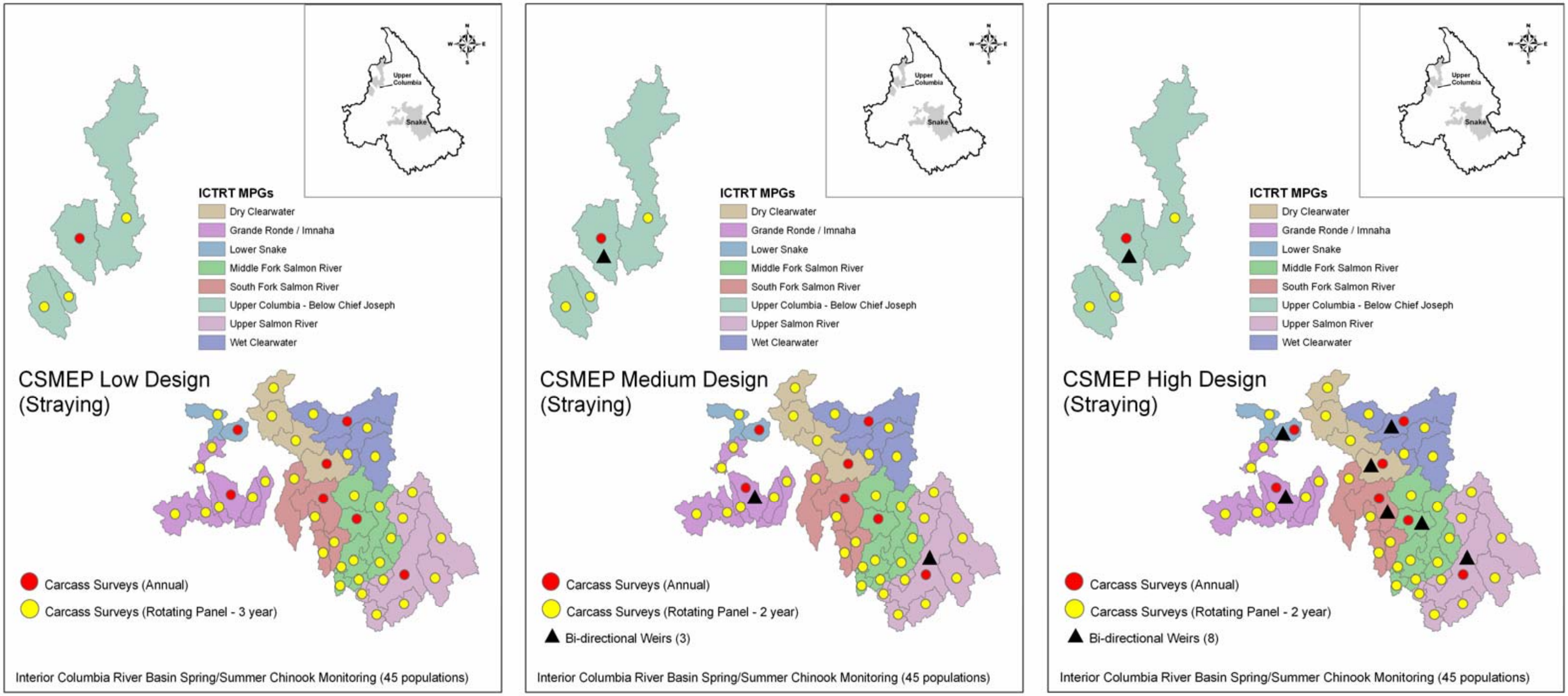

Figure 6.1. CSMEP design alternatives for monitoring hatchery stray ratios for Columbia River Basin populations. The specific mapped locations of carcass surveys and bi-directional weirs within the rotating panel designs are only illustrative at this point and would be determined at a later date.

6.3.2 Relative reproductive success

The CSMEP designs (Figure 6.2) seek to evaluate RRS in target and non-target populations selected to represent the range of hatchery management policies in the interior Columbia River Basin. A few RRS studies are underway or proposed, however they were selected opportunistically and are unlikely to represent the range of hatchery management policies. Given the diversity of broodstock management and escapement protocols utilized by supplementation programs, we ranked populations based on their mean "proportionate natural influence" (PNI) scores for target populations (Table 6.6) and by stray ratio for non-target populations.. We propose to distribute RRS efforts across the range of population mean PNI values using a systematic random approach, thus enabling the results of the studies to be applied to the collection of supplemented Columbia River Basin population whether or not all are included in the study. Inferences to individual supplemented populations, that are not included in the study, can be made by use of models developed from observed data. Objectives by alternatives evaluations for these CMSEP relative reproductive success designs are presented in Table 6.10.

Table 6.10. Objectives by alternatives matrix for the relative reproductive success designs. The ten year duration of the designs is sufficient to return RRS estimates for three brood years of stream-type Chinook salmon. The 'Low' design is based on parent to progeny ratios, and thus has a five year sampling duration as opposed to a ten year sampling duration for the 'Medium' and 'High' designs, which require parent to progeny and recruit per spawner ratios. Per site sampling costs for the 'Low', 'Medium', and 'High' designs are identical for the first three years, in subsequent years the 'Low' design costs decrease because only juveniles are sampled and the operation of weirs can be discontinued (for the purposes of this study). Cost estimates include total annual cost, percentage of total annual cost covered by existing programs (e.g., weirs currently operated under other projects), and total annual cost adjusted for existing effort (i.e., net "new" expenditures). Qualitative evaluations (Q): 5 = excellent; 4 = very good; 3 = good; 2 = fair; 1 = poor; ? = Unknown; n.a. not applicable.

Design objectives	Performance measures	Design Alternatives			
		Status Quo	Low	Med	High
Inferential ability (Qualitative)	Ability to representatively estimate relative reproductive success across PNI	n.a. or ?	(3) Adult to juvenile only	(4)	(4)
	Ability to estimate RRS of strays in non-target populations	1	(3) Hatchery influenced only	(3) Hatchery influenced only	(5) Supplemented and un-supplemented
	Life stage specific impact assessment	Varies	(3) Juvenile/Adult	(5) Juvenile/Adult and Adult/Adult	(5) Juvenile/Adult and Adult/Adult
Cost	Average total annual cost	N/A	$241,000	$469,000	$938,000
	(% of cost covered by existing operations)		(85%)	(85%)	(42%)
	Adjusted total annual cost		$36,000	$70,000	$544,000
Statistical Reliability (N)	Robust to changes in overall productivity	N/A	(3)	(3)	(5)

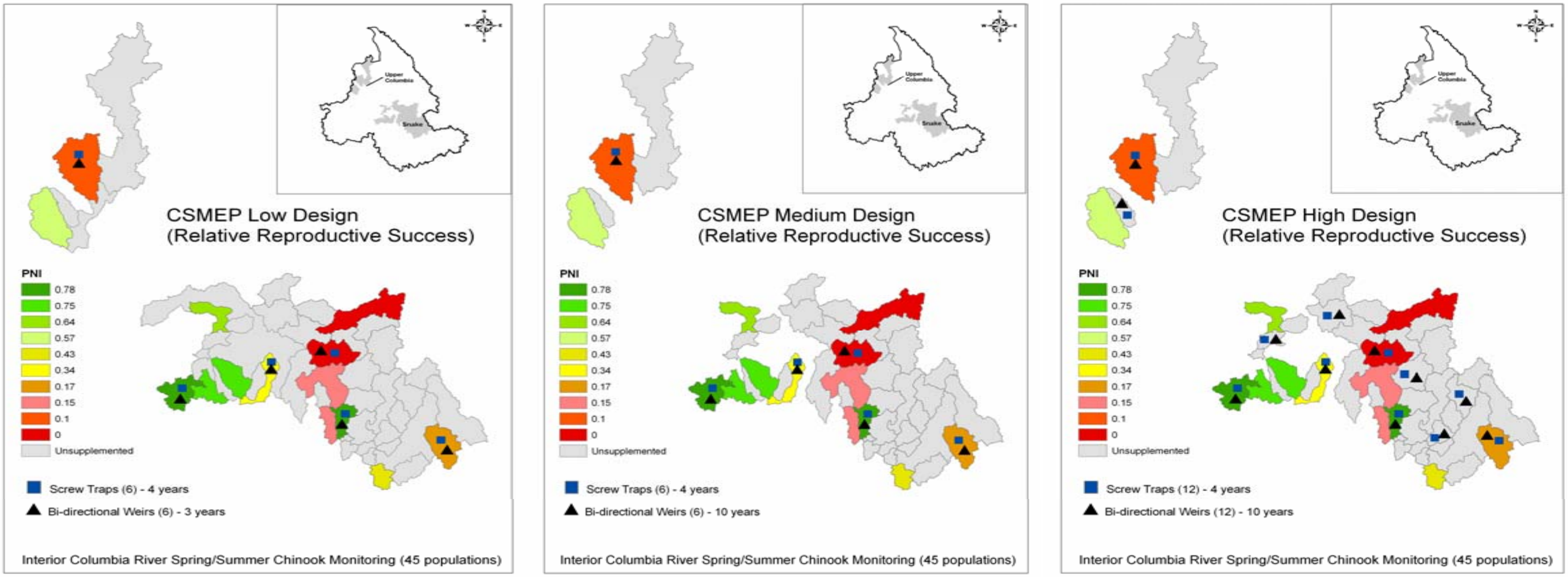

Figure 6.2. CSMEP design alternatives for monitoring relative reproductive success (RRS) of Columbia River Basin populations. The specific mapped locations of screw traps and bi-directional weirs are only illustrative at this point and would be determined at a later date.

6.3.2.1 RRS Low Design

The proposed low design estimates RRS for six deliberately supplemented (target) populations apportioning juvenile production to naturally spawning hatchery and natural origin adults. The resulting information allows estimation of the number of juvenile emigrants per adult spawner separately for naturally spawning hatchery and natural origin adults. In order to estimate variance in RRS within supplemented populations, at least three consecutive broods should be sampled. This would require the operation of adult weirs in each of the study streams for a period of three years, during which tissue samples would be taken non-lethally from every (or nearly every) adult allowed to escape for natural spawning. Juvenile rotary screw traps would be operated in each study stream for a period of four years to sub-sample the juvenile progeny of sampled adults (Table 6.11). Methods to estimate the number of juveniles that must be sub-sampled are under development and will be a CSMEP product in 2008. Molecular genetics methods would then be used to assign sampled juveniles to one or more of the adult spawners.

Table 6.11. Sampling activities associated with the RRS low design alternative (BY = Brood Year).

Calendar Year	Sampling Activity				
	Adult Capture (Weir)	Juvenile Capture (Rotary Screw Trap			
		Fry	Parr	Presmolt	Smolt
2008	BY 2008				
2009	BY 2009	BY 2008	BY 2008	BY 2008	
2010	BY 2010	BY 2009	BY 2009	BY 2009	BY 2008
2011		BY 2010	BY 2010	BY 2010	BY 2009
2012					BY 2010

The low design suffers from two weaknesses:

1. It tracks RRS only from the adult spawner to juvenile emigrant stage; thus, one must assume that any deleterious impact associated with hatchery rearing would manifest during this stage.
2. Information is only generated for deliberately supplemented streams, thus the impacts of stray hatchery origin adults could only be evaluated if managers were willing to allow hatchery origin strays above weirs to spawn naturally.

The first weakness can be partially addressed by implanting Passive Integrated Transponder (PIT) tags in juveniles that are non-lethally sampled for genetic analysis. These PIT tagged juveniles could be used to monitor the subsequent survival of juveniles based on the origin (hatchery, natural, or hatchery and natural) of their parents. While the rate of PIT tagging is potentially sufficient to evaluate survival during emigration through the hydrosystem, it should be noted that juvenile tagging effort will likely be insufficient to accurately estimate survival to adult return.

The second weakness could be addressed by allowing the escapement of volunteering hatchery origin strays. However, if few hatchery origin strays volunteer, juvenile sampling may have to be dramatically increased to maintain a reasonable likelihood of sampling their progeny. Likewise, some may question the validity of estimating the impacts of hatchery origin strays in a deliberately supplemented population. For example, if supplementation origin adults (hatchery non-strays) exhibit very limited reproductive success, the ability to estimate production by strays may be very low. Additionally, it could be argued that the reproductive success of hatchery origin strays might be greater in the presence of hatchery origin non-strays. For example, If hatchery origin adults (strays and non-strays) exhibit non-random mating, preferring to spawn with other hatchery origin adults, the productivity of hatchery origin adults (stray and non-stray) might increase as a function of increased numbers of hatchery origin adults.

6.3.2.2 RRS Medium Design

The medium design also utilizes adult and juvenile sampling in six deliberately supplemented (target) populations, however weirs would be operated for approximately 10 years in order to also assign returning adult progeny to the adult(s) that gave rise to them (Table 6.12). Under this alternative, three brood years of RRS information would be available for the adult to juvenile and adult to adult life stages.

Table 6.12. Sampling activities associated with the RRS medium design alternative (BY = Brood Year).

Calendar Year	Sampling Activity									
	Adult Capture (Weir)	Juvenile Capture (Rotary Screw Trap				Adult Progeny Capture (Weir)				
		Fry	Parr	Presmolt	Smolt	Jack	Age 3	Age 4	Age 5	Age 6
2008	BY 2008									
2009	BY 2009	BY 2008	BY 2008	BY 2008						
2010	BY 2010	BY 2009	BY 2009	BY 2009	BY 2008					
2011		BY 2010	BY 2010	BY 2010	BY 2009	BY 2008				
2012					BY 2010	BY 2009	BY 2008			
2013						BY 2010	BY 2009	BY 2008		
2014							BY 2010	BY 2009	BY 2008	
2015								BY 2010	BY 2009	BY 2008
2016									BY 2010	BY 2009
2017										BY 2010

Although the medium design provides information for the adult to juvenile and adult to adult life history stages, it still suffers from the fact that information is generated only for deliberately supplemented streams.

6.3.2.2 RRS High Design

Sampling within study streams selected for the high design is the same as the medium design (Table 6.12). However, the high design includes identical sampling in six un-supplemented populations selected using a systematic random sampling approach across the range of stray ratios observed in Columbia River Basin populations. Thus the high design provides information for the adult to juvenile and adult to adult life history stages for hatchery origin strays and non-strays in deliberately supplemented streams and for hatchery origin strays in un-supplemented streams. As a result the high design does not suffer from either of the weaknesses associated with the low and medium designs, and also offers a number of benefits:

1. Information from the un-supplemented streams can be used as a reference to evaluate whether supplementation results in a decrease in productivity that may not be detectable using measures of RRS solely in supplemented streams.
2. The un-supplemented streams could be used as a reference to evaluate whether variance in RRS increases as a result of supplementation.

Because un-supplemented streams would constitute a systematic-random sample representing the range of stray ratios in un-supplemented streams, the resulting information would enable an evaluation of what (if any) contribution by strays can be sustained without negatively impacting productivity in non-target (natural) populations.

6.4 Conclusions and recommendations

As described in previous CSMEP hatchery subgroup documents (CSMEP 2005), current (*status quo*) Columbia River Basin hatchery RME is primarily focused at the scale of individual projects. At that scale, existing RME is likely to provide adequate information to address the impacts of hatcheries on abundance and productivity of those specific targeted populations. Alternatively, little existing research is focused on the aggregate impact of hatcheries, particularly with regard to non-target populations. After extensively reviewing existing hatchery RME, we have found that the most intensive RME projects (e.g., those employing RRS) generally tend to accompany the most innovative supplementation projects. Likewise much less intensive RME, with regard to genetically-based RRS or simple mark recovery effort, accompanies non-target populations. This non-random distribution of effort precludes statistically valid inference from sampled to un-sampled populations. As a result, under the *status quo*, monitoring effort must be deployed wherever we want an answer. Additionally, we have determined that methods for collecting, analyzing, and reporting data vary significantly among agencies. Thus, even if effort were representatively distributed, it is unclear whether the resulting information could be aggregated and analyzed to enable statistically valid inference to un-sampled populations.

CSMEP Hatchery Subgroup efforts have thus focused on the development of systematic sampling designs that representatively sample populations and enable strong statistical inference for un-sampled populations. Likewise, we have identified the need for standardized sampling, analysis, and reporting methods; although we will likely rely on other collaborative efforts to lead the development of those protocols.

Unlike other CSMEP subgroups, for both the stray ratio and RRS design alternatives the differences between the low, medium, and high designs developed by the hatchery subgroup are best illustrated by considering the secondary management questions that could be informed by the designs. For example, while it is true that selecting the medium or high level straying design offers improved precision relative to the low design, the medium and high level designs have a secondary benefit in that they provide additional information – namely, an improved ability to identify where strays originate, as opposed to simply their number. The high design alternative provides information at the MPG scale, and thus may be more useful for de-listing decisions based on TRT criteria. Similarly, the high level RRS design alternative yields direct estimates of the RRS of stray hatchery origin fish in un-supplemented populations, whereas that information must be inferred for either the medium or low design alternatives. Although not directly required *per se* to address the primary management question, that information is likely to be useful in de-listing evaluations and as a means to control for the effect of strays for habitat or hatchery action effectiveness evaluations that rely on treatment versus reference comparisons.

Lastly, the implementation of even the low stray ratio and RRS hatchery designs offers substantial improvement over the *status quo*. While RME costs would increase over the short-term, in the long-term the inferential ability afforded by even the low designs will significantly reduce long-term RME expenditures within the Columbia River Basin. This statement follows from the simple fact that under the *status quo,* RME is required for every program/population for which information is desired. Thus any new propagation program would have to be accompanied by substantial RME. While the CSMEP designs do not supplant the need for all program specific RME, they do significantly reduce the breadth of RME that would otherwise be required to accompany all programs. In addition, the CSMEP designs enable an evaluation of the aggregate impacts of hatcheries, which cannot be achieved given existing RME. Perhaps most importantly, the CSMEP designs enable informed decisions with regard to the use of hatcheries, and achieve this goal by building on existing RME effort, thus affording substantial cost-efficiency.

Stray ratio design

The consensus opinion of the hatchery subgroup is to recommend implementation of the medium-level stray ratio design alternative. The medium-level design alternative provides stray ratio estimates at the population scale and enables estimates of precision and bias in carcass recovery methods for a single population within each of three MPGs. However, if there is reason to believe that the precision and/or bias of carcass recovery efforts would vary among MPGs, it may be prudent to implement the high design and/or to move the three experimental bi-direction weirs periodically to evaluate bias and precision within each MPG.

Relative reproductive success design

The consensus opinion of the hatchery subgroup is to recommend implementation of the medium-level RRS design alternative. The medium level design ensures that RRS can be calculated over the entire life-cycle, although it will not give comparable productivity estimates in un-supplemented populations. If there are reasons to suspect that the reproductive success of naturally spawning hatchery origin fish might change in the presence of greater numbers of hatchery origin adults, it would be prudent to implement the high level design.

7. Integrated Monitoring

Monitoring and evaluation involves systematic long-term data collection and analysis to measure the status of the resource, detect changes over time and test action effectiveness. These efforts can be used to evaluate the success of management strategies, potentially revise these strategies, or to focus research on determining the reason for observed changes. Currently, fish populations in the Columbia River Basin are monitored by a number of separate programs established by different agencies. Most of the fish monitoring programs were designed to answer specific management questions at small spatial and temporal scales (e.g., targeting a particular stream or a particular component of the life cycle) and utilize different measurement protocols and sampling designs. This has resulted in an inability to efficiently integrate monitoring at larger spatial scales required for ESU or regional fish population assessment. There is a need for consistent, long-term integrated monitoring of Columbia River Basin fish populations. However, integrated monitoring cannot be carried out by one organization or agency alone. The design and implementation of integrated monitoring at the Columbia Basin scale is problematic, not least because of the constraints imposed by the need to make maximum use of existing monitoring sites and networks. Major program design issues with truly integrated monitoring include the need to address multiple objectives across agencies, the role of existing monitoring sites and operational aspects of integrating program infrastructures.

One of the most difficult aspects of designing a comprehensive monitoring program is integration of many different monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts (NPS 2006). Full integration requires consideration of five dimensions, including space, time, life history stages, multiple species, and multiple programs:

- *Spatial integration* involves establishing linkages of measurements made at different spatial scales within a monitoring network, or between individual programs and broader regional programs. It requires understanding of ecological processes, spatially representative monitoring sites, and the design of statistical sampling frameworks that permit the extrapolation and interpolation of data.
- *Temporal integration* involves linking measurements made at various frequencies (e.g., daily flow and temperature measurements, annual redd counts, channel and vegetation assessments every few years). Temporal integration requires nesting the more frequent (and often more intensive sampling) within the context of less frequent sampling.
- *Life history integration* involves assessing survival and habitat requirements throughout the entire life cycle of the fish.
- *Species integration* involves efficiently collecting information for multiple species present in the system.
- *Programmatic Integration* involves the coordination and communication of monitoring activities within and among federal, state and tribal agencies, to promote broad collaborative participation in monitoring designs, consistent monitoring protocols wherever feasible, and multiple uses of the resulting data.

CSMEP has begun to explore alternative approaches for integrating designs across M&E domains within its Snake River Basin Pilot Study. These efforts are intended to identify strategies and develop analytical tools to assist integration efforts. Improved monitoring efficiencies through integrated designs across multiple questions and scales, is a common challenge and goal in all basins; hence the results from CSMEP’s pilot work will benefit the entire Columbia River Basin.

7.1.1 Integration strategies

CSMEP subgroups have each developed M&E designs to address specific questions relevant to decision makers in their particular domain. These designs have (to date) been developed separately from the designs of the other domains, with only limited effort to integrate them. Now that subgroup-specific designs have been formulated for identified priority questions, CSMEP can assess where elements of these designs may converge (spatially, temporally, ecologically and programmatically). Identification of the common elements within the designs will provide the 'building blocks' to develop a Columbia River Basin-wide integrated M&E program to address a suite of management questions. This will be an iterative learning process, through which CSMEP will identify workable strategies for simultaneously addressing multiple questions across domains.

Strategies for integration that CSMEP is pursuing include:

1. *Building on a Status & Trends foundation.* Layering of action effectiveness M&E alternatives on a consistent foundation of spatially representative Status and Trends monitoring.
2. *Integration within domains*. Evaluating how alternative designs could best address multiple questions within a particular M&E domain (i.e., Hydrosystem, Hatchery, Harvest, Habitat, or Status & Trends specific).
3. *Integration across domains*. Evaluating how alternative designs could best address multiple questions across M&E domains (e.g., what elements of each subgroup's designs can serve multiple functions).
4. *Maximizing benefits of monitoring techniques*. Evaluating how any particular monitoring technique can help address multiple questions across M&E domains (e.g., PIT tagging to address a suite of questions).
5. *Maximizing sampling efficiencies and minimizing redundancies in designs*. Evaluating shared costs and data gathering opportunities across overlapping designs.

CSMEP is consolidating an initial set of base designs for the five M&E domains and beginning to identify opportunities to address specific questions in multiple domains simultaneously (Figure 7.1). For example, CSMEP's hydrosystem and hatchery stray monitoring strategies are building on the preliminary designs developed by the Status and Trend group. Ultimately, it is CSMEP's intent to develop examples of integrated sets of 'Low', 'Medium', 'High' designs across all five M&E domains to illustrate various dimensions of M&E tradeoffs (i.e., cost, precision, monitoring objectives).

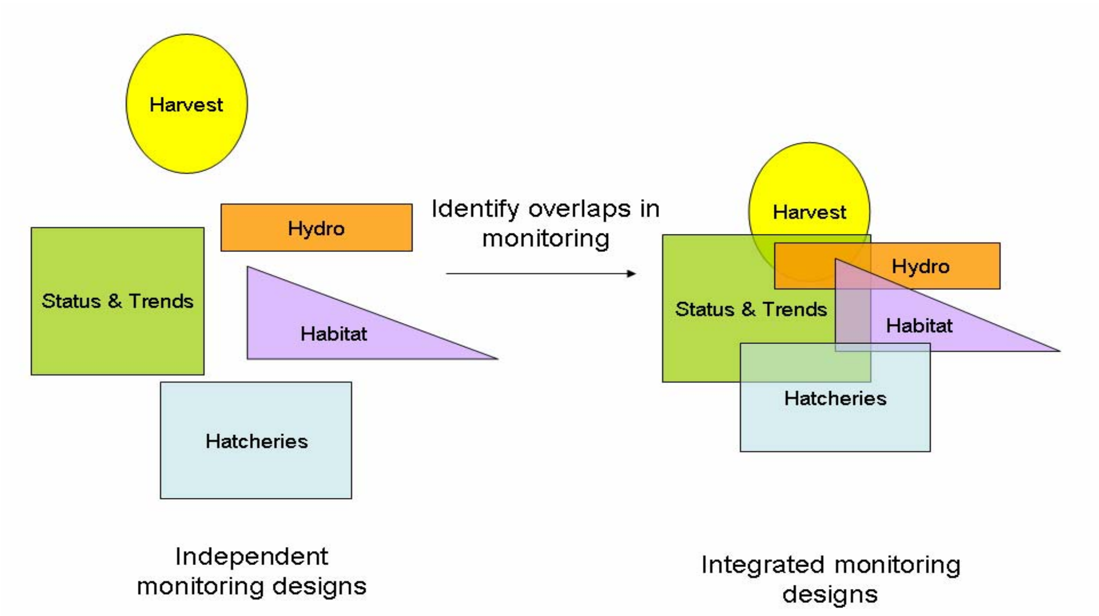

Figure 7.1. Conceptual illustration of identification of opportunities and subsequent development of integrated monitoring designs across CSMEP subgroups.

Integration of M&E depends on the policy and management priorities of each domain and its constituent questions. Consequently, there is no “optimal” design that will exactly suit the preferences of all agencies. Therefore, program managers will need to iteratively review and collaboratively revise integrative strategies and designs. To this end CSMEP has been developing a suite of analytical tools and simulation models that will allow managers and scientists to jointly explore alternative M&E designs and associated trade-offs (i.e., statistical power, costs, sampling effort, etc.).

CSMEP has completed a preliminary analysis of the potential for an integrated PIT-tagging program to address a range of monitoring questions across M&E domains. The intent was to evaluate what intensities of basin-wide PIT-tagging would be required at which life stages and locations (Table 7.1) to provide reliable estimates of survival. CSMEP intends to extend this approach to assess statistical-cost tradeoffs; and evaluate other marking and monitoring techniques that have the potential for integration across domains. Figure 7.2 illustrates some of the linkages across M&E domains that are possible using PIT tags and other monitoring techniques.

Table 7.1. Abbreviated list of questions answerable in whole or in part with PIT-tagged fish.[9]

CSMEP Subgroup:	Question:	Indicator:	Tagging:	Detection:
Status & Trend	Straying of hatchery fish in to wild	Detections of tagged hatchery adults	Hatchery smolts	At tributary weirs or in carcass surveys
	Productivity (smolts per spawner)	Enumeration of smolt emigrants	Parr (for trap efficiency, early emigration), smolts	At smolt trap
	Productivity (adult recruits per spawner)	Age-at-return for adults	Parr or smolts	At LGR as adults or at weir
	SARs	Smolt-to-adult survival	Parr or smolts in tributary	At LGR as adults or at weir
	Hatchery-origin fish spawning in wild	hatchery-origin PIT tagged fish	As smolts in hatchery	At weir or carcass surveys
Habitat effectiveness	Parr abundance, treatment/control areas	Parr #'s	Parr in T/C areas	At traps, flat plate detectors
	Parr-to-smolt survival - treatment/control areas	Parr-to-smolt survival	Parr in treatment, control areas	At dams
	SAR - treatment/control areas	SAR	Parr or smolts in treatment, control areas	At dams
Harvest	Stock composition	Rates of adult tag recovery at dams, in harvest	Parr or smolts	At dam ladders, or in harvested fish
	Age composition of harvested fish	Age-at-return for adults	Parr or smolts	At dam ladders, or in harvested fish
	Harvest rates for listed stocks	Harvest rates	As parr or smolts in Snake	At netting or landing - must happen before fish are gutted
	Upstream survival rate	Upstream survival rate	As parr or smolts in Snake	At BON and LGR adult ladders
Supplementation Hatchery	In-season vs. pre-season adult return estimates	SAR, # of adults returning to supplementation hatchery	Parr or smolts at hatchery	At LGR as adults or at hatchery weir
	Harvest contribution of supplementation fish	Rates of adult tag recovery at dams, in harvest	Parr or smolts at hatchery	At dam ladders, or in harvested fish
	Life-stage survival rates, supplemented pops	Parr-to-smolt survival	Parr	At dams
	Upstream survival	SAR, survival BON to LGR	parr or smolts	At BON and LGR adult ladders
Hydro	Hydrosystem survival, inriver migrants	Smolt survival	Parr or smolts	At dams
	SAR, inriver migrants	SAR	Parr or smolts	At BON and LGR adult ladders
	SAR, transported fish	SAR	Parr or smolts	At BON and LGR adult ladders

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[9] The full analysis can be found at www.cbfwa.org/csmep/web/documents/general/Documents/PITtagV4-12-14-05.pdf

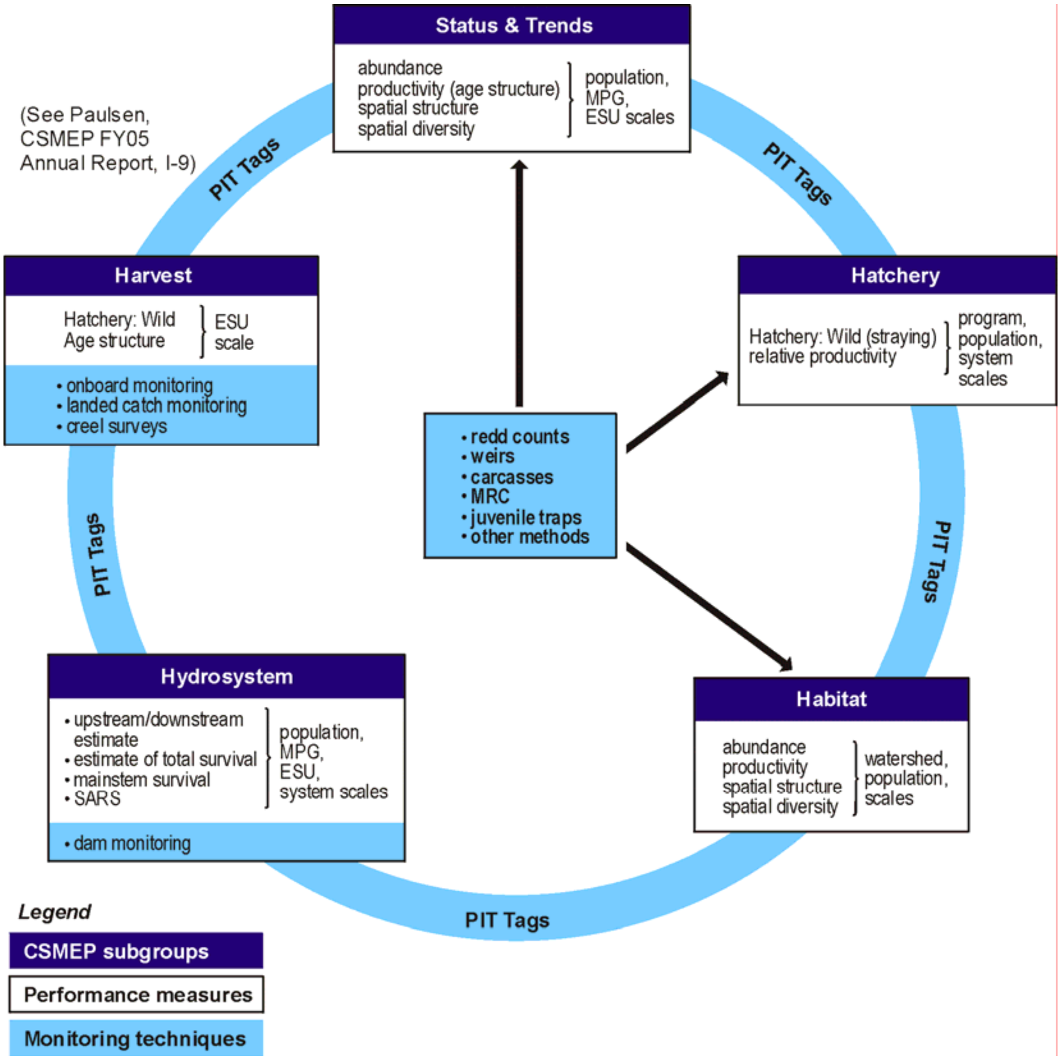
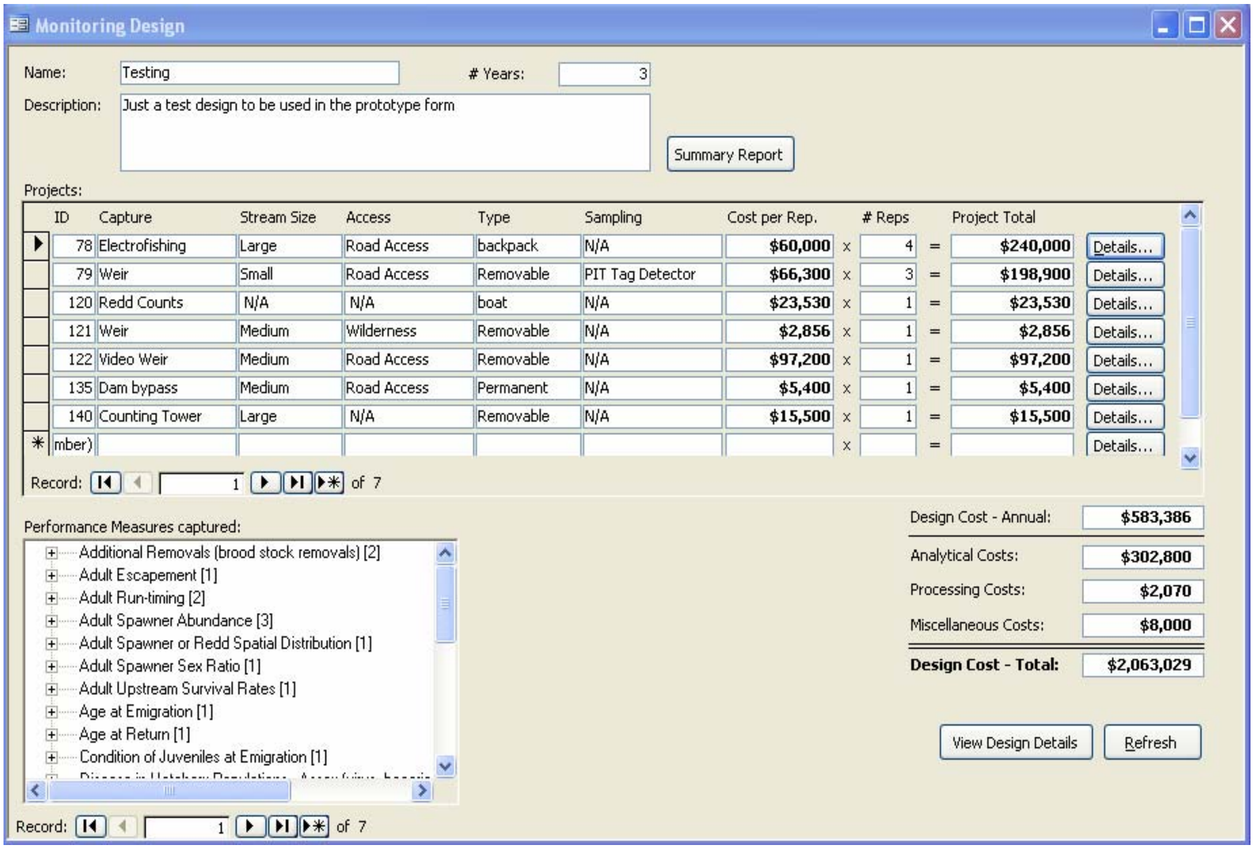


Figure 7.2. Monitoring techniques and potential linkages across status & trends and action effectiveness monitoring.

CSMEP is also developing an Integrated Costs Database Tool, a relational database that will assist evaluations of the cost and performance of integrated monitoring designs. The tool is able to combine the varied costs of equipment, personnel and analyses required for both stationary (weirs, smolt traps, etc.) and mobile techniques (redd counts, snorkeling, electroshocking, etc.) used for monitoring. The tool simulates deployment of field crews and specialized analysts working on component projects, and also incorporates the additional costs of different types of fish marking or processing required for analyses. The tool will also identify the full range of performance measures that can be captured across domains as proposed alternative monitoring components are built into an integrated M&E design. As individual domain-specific M&E designs are developed, the tool will help identify infrastructure redundancies and quantify the improved cost efficiencies of overlaying and integrating design components. This database tool and accompanying User Guide will be available shortly for download from the CSMEP public website. A screen capture of the front-end user interface for this developing database tool is shown in Figure 7.3.



Name: Testing

Years: 3

Description: Just a test design to be used in the prototype form

Projects:

ID	Capture	Stream Size	Access	Type	Sampling	Cost per Rep.		# Reps		Project Total
78	Electrofishing	Large	Road Access	backpack	N/A	$60,000	x	4	=	$240,000
79	Weir	Small	Road Access	Removable	PIT Tag Detector	$66,300	x	3	=	$198,900
120	Redd Counts	N/A	N/A	boat	N/A	$23,530	x	1	=	$23,530
121	Weir	Medium	Wilderness	Removable	N/A	$2,856	x	1	=	$2,856
122	Video Weir	Medium	Road Access	Removable	N/A	$97,200	x	1	=	$97,200
135	Dam bypass	Medium	Road Access	Permanent	N/A	$5,400	x	1	=	$5,400
140	Counting Tower	Large	N/A	Removable	N/A	$15,500	x	1	=	$15,500
mber)							x		=	

Record: 1 of 7

Performance Measures captured:

- Additional Removals (brood stock removals) [2]
- Adult Escapement [1]
- Adult Run-timing [2]
- Adult Spawner Abundance [3]
- Adult Spawner or Redd Spatial Distribution [1]
- Adult Spawner Sex Ratio [1]
- Adult Upstream Survival Rates [1]
- Age at Emigration [1]
- Age at Return [1]
- Condition of Juveniles at Emigration [1]

Design Cost - Annual:	$583,386
Analytical Costs:	$302,800
Processing Costs:	$2,070
Miscellaneous Costs:	$8,000
Design Cost - Total:	**$2,063,029**

Record: 1 of 7

Figure 7.3. Front-end user interface for CSMEP’s Cost Integration Database Tool.

8. Summary of General Recommendations

Based upon analyses undertaken within its Snake River Basin Pilot study CSMEP suggests the following general recommendations for developing consistent, cost effective, coordinated, regional status & trends monitoring and action effectiveness monitoring within and among all the ‘Hs’ (Harvest, Hydro, Habitat, and Hatcheries). Recommendations specific to CSMEP designs for each M&E domain were identified in Sections 2–6.

Recommendation 1

Regional M&E for fish populations should be developed through a long term, systematic process that has the following attributes:

a) involves dialogue with Columbia River Basin fish managers and decision makers to identify the key management decisions, spatial and temporal scales of decisions, information needs, time frame for actions, and the level of acceptable risks when making the decisions;

b) conducts an inventory of existing M&E methods and evaluates their strengths and weaknesses for meeting information needs;

c) involves the long term participation of Columbia River Basin scientists with both field and statistical expertise, to ensure that M&E approaches meet information needs, are cost-effective, practical, statistically reliable, and have the support of state and tribal agencies;

d) recognizes that information needs, available funding, and scales of interest vary across agencies and it addresses the tradeoffs among design objectives and evaluation criteria; and

e) recognizes that M&E is an essential element of an adaptive management loop (Figure 8.1) to iteratively improve habitat, hydrosystem, and fisheries management actions, and that M&E approaches themselves need to be iteratively improved through the evaluation of projects.

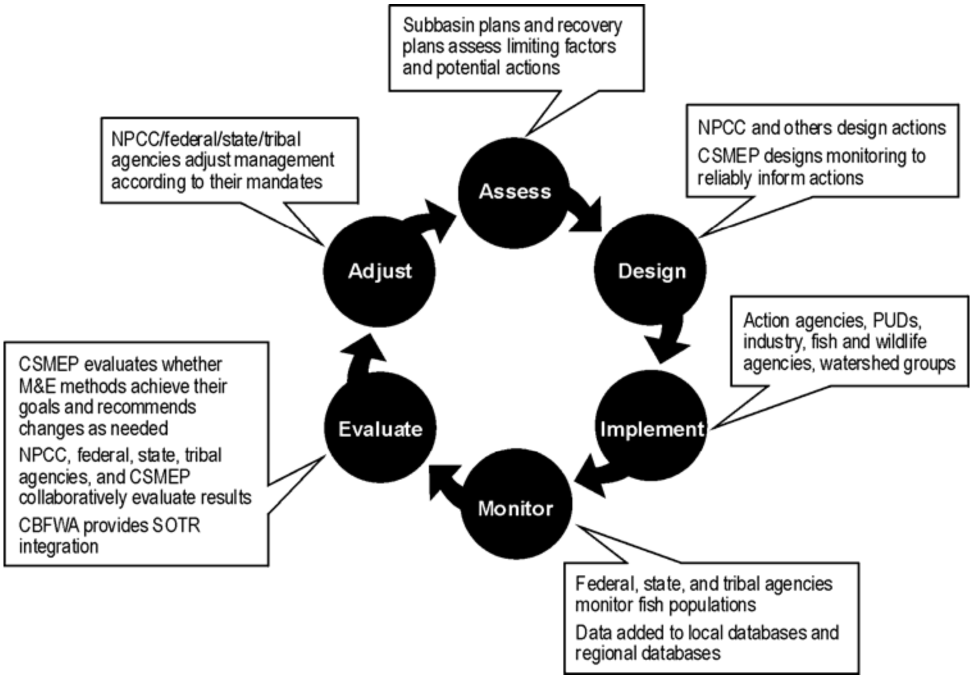


Figure 8.1. The adaptive management cycle, with example Columbia Basin entities included. The rigorous M&E designs being developed by CSMEP are essential for adaptive management.

Decisions on regional M&E designs need to be based on a quantitative evaluation of the costs and benefits of the Status Quo and alternative designs to answer management questions. The alternative designs should build on the strengths of each subbasin’s existing monitoring infrastructure and data, remedy some of the major weaknesses, and adapt to regional variations that affect monitoring protocols. Without a formal quantitative evaluation of costs and benefits (e.g., statistical reliability, cost, ability to answer key questions, practicality), there is a risk that *ad hoc* M&E decisions will be made that are not cost-effective and preclude data aggregation for decisions and evaluations at greater spatial or temporal scales. Each region in the Columbia River Basin has invested considerable resources to develop a monitoring infrastructure that is primarily adapted to address local needs. It is much more cost-effective to build on the strengths of the existing monitoring infrastructure, rather than applying a uniform “cookie-cutter” approach throughout the Columbia River Basin. These improved designs can be developed to overcome weakness in the existing M&E programs to allow assessments at larger spatial and longer temporal scales.

Recommendation 2

The development and implementation of sound M&E designs must be accompanied by strong data management systems which facilitate the sharing, analysis and synthesis of data across agencies, spatial and temporal scales, and disciplines. Without a strong investment in data management, even the best monitoring designs will falter.

Recommendation 3

Status and trends monitoring should provide the foundation of a regional M&E program but it must be integrated with action effectiveness monitoring. An integrated M&E program provides economy of scale, prevents duplicative efforts, and is cost effective. Action effectiveness monitoring is more focused on specific questions that influence fish populations hence, it is typically of fixed duration and usually provides more precision. Action effectiveness M&E can respond to adaptive management needs by focusing its efforts to address the mechanistic causes of uncertainty in the relationship between management actions and fish population responses.

Recommendation 4

Status and trends monitoring of fish populations must satisfy the needs of population and ESU level assessments (for both listed and unlisted species) of viability, as well as assessments of overall trends in population abundance and productivity at larger spatial and longer temporal scales. It must also meet the needs of multiple agencies with different objectives, questions, and scales of interest. There are challenging tradeoffs to meet all M&E objectives but using the collaborative process CSMEP has adapted should result in cost effective designs to adequately address information needs.

Recommendation 5

M&E designs under development must also be integrated across species. CSMEP is currently working to incorporate steelhead into the Chinook salmon designs that have been developed for the Snake and mid-Columbia basins. CSMEP is working to integrate the use of PIT-tags and other techniques to answer multiple questions, improving the cost-effectiveness of Status & Trends, Habitat, Hydrosystem, Harvest, and Hatchery M&E designs.

Recommendation 6

Agencies should evaluate hybrid sampling designs to improve fish population monitoring that is based on fixed index sites. A hybrid sampling design would supplement the existing non-random, index monitoring sites with spatially representative sites. While index sites are not representative, sampling random sites throughout the range of a fish population is often not efficient (considerable time can be spent getting to each site). The hybrid approach takes advantage of the fact that index sites often efficiently sample a large fraction of the population and uses the supplementary random sampling to accurately determine just how big that fraction is. This approach would allow agencies to assess the bias in index sites, get reliable estimates of population abundance for viability assessments, permit aggregation to a variety of larger spatial scales (e.g., MPG, sub-basin), support the sharing of data collected by different agencies with different interests, and facilitate data analyses.

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Appendix 2A: Status Quo Design

Actual M&E being done on a yearly basis in each population.

index = a one time count in "index" areas

HY = weir is associated with a hatchery program and would be operated regardless of Status and Trends M&E (Natural counts at hatchery weirs may be inflated due to hatchery misclips--ASSUME NO ERROR FOR MODEL RUNS)

ISS = Idaho Supplemention Studies (a long term Chinook supplementation research project 1992 - 2012?, IDFG, NPT, SBT).

Major Population Group Population	Redd count type	Weir	Comments on monitoring	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Lower Snake								
Asotin Creek	two-time census ground	yes	Weir is upstream of George Creek but there is no Chinook spawning in George Creek. covers all historic spawning area, Glenn Mendel, WDFW, Dayton, WA.	100% Glen Mendel, WDFW --number of spawners upstream of the weir.	Unbiased, high precision	Good	Good	1MaSA
Tucannon River	multiple ground-census	yes (HY)	Hatchery weir at river kilometer (RK) 59; about 70% of all spawning is upstream of the weir.	70% Glen Mendel, WDFW--number of spawners upstream of the weir.	Unbiased, high precision	Good	Good	1MaSA, 1 MiSA
Grande Ronde/Imnaha Rivers								
Big Sheep Creek	one-time ground census with some multi-pass index sites	no	Considered functionally extinct. Most (>90%) spawners are hatchery adult outplants (ODFW).	na	Unbiased, med precision	Good	Poor	1MiSA
Catherine Creek	multiple ground-census	yes (HY)	Assume weir captures all spawners. Mark-recap done.	100	Unbiased, high precision	Good	Good	2MaSA, 2 MiSA
Grande Ronde River upper mainstem	multiple ground-census	yes (HY)	Spawning occurs downstream of weir. Mark-recap done.	60% Fred Monzyk. ODFW LaGrande. 1997-2006 % of natural female carcass recoveries found upstream of the weir.	Unbiased, high precision	Good	Good	3MaSA, 2 MiSA
Imnaha River mainstem	multiple ground-census	yes (HY)	Spawning occurs downstream of weir. Mark-recap done. Spawning area downstream of weir has multi-census count.	69% Fred Monzyk. ODFW LaGrande. 1991-2006 % of natural female carcass recoveries found upstream of the weir.	Unbiased, high precision	Good	Good	1MaSA, 1 MiSA
Lookinglass Creek	multiple ground-census	yes (HY)	Re-introduction effort (ODFW).	100	Unbiased, high precision	Good	Good	1MiSA

Major Population Group Population	Redd count type	Weir	Comments on monitoring	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Minam River	multiple ground-census	no		na	unbiased, medium precision	Good	Good	2MaSA
Wallowa/Lostine River	multiple-census in Lostine. One-pass census in Wallowa. All ground counts.	yes - HY	Weir in Lostine Creek with multi-census count. One time-census (complete area survey) done in Bear Ck, Hurricane Ck, Wallowa River.	84% - Fred Monzyk. ODFW LaGrande. 1997-2006 % of natural female carcass recoveries found upstream of the weir.	Unbiased, high precision	Good	Good	3MaSA, 1 MiSA
Wenaha River	one time-census	no		na	unbiased, medium precision	Good	Poor	1MaSA
South Fork Salmon River								
East Fork SF Salmon River	One pass index (aerial)	yes (HY)	NPT does multi-pass index ground counts in Johnson Creek. Weir on Johnson Creek (captures all Johnson Ck spawners only) for NPT program. Index counts are also done in the EFSF (ground).	80% Kim Apperson, IDFG. Based on the proportion of redds in IDFG index sites.	Overall: unbiased, medium precision Unbiased, high precision for Johnson, biased & low precision East Fork	Good	Good	2 MaSAs surveyed. No MSAs.
Little Salmon River	none	yes (HY)	Weir is in Rapid River, part of Rapid River Hatchery. Weir may not be representative of the population in this case. IDFG (ISS) is doing a multi-pass ground count in Slate Creek. No IDFG index sites in this population.	50% Assumed--based on drainage area of streams in this population.	Overall: biased, medium precision Unbiased, high precision for Rapid River, biased & med precision Slate Creek, nothing in Whitebird	None	Poor	only 2 of 3 MiSAs surveyed. Whitebird isn't surveyed.
Secesh River	One pass index (aerial)	yes Didson	Didson weir located in Lake Creek. NPT (ISS) does multi-pass index counts in Lake Ck and Upper Secesh. Index aerial redd counts downstream of weir & multipass ground counts This covers most of the spawning area used by Chinook in this MaSA. No monitoring in Lick Creek, but this is <10% of the population (TRT).	50% Based on proportion of redds in IDFG index sites from 1992-2006.	Overall: unbiased, medium precision. (unbiased due to weir, the extent of multipass index counts 21km in Lake Creek and 40km of Secesh River, and the small % of population not monitored.	None	Poor	MaSA is surveyed. MiSA isn't, Lick Creek
SF Salmon River mainstem	index (aerial)	yes - HY	IDFG (ISS) does multi-pass census upstream of the weir. There is a lot of spawning area downstream of weir that is only monitored with aerial index. Weir at RK 113 is for McCall Hatchery.	25% Based on proportion of redds in IDFG index sites.	Biased, low precision	None	Poor	2 MaSAs is surveyed, 2 MiSAs not: Warren, Crooked Rivers.
Middle Fork Salmon River								
Bear Valley Creek	One pass index (ground)	no	SBT does multi-pass ground index counts, 36km. (recent, associated with ISS study).	na	biased, medium precision	Good	Poor	3MaSAs is surveyed, no MiSAs
Big Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	3 MaSAs - 2 of 3 is surveyed, missing Monumental. no MiSAs

Major Population Group Population	Redd count type	Weir	Comments on monitoring	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Camas Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	1 MaSA is surveyed, 1 MiSAs is not surveyed: Yellowjacket Creek
Chamberlain Creek	One pass index (ground)	no		na	Biased, low precision	None	None	1 MaSA is surveyed, 3 MiSAs is not surveyed: Bargamin, McCalla, Sabe
Loon Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	1 MaSA is surveyed, no MiSAs
Marsh Creek	One pass index (ground)	no	IDFG does multi-pass index counts, 11km which probably covers ~80% of all spawning (recent, associated with ISS study)	na	biased, medium precision	Good	Poor	1 MaSA is surveyed, no MiSAs
MF Salmon River above Indian Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	1 MaSA is surveyed, 2 MiSAs - 1 of 2 is surveyed: Marble Creek
MF Salmon River below Indian Creek	none	no	No recent consistent redd counts. There have been some sporadic air counts from the mouth to Indian Creek. There was a study through USFS (Russ Thurow) with some information, but won't include in SQ ongoing monitoring. No IDFG index sites in this population.	na	Biased, low precision (no abundance info currently measured)	None	None	no MaSA, 1 MiSAs
Sulphur Creek	One pass index (ground)	no		na	Biased, low precision	Good	None	1 MaSA, no MiSAs
Upper Salmon River								
East Fork Salmon River	One pass index (aerial)	yes (HY)	Weir is at river km 25 part of Sawtooth Hatchery operations. There is a lot of spawning area downstream of weir. Multi-pass index counts done by SBT (ISS), 15km.	17% Based on proportion of redd counts in IDFG index sites, 1998-2006.	biased, medium precision	Good	Poor	only 1 MaSA identified
Lemhi River	One pass index (aerial)	no	Multi-pass index (combo ground/aerial) counts done by IDFG (ISS)		biased, medium precision	None	Poor	3 MaSA - 1 of 3 is surveyed: Texas & 18 mile is not surveyed, 2 MiSAs - 1 of 2 is surveyed: Carmen
NF Salmon River	One pass index (ground)	no	Multi-pass index ground counts done by IDFG (ISS)		biased, medium precision	Good	Poor	only 1 MaSA identified
Pahsimeroi River	One pass index (aerial)	yes (HY)	Multi-pass index counts done by IDFG (ISS). Pahsimeroi Hatchery weir.	100	Unbiased, high precision	Good	Good	only 1 MaSA identified

Major Population Group Population	Redd count type	Weir	Comments on monitoring	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Panther Creek	One pass index (aerial)	no	Extirpated, population.		biased, med precision	None	Poor	Abundance and Diversity were both bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Salmon River Lower Mainstem	One pass index (aerial)	no			biased, med precision	Poor	Poor	Refer to TRT. Abundance and Diversity were both bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Salmon River Upper Mainstem	One pass index (aerial)	yes (HY)	Sawtooth Hatchery weir.	100	Unbiased, high precision	Good	Good	index sites in all 3 MaSAs
Valley Creek	One pass index (aerial)	no	Multi-pass index ground counts done by SBT in 33km of Valley Creek (ISS)		biased, medium precision	Good	Poor	only 1 MaSA identified
Yankee Fork Salmon River	One pass index (aerial)	no	Multi-pass index ground counts (ISS) done in West Fork YF by SBT.		Biased, low precision	Good	Poor	only 1 MaSA identified

Appendix 2B: Low Design

No weirs, one time redd counts in index areas only.

index = a one time count in "index" areas

Spatial coverage = L unless there is only one MaSA or MiSa in the population (then = H)

Although this design (and the corresponding results) does not include weirs; the existing hatchery weirs identified in the SQ design are likely to continue to operate. Hence data for diversity (and abundancee) could be obtained at those sites

(HY) = hatchery weir in this population

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Lower Snake								
Asotin Creek	One pass index (ground)	no		na	Biased, low precision	Good	None	
Tucannon River	One pass index (aerial)	no (HY)		na	Biased, low precision	None	None	
Grande Ronde/Imnaha Rivers								
Big Sheep Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Catherine Creek	One pass index (ground)	no (HY)		na	Biased, low precision	None	None	
Grande Ronde River upper mainstem	One pass index (aerial)	no (HY)		na	Biased, low precision	None	None	
Imnaha River mainstem	One pass index (aerial)	no (HY)		na	Biased, low precision	Good	None	2 spawning areas but index sites located in both
Lookinglass Creek	One pass index (ground)	no (HY)		na	Biased, low precision	Good	None	
Minam River	One pass index (ground)	no		na	Biased, low precision	None	None	
Wallowa/Lostine River	One pass index (aerial)	no (HY)		na	Biased, low precision	None	None	
Wenaha River	One pass index (ground)	no		na	Biased, low precision	Good	None	
South Fork Salmon River								
East Fork SF Salmon River	One pass index (aerial)	no (HY)		na	Biased, low precision	None	None	
Little Salmon River	One pass index (ground)	no (HY)	Should be ground counts--narrow canyons, probably cannot fly safely.	na	Biased, low precision	None	None	
Secesh River	One pass index (aerial)	no		na	Biased, low precision	None	None	
SF Salmon River mainstem	One pass index (aerial)	no (HY)		na	Biased, low precision	None	None	
Middle Fork Salmon River								
Bear Valley Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Big Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	
Camas Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	
Chamberlain Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	
Loon Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Marsh Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
MF Salmon River above Indian Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	
MF Salmon River below Indian Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Sulphur Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Upper Salmon River								
East Fork Salmon River	One pass index (aerial)	no (HY)		na	Biased, low precision	Good	None	
Lemhi River	One pass index (aerial)	no		na	Biased, low precision	None	None	
NF Salmon River	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Pahsimeroi River	One pass index (aerial)	no (HY)		na	Biased, low precision	Good	None	
Panther Creek	One pass index (aerial)	no		na	Biased, low precision	None	None	
Salmon River Lower Mainstem	One pass index (aerial)	no		na	Biased, low precision	None	None	
Salmon River Upper Mainstem	One pass index (aerial)	no (HY)		na	Biased, low precision	Good	None	3 Spawning Areas but index sites located in all of them.
Valley Creek	One pass index (aerial)	no		na	Biased, low precision	Good	None	
Yankee Fork Salmon River	One pass index (aerial)	no		na	Biased, low precision	Good	None	

Appendix 2C: Medium Design

One weir per MPG, multi-pass redd counts in all populations with a one time census count for spatial structure included.

This design includes 5 weirs (noted as YES in Weir column), however additional weirs associated with hatcheries may continue to operate (noted as no- HY, in Weir column).

Use the same method (air or ground) used in the Status Quo design for the multiple index counts 14 ground, 18 aerial)

Ground Counts: a minimum of 3 ground counts. If census is ground (6 cases) then just add on to 3rd pass, if census is aerial (8 cases) then do in addition to 3 pass ground counts.

(HY) = hatchery weir in this population

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Lower Snake								
Asotin Creek	3 pass ground index, 3rd pass is spatial census ground count	no		100%	Unbiased, med precision	Good	Good	
Tucannon River	3 pass ground index + 1pass spatial census aerial count	yes		70%	Unbiased, high precision	Good	Good	
Grande Ronde/Imnaha Rivers								
Big Sheep Creek	3 pass ground index + 1pass spatial census aerial count	no		na	Unbiased, med precision	Good	Good	
Catherine Creek	3 pass ground index, 3rd pass is spatial census ground count	no (HY)		100%	Unbiased, med precision	Good	Good	
Grande Ronde River upper mainstem	3 pass ground index + 1pass spatial census aerial count	no (HY)		60%	Unbiased, med precision	Good	Good	
Imnaha River mainstem	3 pass ground index + 1pass spatial census aerial count	no (HY)		69%	Unbiased, med precision	Good	Good	
Lookinglass Creek	3 pass ground index, 3rd pass is spatial census ground count	no (HY)		100%	Unbiased, med precision	Good	Good	
Minam River	3 pass ground index, 3rd pass is spatial census ground count	no		na	Unbiased, med precision	Good	Good	

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Wallowa/Lostine River	3 pass ground index + 1pass spatial census aerial count	yes		84%	Unbiased, high precision	Good	Good	
Wenaha River	3 pass ground index, 3rd pass is spatial census ground count	no		na	Unbiased, med precision	Good	Good	
South Fork Salmon River								
East Fork SF Salmon River	3 pass air index, 3rd pass is spatial census aerial count	yes		80%	Unbiased, med precision	Good	Good	
Little Salmon River	3 pass ground index, 3rd pass is spatial census ground count	no (HY)	This population should also have a one-time ground census (narrow canyons--may not be able to fly safely)	50%	Unbiased, med precision	Good	Good	
Secesh River	3 pass air index, 3rd pass is spatial census aerial count	no		50%	Unbiased, med precision	Good	Poor	Abundance and Diversity were both bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
SF Salmon River mainstem	3 pass air index, 3rd pass is spatial census aerial count	no (HY)		25%	Unbiased, high precision	Good	Poor	Abundance and Diversity were both bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Middle Fork Salmon River								
Bear Valley Creek	3 pass ground index + 1pass spatial census aerial count	no	Index sites are done by ground in SQ design but can be done by air	na	Unbiased, med precision	Good	Good	
Big Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Camas Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Chamberlain Creek	3 pass air index, 3rd pass is spatial census aerial count	no	Change from ground (SQ) to air. index sites done by ground in SQ design but can be done by air. This is a wilderness population so the multi-pass counts should be done by air to save on cost.	na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Loon Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Marsh Creek	3 pass ground index + 1pass spatial census aerial count	yes	Place weir just upstream of Capehorn Creek. Index sites are done by ground in SQ design but can be done by air	52% Based on ground index redd counts 2000-2006 in Marsh, Capehorn,Beaver creeks.	Unbiased, high precision	Good	Good	
MF Salmon River above Indian Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
MF Salmon River below Indian Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Sulphur Creek	3 pass air index	no	Change from ground (SQ) to air. index sites done by ground in SQ design but can be done by air. This is a wilderness population so the multi-pass counts should be done by air to save on cost.	na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Upper Salmon River								
East Fork Salmon River	3 pass air index, 3rd pass is spatial census aerial count	no (HY)	Low Chinook abundance	17%	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Lemhi River	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	
NF Salmon River	3 pass ground index + 1pass spatial census aerial count	no	Index sites are done by ground in SQ design but can be done by air	na	Unbiased, med precision	Good	Good	
Pahsimeroi River	3 pass air index, 3rd pass is spatial census aerial count	no (HY)	Summer population	100%	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Panther Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Salmon River Lower Mainstem	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Salmon River Upper Mainstem	3 pass air index, 3rd pass is spatial census aerial count	yes	Spring population so its a better representation of other populations in this MPG	100%	Unbiased, med precision	Good	Good	
Valley Creek	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied
Yankee Fork Salmon River	3 pass air index, 3rd pass is spatial census aerial count	no		na	Unbiased, med precision	Good	Poor	Diversity was bumped up from Low to Medium based on the assumption that information from neighboring populations can be applied

Appendix 2D: High Design

Weirs in all 32 populations with multiple redd counts in those population where the weir captures < 40% of all spawners, plus a one time census redd count for spatial structure.

One pass census redd count for every population (6 ground and 26 air)

multi-pass redd counts in populations where the weir captures < 40% of the spawners (5 populations)

yes-new, refers to populations where a new weir must be installed

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Lower Snake								
Asotin Creek	1 pass spatial census ground count	yes	Existing weir	100%	Unbiased, high precision	Good	Good	
Tucannon River	1 pass spatial census aerial count	yes	Existing hatchery weir	70%	Unbiased, high precision	Good	Good	
Grande Ronde/Imnaha Rivers								
Big Sheep Creek	1 pass spatial census aerial count	yes-new	Small system, assume weir placed at mouth (presently extirpated)	100%	Unbiased, high precision	Good	Good	
Catherine Creek	1 pass spatial census ground count	yes	Existing hatchery weir	100%	Unbiased, high precision	Good	Good	
Grande Ronde River upper mainstem	1 pass spatial census aerial count	yes	Existing hatchery weir	60%	Unbiased, high precision	Good	Good	
Imnaha River mainstem	1 pass spatial census aerial count	yes	Existing hatchery weir	69%	Unbiased, high precision	Good	Good	
Lookinglass Creek	1 pass spatial census ground count	yes	Existing hatchery weir	100%	Unbiased, high precision	Good	Good	

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Minam River	1 pass spatial census ground count	yes-new	Medium sized stream, assumes weir can be place below spawning area	100%	Unbiased, high precision	Good	Good	
Wallowa/Lostine River	1 pass spatial census aerial count	yes	Existing hatchery weir	84%	Unbiased, high precision	Good	Good	
Wenaha River	1 pass spatial census ground count	yes-new	Medium sized stream, assumes weir can be place below spawning area	100%	Unbiased, high precision	Good	Good	
South Fork Salmon River								
East Fork SF Salmon River	1 pass spatial census aerial count	yes	Existing hatchery weir (Johnson Creek weir)	80%	Unbiased, high precision	Good	Good	
Little Salmon River	1 pass spatial census ground count	yes	Existing hatchery weir (Rapid River)	50%	Unbiased, high precision	Good	Good	
Secesh River	1 pass spatial census aerial count	yes -new	Didson weir replaced with traditional weir so fish can be handled. in Lake Creek at Didson site	40%	Unbiased, high precision	Good	Good	
SF Salmon River mainstem	1 pass spatial census aerial count + 3 pass index ground counts	yes	Existing hatchery weir (IDFG hatchery weir)	25%	Unbiased, high precision	Good	Good	
Middle Fork Salmon River								
Bear Valley Creek	1 pass spatial census aerial count	yes-new	Install weir on Elk Creek	40% Based on proportion of spawning in Elk Creek (see TRT PVA)	Unbiased, high precision	Good	Good	
Big Creek	1 pass spatial census aerial count	yes-new	Install weir at Taylor Ranch	80% Based on IDFG index redd counts 1996-2006	Unbiased, high precision	Good	Good	
Camas Creek	1 pass spatial census aerial count	yes-new	Install weir at Meyers Cove area	40% Guess based on streamlength covered	Unbiased, high precision	Good	Good	
Chamberlain Creek	1 pass spatial census aerial count	yes-new	Install weir in Chamberlain Basin	50% Guess based on streamlength covered	Unbiased, high precision	Good	Good	

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Loon Creek	1 pass spatial census aerial count	yes-new	Near mouth of Loon Creek	100% Assume weir can be installed before fish arrive	Unbiased, high precision	Good	Good	
Marsh Creek	1 pass spatial census aerial count	yes-new	Install weir just upstream of Capehorn Creek	52% Based on ground index redd counts 2000-2006 in Marsh, Capehorn,Beaver creeks.	Unbiased, high precision	Good	Good	
MF Salmon River above Indian Creek	1 pass spatial census aerial count + 3 pass index raft counts	yes-new	Install weir at Marble Creek	30% See TRT PVA. This is a mainstem spawning population and a weir can't be used in the mainstem	Unbiased, high precision	Good	Good	
MF Salmon River below Indian Creek	1 pass spatial census aerial count + 3 pass index raft counts	yes-new	Install weir at Horse Creek	10% Rough est based on drainage area. This is a mainstem spawning population and a weir can't be used in the mainstem. Probably not many Chinook in Horse Creek.	Unbiased, high precision	Good	Good	
Sulphur Creek	1 pass spatial census aerial count	yes-new	Install weir near mouth of Sulphur Creek	100% Assume weir can be installed before fish arrive	Unbiased, high precision	Good	Good	
Upper Salmon River								
East Fork Salmon River	1 pass spatial census aerial count + 3 pass index ground counts	yes	IDFG hatchery weir upstream of Big Boulder Creek	17%	Unbiased, high precision	Good	Good	
Lemhi River	1 pass spatial census aerial count	yes-new	Use old weir site near Hayden Creek	90% Nearly all spawning is upstream of Hayden Creek	Unbiased, high precision	Good	Good	
NF Salmon River	1 pass spatial census aerial count	yes-new	Install weir near mouth, but may not be able to install a weir until some fish have arrived. Need to wait for flows to drop.	100% Assume weir can be installed before fish arrive	Unbiased, high precision	Good	Good	
Pahsimeroi River	1 pass spatial census aerial count	yes	Use existing hatchery weir	100%	Unbiased, high precision	Good	Good	

Major Population Group Population	Redd count type	Weir	Comments	Proportion of spawning area covered by weir	Abundance Assumptions	Spatial coverage	Ability to assess diversity metrics	Comments on model assumptions
Panther Creek	1 pass spatial census aerial count	yes-new	Install weir downstream of spawning area, but may not be able to install a weir until some fish have arrived. Need to wait for flows to drop.	100% Assume weir can be installed before fish arrive	Unbiased, high precision	Good	Good	
Salmon River Lower Mainstem	1 pass spatial census aerial count + 3 pass index ground counts	yes-new	Install weir in Challis Creek	10% May not be any Chinook in Challis. This is a mainstem spawning population and a weir can't be used in the mainstem.	Unbiased, high precision	Good	Good	
Salmon River Upper Mainstem	1 pass spatial census aerial count	yes	Use existing Sawtooth Hatchery weir	100	Unbiased, high precision	Good	Good	
Valley Creek	1 pass spatial census aerial count	yes-new	Install weir near mouth of Valley Creek	100% Assume weir can be installed before fish arrive	Unbiased, high precision	Good	Good	
Yankee Fork Salmon River	1 pass spatial census aerial count	yes-new	Install weir in Yankee Fork upstream of WF Yankee Fork	60% Assumes weir can be installed before fish arrive	Unbiased, high precision	Good	Good	

Appendix 3A: Snake River spring Chinook Salmon Pilot Study: A Sensitivity Analysis of Quantities for Fish Mortality From In-river Fisheries

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The 2007 work of the Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) focuses on Snake River spring/summer Chinook salmon for a pilot study. An important harvest management question links preseason and in-season forecasts of fish return size (abundance, aka run) to management decisions that impact multiple fish stocks. To address the issue, we need to analyze how the forecasts affect in-river harvest decisions.

At present, the US v. Oregon Technical Advisory Committee (TAC), which is Columbia River harvest management entity, makes preseason and in-season forecasts of run size of “aggregated” upriver spring Chinook salmon that include Snake River population, and uses the forecasts for in-season harvest management. **The US v. Oregon TAC does not use run forecasts of Snake River population for in-season management** (S. Ellis, US v. Oregon TAC, Portland, OR, USA, personal Communication). We use aggregated upriver spring Chinook salmon for our pilot study’s target species.

In-river main-stem harvest of upriver spring Chinook salmon occurs in zones 1-6, areas from Columbia River estuary to McNary Dam. Commercial non-tribal harvest is limited to zones 1-5, downstream of Bonneville Dam. The harvest is selective, meaning that only hatchery fish are allowed to be caught and retained and by-catch of wild fish must be released. Tribal harvest occurs in zone 6, upstream of Bonneville Dam in a traditional fishery where both and hatchery and wild fish may be caught and retained. Because of the selective fisheries in zones 1-5, in-season harvest management is complicated in those zones.

The US v. Oregon TAC calculates fish mortality due to harvest effects, and uses the mortality for harvest decisions. The mortality is called “Impact” that is a function of multi-quantities, which include run forecasts. We describe how Impact is related to the input quantities, and more importantly study how sensitive Impact is to those quantities. **The study of sensitivity analysis (SA) enables us to identify input quantities in order of importance, leading to improvement in monitoring design, which is a key objective of CSMEP.**

Definition of Impact

The U.S. v. Oregon TAC defines Impact of a fishery on a wild fish population as total mortality (rate) of the population derived from in-river harvest effects. During the season when adult fish return, the US v. Oregon TAC updates Impact for harvest decisions. The basic equation of Impact, *I* at time *t* in a run season is

$$I_t = \frac{\text{number of wild fish that die from fishery effects up to time } t}{\text{number of wild fish return to the Columbia River}} \qquad (1)$$

Impact is dimensionless, and ranges from 0 to 1. Fishery effects in eq. 1 incorporate both direct catch and post-release mortality. Post-release mortality may occur when unmarked wild fish are released (as required by regulation in the selective fishery for Chinook salmon) but die due to injury or stress incurred during catch and release.

Practically, the US v. Oregon uses the following equation, incorporating the post-release mortality.

$$I_t = \frac{H_t}{N} \cdot M \tag{2}$$

where H_t = cumulative catch (number) up to day t; N = abundance of wild population return to Columbia River mouth; and M = post-release mortality of wild fish. The quantity of fish return size (i.e., N) is used as a preseason forecast of return size before reliable in-season data are collected. As time progresses and reliable in-season data are accumulated, in-season forecast of return size is made and used for N, where subscript time t is added (i.e., N_t) because in-season forecast of return size changes during run.

Interpreting the practical Impact equation, the first fraction of "H_t / N " in eq. 2 means the probability of fish caught, and thus the impact is the product of the probability of fish caught and the post-release mortality.

Quantities that affect Impact of commercial selective fisheries

Commercial harvest of spring Chinook salmon in the lower Columbia River (zones 1-5) is made by selective fisheries where by-catch of unmarked wild fish must be released. The fishery is complicated by operation of two different fishery gears: 4-1/2" mesh tangle net, and 8 or 9" mesh gill net. Post-release mortality of fish differs by fishing gear (Ashbrook et al. 2004).

When two different gears are used in these fisheries, Impact at time t is modified as the following equation:

$$I_t = \frac{(H_{t,S} + H_{t,L})}{N} \cdot \frac{\left(R_{t,S} M_S + R_{t,L} M_L\right)}{(R_{t,S} + R_{t,L})} \tag{3}$$

See Table 3A for notations. This modified equation for Impact involves seven quantities.

Sensitivity analysis (SA)

The US v. Oregon TAC updates Impact during in-season, expressing it as a point value. Status quo practice in calculating Impact fails to measure uncertainty in the quantity of Impact. We do a SA for Impact to identify the relative importance of input quantity with respect to Impact variability.

In a SA, we treat input quantities for Impact as input variables and Impact as output variable, respectively. Before the SA stage, some input quantities were random variables and some were parameters. For example, run forecast, which is one of the input quantities, would have been treated as a random variable whereas post-release mortality was treated as a parameter. The distinction at the SA stage is not necessary, and thus we use the term of variables where Impact, the output variable is a function of input variables.

It is not a trivial task to do a SA for Impact of the selective fisheries (eq. 3), because seven variables involve the calculation of Impact, and data and information on the respective variables are limited.

Numerical method

Because of the many input variables, we take a numerical method of Monte Carlo (MC) for a SA. Letting $\mathbf{X}_t$ be a vector that has N , $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$, we assume $\mathbf{X}_t$ to be multivariate normal. That is,

$$\mathbf{X}_t \sim MVN\left(\boldsymbol{\mu}_t, \Sigma_t\right) \tag{4}$$

where $\boldsymbol{\mu}_t$ = the vector that contains the expected values of elements in $\mathbf{X}_t$; and Σ_t = covariance-variance matrix of elements in $\mathbf{X}_t$. That is, $\boldsymbol{\mu}_t$ is a 5 x 1 column vector,

$$\boldsymbol{\mu}_t = \begin{bmatrix} E(N) \\ E(H_{t,S}) \\ E(H_{t,L}) \\ E(R_s) \\ E(R_L) \end{bmatrix}_{5\times1} \tag{5}$$

and Σ_t is a 5 x 5 matrix,

$$\Sigma_t = \left(s^2_{\mathrm{ij}}\right)_{5\times5} \tag{6}$$

where index i refers to N , $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$ in order, and element s^2_{ij} denotes covariance-variance matrix. For example, s^2_{11} is the variance of N , and s^2_{24} is the covariance between $H_{t,S}$ and $R_{t,S}$.

We consider both independence and dependence between the five variables in eq. 6. In the independence assumption, covariance terms in eq. 6 are all zeroes. In the dependence assumption, we allow correlations between catches from two fishery gear types (i.e., $H_{t,S}$ and $H_{t,L}$), and between the numbers of wild unmarked fish caught and released from two gear types (i.e., $R_{t,S}$ and $R_{t,L}$). Those correlations are likely to be positive because catches from two fishery gear types are proportional to each other during the same season, and also because so are the numbers of wild unmarked fish caught and released from two gear types during the same season. Fish run size (N) is assumed to be independent of the other variables if its value is used as preseason forecast of run size. Preseason forecast is made several months before fish show up in the river, and thus its value is independent of the other variables that are measured in the river. However, if fish run size is used as in-season forecast of run size, its independence assumption is not valid, because data about catches in the lower river as well as escapement to Bonneville Dam are used for in-season forecast of run size. As time progresses, the correlation between catches in the lower river and in-season forecast of run size gets higher because more catches are incorporated to in-season forecast over time.

We assume that M_S and M_L are independent of each other, and also of the other quantities. Those post-release mortality rates are not correlated with each other, and they are not correlated with forecast of return abundance, catch abundance, and by-catch of unmarked wild fish. Because the domain of post-release mortality is from 0 to 1, we assume it to be a beta random variable.

$$M_S \sim Beta\left(\alpha_S, \beta_S\right)$$

$$M_L \sim Beta\left(\alpha_L, \beta_L\right) \tag{7}$$

where $\alpha_S > 0$, $\beta_S > 0$, $\alpha_L > 0$, and $\beta_L > 0$.

The MC procedure is as follows. Given $\boldsymbol{\mu}_t$ and Σ_t, we can generate many random values of N_t, $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$ from the multivariate normal distribution in eq. 4. Also, given α_S, β_S, α_L, and β_L, we can generate many random values of M_S and M_L from beta distributions in eq. 7.

First, we generate tens of thousands of those random values for the respective seven variable, and store them for each variable: e.g., $N_t{}^{(1)}$, $N_t{}^{(2)}$, $\cdots$, $N_t{}^{(k)}$, $H_{t,S}{}^{(1)}$, $H_{t,S}{}^{(2)}$, $\cdots$, $H_{t,S}{}^{(k)}$, $\cdots$, $M_L{}^{(1)}$, $M_L{}^{(2)}$, $\cdots$, $M_L{}^{(k)}$, where *k* random values per each variable are saved. Note that random values for the first five variables of N_t, $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$ must be generated and stored as a set per the variables (eq. 4). There are constraints among *N*, *H*, and *R*.

For both tangle and gill net fisheries, catches (H_s and H_l) cannot exceed fish run size (*N*), and also the number of wild fish caught and released (R_s and R_l) should be less than the catches: i.e., $R_s < H_s < N$ and $R_l < H_l < N$. We discard sets of the five random values that do not satisfy these constraints.
Second, we pass those random values for each variable to the corresponding variable in eq. 3 to calculate Impact. As a result, we have tens of hundreds of random values of Impact. Finally, we can infer Impact from these random values of Impact.

The core part for this calculation is data or information on parameters that govern the multivariate normal and beta densities in eqs. 4 and 7. Because data for those parameters are not all available, we use literature information and plausible values as well. The main intent of the SA is to identify input variables whose variations take into account Impact variability. The intent is not to address bias and precision of Impact.

Reference Impact

For demonstration purposes, we assume the calculation of the Impact on 1 April 2005, using data from that date, literature information, managers' opinions, and plausible values for missing data. Data on weekly in-river fishery harvest from 2005 are available from the US v. Oregon TAC.

Elements of parameters in vector $\boldsymbol{\mu}_t$ and covariance-variance matrix Σ_t are shown in Tables 3A.1 and 3A.2. Elements of α_S, β_S, α_L, and β_L in eq. 7 can be calculated with method of moments (MM), using the mean values and variances of M_S and M_L in Table 3A.1. Finally, feeding those parameter values, we can generate random values of the key seven variables from the corresponding distributions in eqs. 4 and 7, and then calculate random values of Impact with the above MC method. We use the resultant Impact as the standard or reference Impact. We examine how the reference Impact is affected by variations of input variables.

Measuring the main effect of individual input variable

Our SA ultimate goal is to examine the relative importance of each input variable with respect to the Impact variation. This could be done by measuring the main effect or total effect of each individual input variable on the Impact. The main effects can be measured by the so-called partial variance (Sobol' 1993) or correlation ratios (McKay 1997) or Top Marginal Variance (Jansen Rossing and Daamen 1994), which is defined to be the expected variance reduction due to fixing input variable X_i while the remaining $\mathbf{X}_{\sim i}$ vary (Chan et al. 2000). Here, $\mathbf{X}_{\sim i}$ denotes a vector of input variables $\mathbf{X}$ excluding the input value for variable X_i.

Linearization and variance decomposition

Although it is impossible to express Impact to be a linear function of the seven input variables (eq. 3), we can do so with eq. 2 where three input variables are involved. Taking a natural logarithm for Impact in eq. 2, we have a linear function as follows:

$$\log(I_t) = \log(H_t) + \log(M) - \log(N) \tag{8}$$

Post-release mortality (M) is independent of H and N, and H and N are independent of each other when N is used as preseason forecast of run size. Under the independent assumption, variance of $\log(I_t)$ is decomposed as follows:

$$\begin{aligned} Var\left(\log(I_t)\right) &= Var\left(\log(H_t)\right) + Var\left(\log(M)\right) + Var\left(\log(N)\right) \\ &\approx \frac{Var(H_t)}{E(H_t)^2} + \frac{Var(M)}{E(M)^2} + \frac{Var(N)}{E(N)^2} \end{aligned} \tag{9}$$

The second line in the above equation is approximated by Delta method (also called Taylor series approximation) (Rao 1973, Benichou and Gail 1989). This equation helps us to decompose variance of Impact, and to validate results of the above numerical SA.

Results and discussion

Sensitivity analysis (SA)

Distribution of reference Impact is shown in Fig. 1. The mean and median of the distribution were 0.0087 and 0.0061. The variance of the distribution was 0.000164. The distribution of reference Impact was seriously skewed (Fig. 1).

Forecast of run size (*N*) had the most important effect on Impact (Fig. 2). Under both assumptions of independence and dependence between input variables, Impact variance was most sensitive to forecast of run size, and secondly sensitive to post-release mortality from small fishery gear (M_S) (Fig. 2a and 2b). The other input variables could not be ranked in order of importance because their effects on Impact were almost similar (Fig. 2a and 2b).

The effect of forecast of run size in these results was also supported by the decomposition of Impact variance (eq. 9) although, in the decomposition analysis, catches and post-release mortality from different fishery gears (i.e., $H_{t,S}$ vs. $H_{t,L}$; M_S vs. M_L) could not be compared, and also the numbers released from different fishery gears (i.e., $R_{t,S}$ and $R_{t,L}$) were not included. The decomposition was summarized in Fig. 3; forecast of run size takes about 99.9% of variance of Impact.

Forecast of run size: preseason vs. in-season forecast

It looks obvious that uncertainty in Impact comes most from that in forecast of run size (Figs. 2 and 3). That is, we can reduce uncertainty in Impact (i.e., harvest decision's error based on Impact) by improving forecast of run size. Bias and precision of historical preseason forecasts was sometimes questionable. Fig. 4 illustrates performance of historical preseason forecasts of both hatchery and wild upriver spring Chinook salmon return sizes. Although we could not acquire data about preseason forecast performance for only wild fish runs, we can get insight about how unstable preseason forecast's reliability is. The US v. Oregon TAC does not make preseason forecast separately of only wild or hatchery spring run (S. Ellis, US v. Oregon TAC, Portland, OR, USA, personal Communication).

Methods for preseason forecast of upriver spring Chinook salmon return is an ordinary linear regression model of relating sibling returns. Overall, preseason forecasts of fish returns are not accurate enough for harvest decisions because of uncertainty from the following sources: environmental conditions, production analyses and data, and management error (ISAB 2005). Thus, once fish show up in the river, managers collect in-season data, and start to make in-season forecast of return size.

In examining in-season forecast, we used data about Columbia River spring Chinook salmon escapement to Bonneville Dam, which included upriver spring fish. Columbia River spring Chinook salmon escapement to Bonneville Dam has been recorded on a daily basis at the dam since 1938, whereas daily data about only upriver spring Chinook salmon were not available. Indeed, the US v. Oregon TAC uses data about historical daily escapement to Bonneville Dam and catch data in the lower river when making in-season forecast. Data about historical daily escapement to Bonneville Dam are directly available from the website (www.cbr.washington.edu/dart/adult.html with courtesy of US Army Corps of Engineers, NWD), whereas historical catch data in the lower river are not available. Regardless of presence or absence of catch data, the principle of making in-season forecast remains the same. The main difficulty in making accurate in-season forecast early during fish run is due to a large year-to-year variability in fish run timing. Fig. 5a shows run timing of Columbia River spring Chinook salmon escapement to Bonneville Dam from 1980-2006. Escapement proportions at day are used as a run timing index. Fig. 5a illustrates that escapement from 2001 was early returns and those from 2005 and 2006 were extremely late returns. Year-to-year variability during early stages in fish run was high with about coefficient of variation (CV = $\sqrt{\mathrm{var}}/\mathrm{mean}$) of 3.5 (i.e., 350%) (Fig. 5b). The CV decreased below 0.5 (i.e., 50%) after about Julian day 100 (= 10 Apr). Positive lag-1 autocorrelation was found between yearly escapement proportions at day after Julian day 125 (= 5 May) (Fig. 5c).

The US v. Oregon TAC's methods for in-season forecast of fish return size are simple. They monitor fish run size during in-season, and their calculation of total fish run size is from the division of cumulative run size at a day by the average of run proportions at the day from a certain number of historical years. The certain number of historical years is usually at least 10 years, but it is easily chosen as a different range. Using a hind-casting procedure where only data prior to a forecast time are used, we made the traditional in-season forecasts of total escapements in 1995-2006 (Fig. 5d). Because of autocorrelation of yearly escapement proportions at a day, we used the hind-casting forecast method. If there were no autocorrelation, we could deploy other method such as cross-validation, which assumes independence between each data. Fig. 5d shows that absolute values of relative errors (%) of forecasts made before Julian day 105 (= 15 April) were more than 100%.

This examination of in-season forecast performance indicates that even after fish show up in the river, in-season forecast made at the early stage in the season are not reliable. If fish run timing is extremely early or late (e.g., 2001 and 2006 in Fig. 5), in-season forecast is still questionable even after the early stage.

Recommendation for forecasts

We identified how important forecast of fish return size is to in-river harvest decisions. Forecast of return size was the most important to Impact quantity, with which managers make harvest decisions. We recommend improvement in preseason and in-season forecasts of return size by incorporating environment variations, by systematically combining both preseason and in-season forecasts, and by measuring uncertainty in those forecasts.

Incorporating environmental variations will improve forecast accuracy. For example, significant early or late returns in 2001, 2005, and 2006 (Fig. 5a) may have been derived from an abiotic agent. Also, we need to systematically combine available information of both preseason and in-season forecasts. The US v. Oregon TAC makes these two forecasts, but no one seems to try to combine them. Because preseason forecast can be poor (Fig. 4b), and in-season forecast made at the early stage in fish return season still has much uncertainty (Fig. 5d), forecast from mixing these two forecasts will be better than either one at the early stage. Combining those forecasts is doable in a statistics framework (e.g., Bayesian statistics). Finally, forecast outputs are expressed as point values. The status quo approach would be improved by showing at least forecast intervals. Given a point value of forecast, managers are usually concerned about uncertainty in the point value.

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Table 3A.1. Notations.

Indices	
t	Time (day)
S	Small mesh size, referring to tangle net
L	Large mesh size, referring to gill net
CV	Coefficient of variation (= $\sqrt{\mathrm{var}}$ /mean)
r	Correlation coefficient
Cov	Covariance
Variables	
I	Impact (rate)
N_t	Abundance of wild fish population return to Columbia River mouth. The quantity is used as preseason forecast of the return size before in-season data are collected. As time progresses, in-season forecast of the return size is updated and used for N_t. Thus, subscript time t is added.
$H_{t,S}$	Cumulative catch of the population caught by small-mesh gear (e.g., tangle net gear) to time t.
$H_{t,L}$	Cumulative catch of the population caught by large-mesh gear (e.g., gill net gear) to time *t*
$R_{t,S}$	Cumulative number of wild unmarked fish caught by small-mesh gear and released to time *t*
$R_{t,L}$	Cumulative number of wild unmarked fish caught by large-mesh gear and released to time *t*
M_S	Post-release mortality of fish that are released from small-mesh gear. Post-release mortality does not depend on time and its notation does not have subscript time *t*.
M_L	Post-release mortality of fish that are released from large-mesh gear
$\mathbf{X}_t$	Vector of N_t, $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$.
Parameters	
$\boldsymbol{\mu}_t$	Vector that has the respective mean values of N_t, $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$.
Σ_t	Covariance-variance matrix of the vector of N_t, $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$.
α_S, β_S, α_L, β_L	Parameters that govern beta distributions of M_S and M_L.

Table 3A.1. Seven variables required for calculation of Impact of selective fisheries of wild upriver spring Chinook salmon (*Oncorhynchus tshawytscha*) in the lower Columbia River, and the mean, CV, and variance values of those variables at 1 April 2005. Number in parentheses for the first five variables indicates element index in the vector, $\mathbf{X}_t$. Thus, values under "Var" column are diagonal elements (s^2_{ii}) in the covariance-variance matrix in eq. 6**Error! Reference source not found.**, where ii = 11, 22, 33, 44, and 55. Mean values are from data (data source: the U.S. vs. Oregon Technical Advisory Committee (TAC)). CV value of N_t is from empirical experience (Hyun et al. 2006). CV values of $H_{t,S}$, $H_{t,L}$, $R_{t,S}$, and $R_{t,L}$ are plausible values, based on discussion with the US v. Oregon TAC. CV values of M_S and M_L are from study of Ashbrook et al. (2004).

Variable	Mean	CV	Var
N_t (1)	106,800	0.4	1,824,998,400
$H_{t,S}$ (2)	2,417	0.1	58,419
$H_{t,L}$ (3)	591	0.1	3,493
$R_{t,S}$ (4)	778	0.04	968
$R_{t,L}$ (5)	213	0.04	73
M_S	0.185	0.72	0.018
M_L	0.400	0.20	0.006

Table 3A.2. Values of non-diagonal elements in covariance-variance matrix in eq. 6 **Error! Reference source not found.**. Diagonal elements are shown in Table 3A.1. Column *r* denotes correlation coefficients. See Table 3A.1 for subscript index of element. For example, s^2_{12} = s^2_{21} = covariance between N and $H_{t,S}$. Under the dependence assumption, we allow minor positive correlations (= 0.5) between catches from two fishery gear types (i.e., $H_{t,S}$ and $H_{t,L}$), and between the numbers of wild unmarked fish caught and released from two gear types (i.e., $R_{t,S}$ and $R_{t,L}$). Total catch of fish by a small-mesh (or a large-mesh gear) is not necessarily correlated with by-catch of unmarked wild fish by a large-mesh gear (or a small-mesh gear). Thus, $s^2_{25} = 0$; $s^2_{34} = 0$.

Element	Independence scenario		Dependence scenario	
	r	Cov	r	Cov
s^2_{12}	0	0	0	0
s^2_{13}	0	0	0	0
s^2_{14}	0	0	0	0
s^2_{15}	0	0	0	0
s^2_{23}	0	0	0.5	7,142
s^2_{24}	0	0	0	0
s^2_{25}	0	0	0	0
s^2_{34}	0	0	0	0
s^2_{35}	0	0	0	0
s^2_{45}	0	0	0.5	133

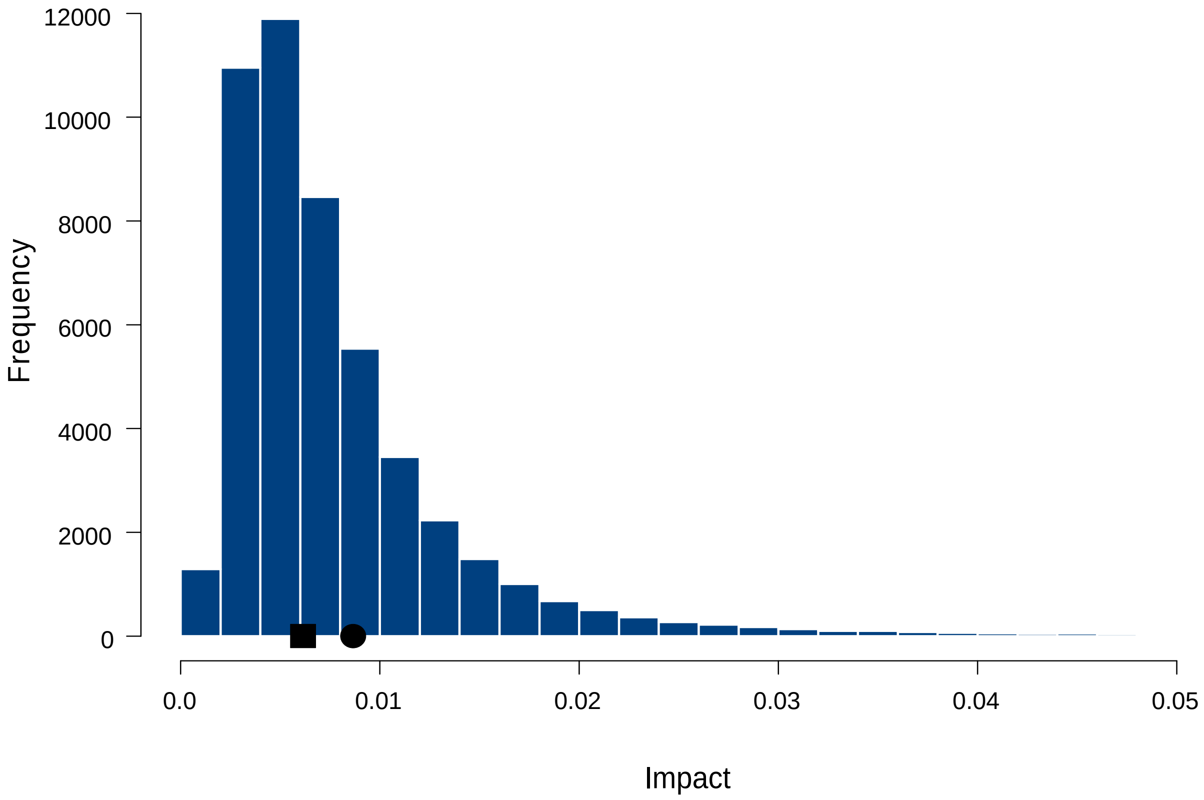

Figure 3A.1. Illustration of reference Impact at 1 April 2005 for selective fisheries that target wild upriver spring Chinook salmon (*Oncorhynchus tshawytscha*) in the lower Columbia River. With Monte Carlo (MC) methods, we calculate the Impact, using values in Tables 3A.2 and 3A.3 for parameters that govern seven variables in eq. 3. Black dot indicates the mean of the reference Impact ($\approx$0.0087), and black box is the median ($\approx$ 0.0061). Variance of the reference Impact is about 0.000164.

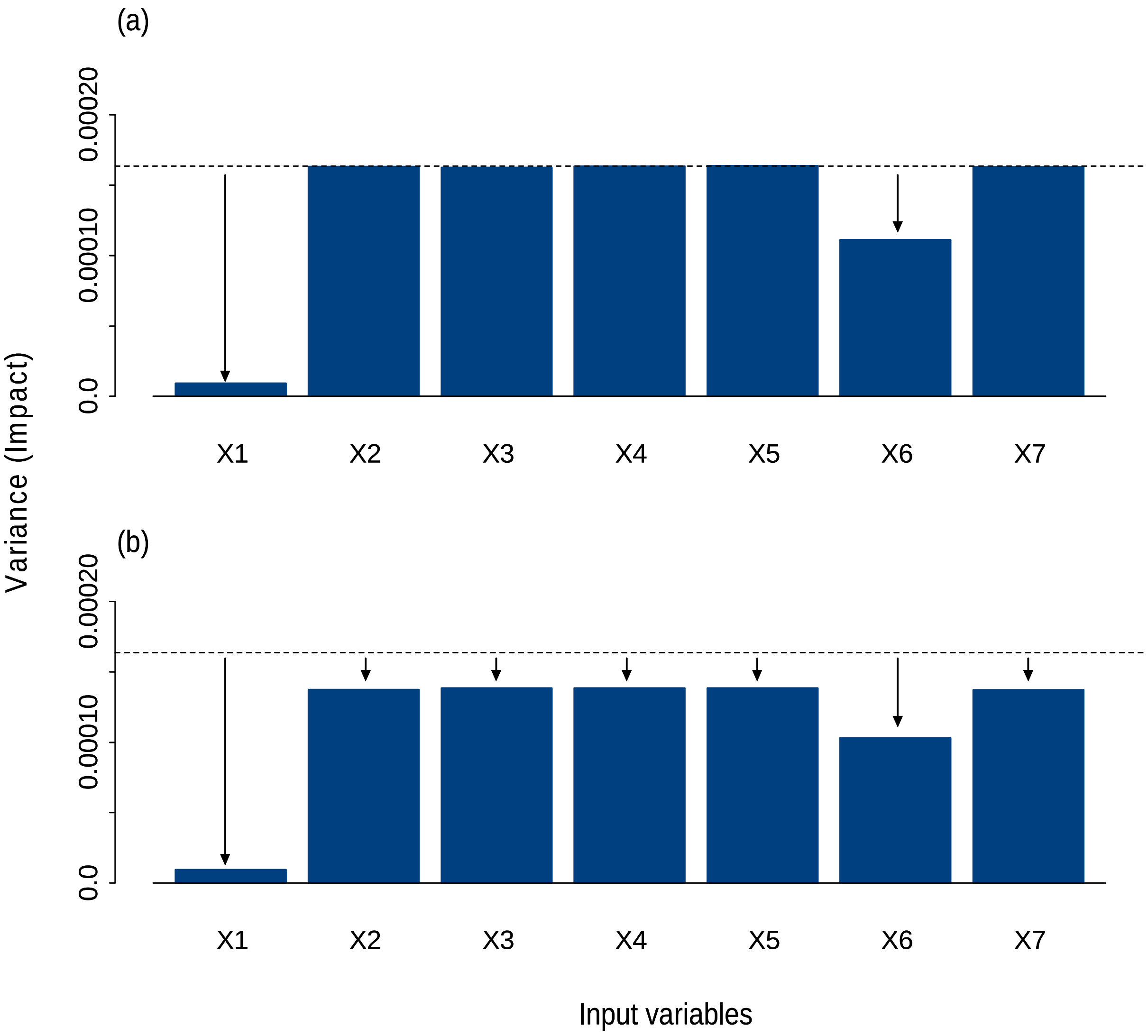

Figure 3A.2. Sensitivity analysis (SA) of input variables for Impact. Variables X_i on *x*-axis are seven input variables in eq. 3: $X_1 = N$; $X_2 = H_{t,S}$; $X_3 = H_{t,L}$; $X_4 = R_{t,S}$; $X_5 = R_{t,L}$; $X_6 = M_S$; and $X_7 = M_L$. Horizontal dotted line is variance of reference Impact. Bar on an input variable indicates variance of Impact calculated when the variable is fixed and the other variables vary under independence assumption (a) and dependence assumption (b) (Table 3A.3). Magnitude of the variance reduction with a variable of interest fixed indicates the effect significance of the variable. Forecast of run size ($X_1 = N$) influences Impact most under the two assumptions.

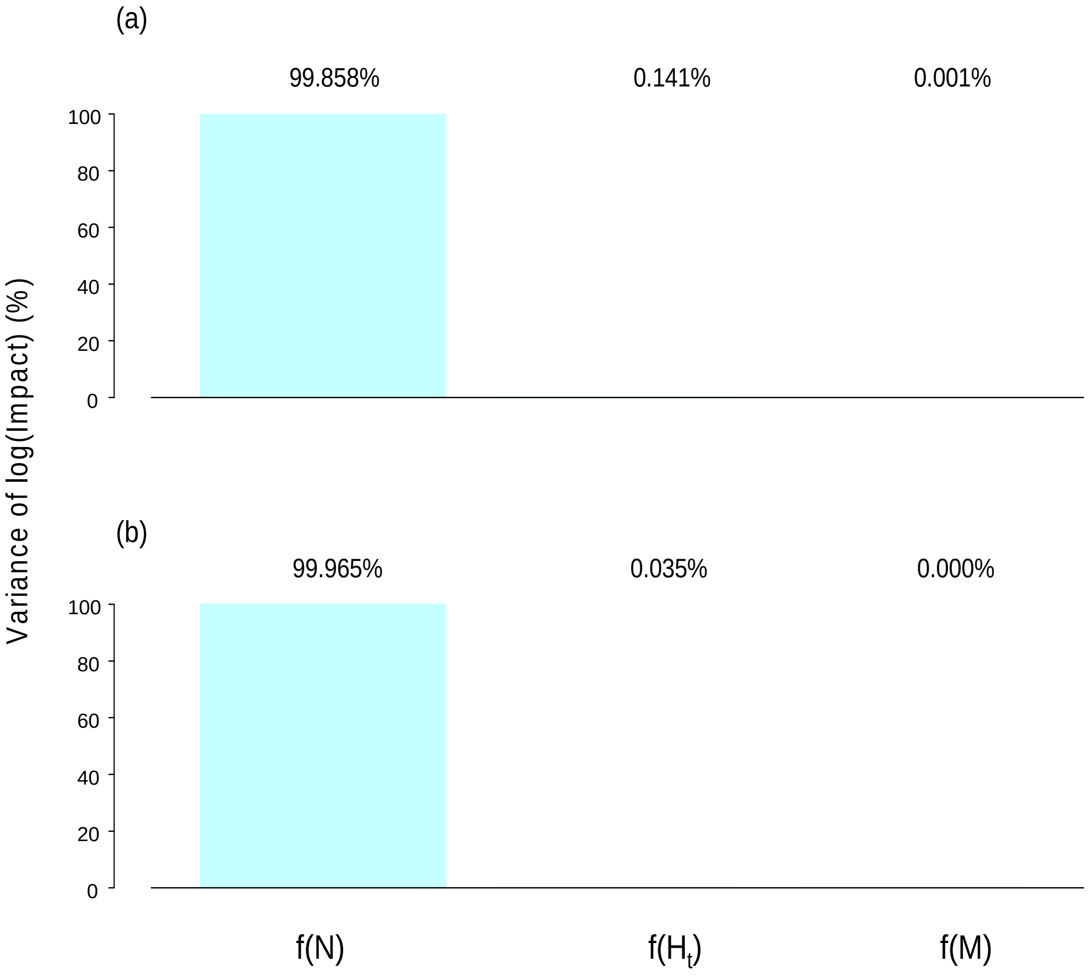

Figure 3A.3. Decomposition of Impact variance. Function *f*(g) on *x*-axis is Var(g)/[E(g)^2] in eq. 9. Bar on the respective function of N , H_t , and M indicates the magnitude of contribution of the variable to variance of log(Impact) (eq. 9). The upper panel (a) is the resultant decomposition of Impact variance in replacing catch and post-release mortality (H_t , and M) with those from small fishery gear (i.e., $H_{t,S}$, and M_S), whereas the lower panel (b) is that in replacing catch and post-release mortality (H_t , and M) with those from large fishery gear (i.e., $H_{t,L}$, and M_L).

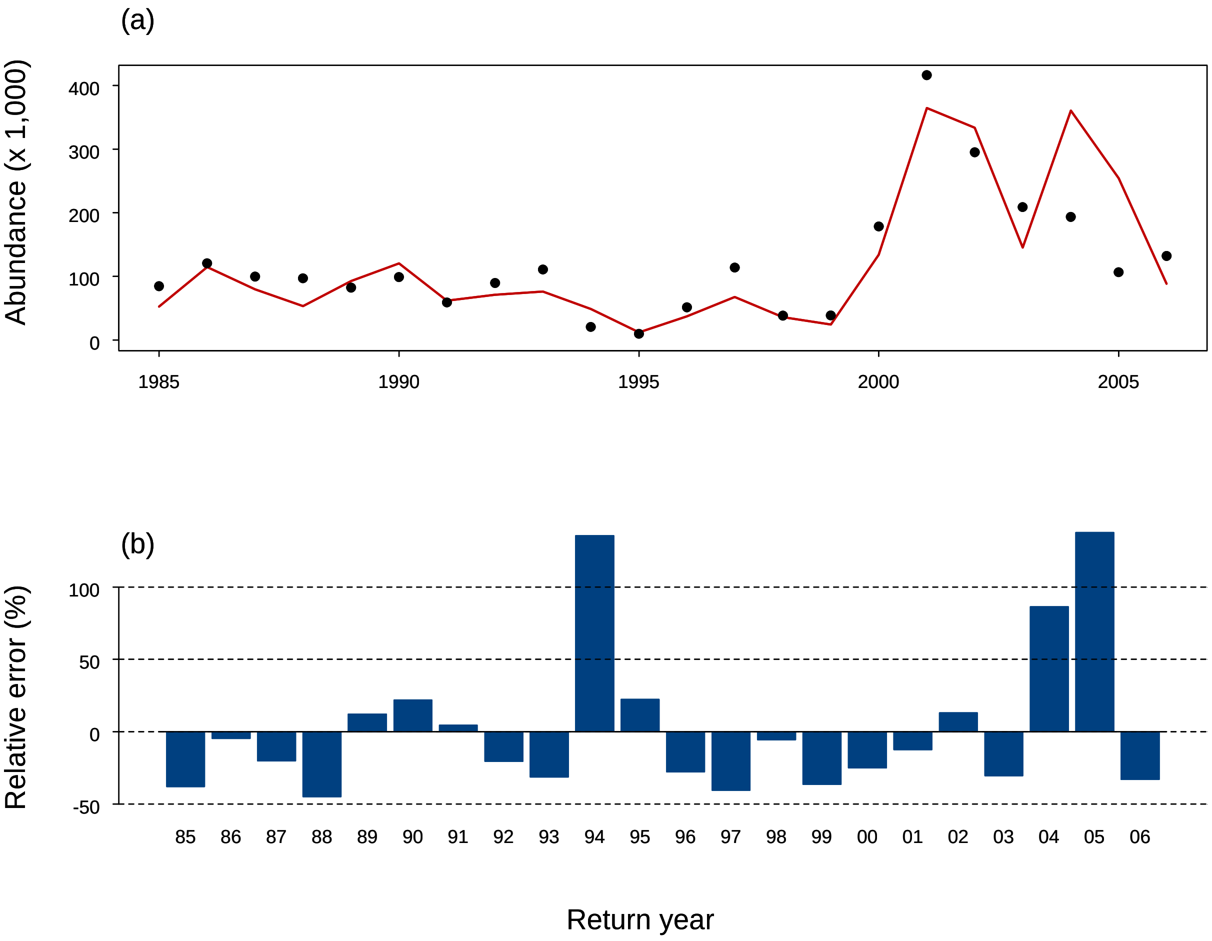

Figure 3A.4. Performance of historical preseason forecasts of both hatchery and wild upriver spring Chinook salmon (*Oncorhynchus tshawytscha*) return size. Year on *x*-axis is return year. Dots and line in panel (a) are actual return size and preseason forecast, respectively. Bar in panel (b) indicates relative error (%) of preseason forecast. These data are from Joint Columbia River Management Staff (2007).

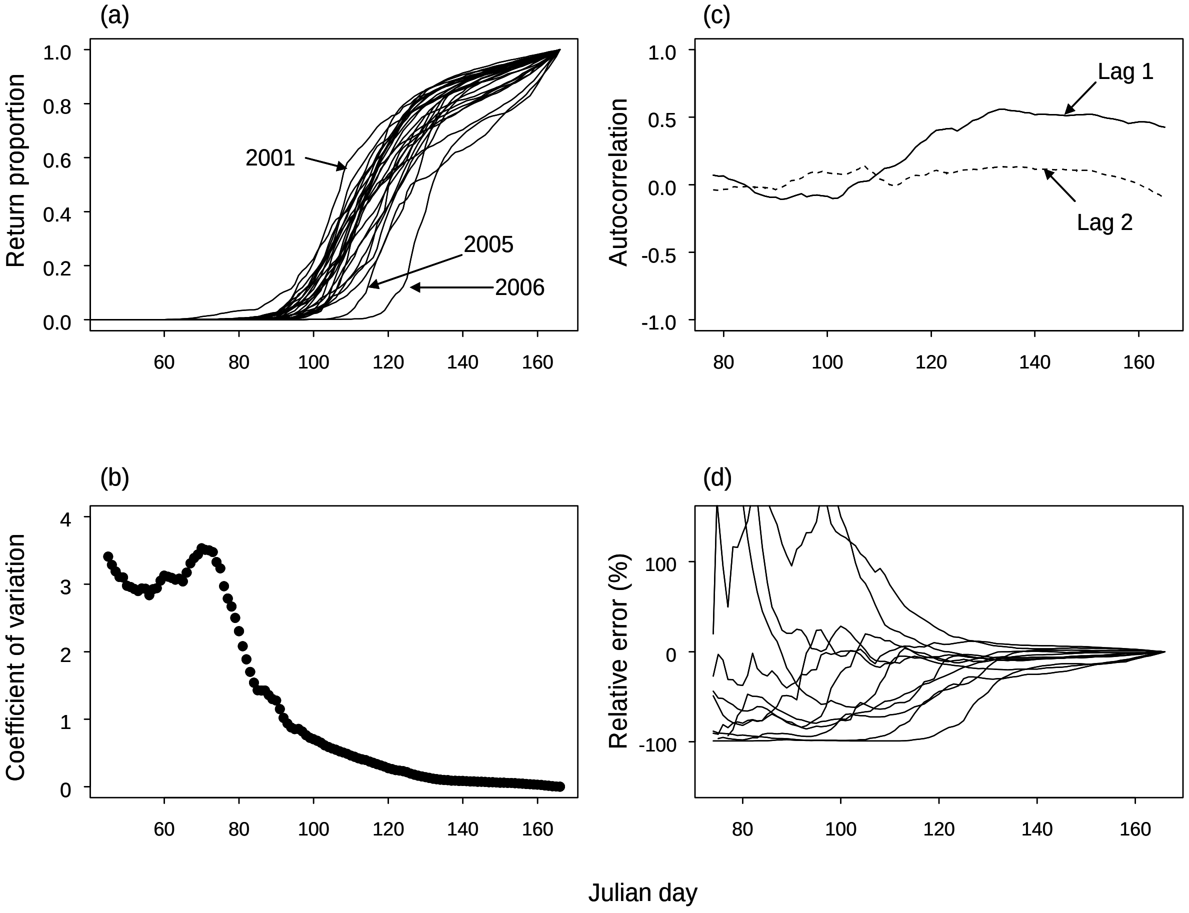

Figure 3A.5. (a) Proportions at day of Columbia River spring Chinook salmon escapement to Bonneville Dam from 1980-2006; (b) Coefficient of variation of the yearly escapement proportions at day; (c) Lag 1 - and lag 2 - autocorrelation coefficients of the yearly escapement proportions at day; (d) Relative errors (%) of the traditional in-season forecasts of total escapements in 1995-2006. Day is expressed as Julian day (i.e., 60 = 1 March; 80 = 21 March; etc.).

Appendix 5: Background on Lemhi Habitat Conservation Plan

Prepared for CSMEP Habitat DQO Design Group

Prepared by Tim Copeland, IDFG

The Lemhi River watershed is a 4th field HUC in east-central Idaho. The main river is formed near the town of Leadore and flows northwest over 100 km through an alluvial valley to its confluence with the Salmon River at rkm 1241, in the town of Salmon. The drainage pattern is trellis-type and the surrounding area is high desert or mountains, with a base elevation of 4004' above msl. Only 2 tributaries, Hayden and Big Springs creeks, are currently connected to the main stem year-round. Big Springs Creek originates from artesian springs downstream of Leadore and flows parallel to the main stem until meeting at rkm 77. Hayden Creek is a flashy, montane tributary that flows into the Lemhi at rkm 51.

Major land uses are agriculture and grazing. There are many irrigation diversions and returns of irrigated water have resulted in increased temperatures and sedimentation. Riparian degradation has exacerbated these trends. During the irrigation season, fish passage in the lower river is difficult and the channel has become de-watered in dry years. There has been channelization in the lower river, resulting in habitat homogenization. The banks are bermed and State Route 28 further constrains the channel. Substrate is largely cobble. There are long stretches of shallow water and few pools in this reach. The main stem Lemhi above Hayden Creek is less confined with a natural meander pattern and a deeper channel. Multiple artesian springs keep flows steady. Substrate has a larger component of gravel, although siltation is a problem in this reach. Currently, most main stem diversions have been screened and a minimum flow agreement is in force for the lower main stem and Hayden Creek. Other ongoing conservation efforts include riparian fencing, diversion modifications, and water conservation measures.

The focal fish species in the watershed are spring Chinook salmon, A-run steelhead trout, and bull trout. Resident bull trout are thought to inhabit most tributaries. Fluvial populations are found in the upper main stem, Hayden and Kenney creeks. Most Chinook spawning occurs in the upper main stem Lemhi upstream of Hayden Creek, with some spawning in Hayden Creek and its major tributary, Bear Valley Creek. Several pulses of juvenile emigration may occur during the year, including the fall, base flow period. The status of steelhead in the watershed is uncertain. Other fishes of concern include redband and westslope cutthroat trout.

Habitat actions

A Lemhi Habitat Conservation Plan (HCP) is being formalized to address ESA issues in the watershed until 2035. The goal of the HCP is "…to provide within-basin habitat conditions in the Lemhi River basin necessary to produce fish in numbers adequate to sustain or increase their populations". In practical terms, the HCP goal is to meet Viable Salmonid Population (VSP) criteria for abundance, productivity, spatial structure and diversity (specific targets have yet to be developed). The underlying assumption of the HCP is that as habitat conditions are improved, fish will respond and desired biological effects will be achieved. The conservation objectives are 1) to provide adequate flow to remove or reduce migration barriers, 2) maintain or enhance riparian conditions, and 3) improve instream conditions with respect to cover, temperature, flow, and sedimentation. The desired actions are:

1) reconnect tributaries to the Lemhi River,
2) alter channel morphology to address fish passage,
3) minimize fish entrainment,
4) enhance spawning and rearing habitat,
5) maintain minimum flows,
6) improve riparian corridors,
7) mimic the natural hydrograph (recent flushing flows have occurred only in 1997).

See Table A.1 for the specific habitat measures proposed. Some of these actions already occur. The main new action will be reconnection of 10-17 tributaries at a rate of 1 every 3 years. Full, year-round reconnection is planned for 4 streams and seasonal reconnection for the rest. At least 4 reconnects will be completed by 2010 and at least 10 by 2025. The intention is to evaluate the first set of reconnects to provide guidance for the remainder. A seasonal reconnection occurred during the 2004 irrigation season and salmon parr were observed in the lower reaches of that stream. Other HCP actions will include placement of vortex weirs and upstream barbs in the lower river, barrier removal/intake screening in tributaries, riparian grazing management (rotation, fencing, easements), screening of return flow structures, and side-channel reconnection/enhancement.

Objectives and proposed strategies vary somewhat between river reaches. From the mouth to L6 diversion, the objective is to improve fish passage. Management tools proposed include minimum flows, channel modifications, creation of pools, and riparian management. From L6 to Agency Creek, passage is also an issue, and riparian management and creation of pools have been proposed. From Agency Creek to Hayden Creek, the objective is to improve rearing habitat by riparian management and creation of pools and off-channel habitat. These reaches have been lumped into Area A by the CSMEP habitat group. The upper river, Area B, is upstream of Hayden Creek. The objectives here are to improve spawning and rearing habitat. Minimum flows, a spring flush, riparian management, creation of pools and off-channel habitat have been proposed.

Several tributaries have been proposed for some kind of reconnection. Type and timing will depend on negotiations with irrigators. Objectives are to provide thermal refuges for Chinook parr during summer (both in the main stem and the lower tributary reach), to support objectives in the main stem, and allow free passage of other species into the headwaters. Reconnections will be associated with barrier removal, diversion screening, and riparian management in the lower reaches of the tributary. Six reconnects are possible in Area A and ten in Area B. Six tributaries are believed to have potential to support Chinook spawning (4 in Area B, 1 in Area A, and Hayden Creek). Potentially, 6 reconnects will support flushing flows in the upper main stem.

No reconnects are anticipated in Hayden Creek (Area C). Management consists of a minimum flow at the mouth. This flow currently supports minimum flow targets in the lower main stem. Future management will maintain these flows with the goal of allowing fish passage.

Monitoring activities

Current fish monitoring in the Lemhi watershed is largely conducted by IDFG. Chinook redd counts are completed in the upper Lemhi by IDFG personnel. The lower portion of Area B is hard to access and redd counts are completed by 2 aerial counts (fixed wing). The remainder is covered by both 3-pass ground surveys and aerial counts (the latter for IDFG trend data). Snorkeling takes place annually at 11 sites on the main stem/Big Springs and 7 in Hayden/Bear Valley creeks. Other sites are occasionally snorkeled.

Screw traps are operated March-November on the main stem just upstream of Hayden Creek and near the mouth. The lower site is hard to sample at all flows and the search for an optimal site in the lower reach continues. Bull trout redd counts are done in Bear Valley, Hayden, and Big Timber Creeks. Intensive electrofishing surveys have taken place on 6 tributaries, systematically sampling segments (3-pass depletion every third kilometer) to the upstream limits of fish occurrence. Tissue samples were collected from salmonids in selected middle, lower, and upper reaches in each tributary (30 samples per reach). Four major diversion bypasses in the lower Lemhi have been outfitted with PIT detectors; large numbers of parr tagged at the upper screw trap have been detected at these diversions. On occasion, the presence of steelhead in the basin is qualitatively assessed by visual observations.

There are other efforts as well. The Shoshone Bannock Tribes conduct work in the Hayden Creek drainage. Redd counts in Hayden Creek are done by BLM personnel. Some telemetry (by Idaho State University personnel) on fluvial trout is on-going in the upper Salmon basin, including the Lemhi. Some telemetry was done by University of Idaho personnel in the Lemhi in recent years. Idaho Department of Water Resources conducts flow and temperature monitoring at several sites. Flow modeling is being undertaken by Bureau of Reclamation and University of Idaho. Recently, Idaho Department of Environmental quality contracted a FLIR flight of the main stem. Baseline instream and riparian data were taken in 1994 by a multi-agency effort. The entire mainstem and Big Springs Creek, as well as the lower 14 km of Hayden Creek, were inventoried.

There are several planned and potential future activities identified. The possibility of installing a third screw trap at the mouth of Hayden Creek is being explored, although finding a suitable site may be difficult. Recent reconnaissance of the area suggests that DIDSON units could be installed at the L6 diversion and Ted Bjornn’s old weir. IDFG is planning to increase the intensity of ground redd surveys to include the entire upper reach. A seasonal weir may be operated on Big Timber before and after permanent reconnection, to focus on movements of fluvial trout. Expanded telemetry work in upper Lemhi is also likely. The Hayden Creek drainage will be sampled to place PIT tags in juvenile *O. mykiss* to locate steelhead production reaches. The intensive tributary surveys will continue at rate of 6 per year, thus establishing a baseline for all potential reconnect streams within a few years. These surveys can serve as fixed monitoring sites as needed. Lastly, temperature monitoring has been initiated recently and is expanding (10+ sites in the mainstem and selected tributaries).

Lemhi Information types & sources:

1) ***Chinook redd counts*** are completed in the upper Lemhi by IDFG personnel. The lower portion of Area B is hard to access and redd counts are completed by 2 aerial counts (fixed wing). The remainder is covered by both 3-pass ground surveys and aerial counts (the latter for IDFG trend data). Redd counts in Hayden Creek are done by BLM personnel at peak of spawning. Recent reconnaissance of the area suggests that DIDSON units could be installed at the L6 diversion and Ted Bjornn’s old weir. IDFG is planning to increase the intensity of ground redd surveys to include the entire upper reach of the main stem.
2) ***Snorkeling*** takes place annually at 11 sites on the main stem/Big Springs (Section B) and 7 in Hayden/Bear Valley creeks (Section C). Some sites are part of the annual GPM surveys, others are annual evaluations of instream habitat structures. Other sites are occasionally snorkeled (some in Section A). Site selection is not random or systematic.
3) ***Screw traps*** are operated March-November on the main stem just upstream of Hayden Creek and near the mouth. The upper site has been run for more than 10 years. The lower site is hard to sample at all flows and the search for an optimal site in the lower reach continues. The possibility of installing a third screw trap at the mouth of Hayden Creek is being explored, although finding a suitable site may be difficult.

4) ***Tributary data*** are mostly of recent origin. Bull trout redd counts are done in Bear Valley, Hayden, and Big Timber Creeks. Intensive electrofishing surveys have taken place on 6 tributaries, systematically sampling segments (3-pass depletion every third kilometer) to the upstream limits of fish occurrence. Tissue samples were collected from salmonids in selected middle, lower, and upper reaches in each tributary (30 samples per reach). The intensive tributary surveys will continue at rate of 6 per year, thus establishing a baseline for all potential reconnect streams within a few years. These surveys can serve as fixed monitoring sites as needed. A seasonal weir may be operated on Big Timber before and after permanent reconnection, to focus on movements of fluvial trout. This work is in the feasibility/planning stages.

5) ***PIT tag Detectors***: Four major diversion bypasses in the lower Lemhi have been outfitted with PIT detectors. The purpose is to examine the effectiveness of the diversion bypass system in preventing entrainment; however, large numbers of parr tagged at the upper screw trap have been detected in the bypass on their way back to the main channel. This monitoring will continue for the near future, but no expansion is planned at this time.

6) ***Marking and tracking***: Several studies have marked and tracked fish in the Lemhi. The upper screw trap is used to PIT tag Chinook parr. The Hayden Creek drainage will be sampled this summer (2005) by flyfishing to place PIT tags in juvenile *O. mykiss* to locate steelhead production reaches. Some telemetry (by Idaho State University personnel) on fluvial trout is on-going in the upper Salmon basin, including the Lemhi. In the Lemhi, this work focused on bull trout in the upper main stem and Hayden Creek (Section B & C). Fish tracked in the Salmon River pass the mouth of the Lemhi but none have moved into the lower Lemhi (Section A). Expanded telemetry work in upper Lemhi is likely in the near future, perhaps in association with the proposed weir on Big Timber Creek. Some telemetry was done by University of Idaho personnel in the Lemhi in recent years, following adult Chinook tagged at Bonneville Dam upstream.

7) ***Flow and temperature***: Idaho Department of Water Resources conducts flow and temperature monitoring at several sites (not sure if staff gauges used or where). There are 3 USGS flow gauges along the main stem, one in the upper reach (Section B) and two in the lower reach (Section A). Mandatory minimum flows are measured at these gauges. Flow modeling is being undertaken by Bureau of Reclamation and University of Idaho. Recently, Idaho Department of Environmental Quality (Idaho Falls office) contracted a FLIR flight of the main stem. Lastly, temperature monitoring at remote sites by IDFG has been initiated recently and is expanding (10+ sites in the mainstem and selected tributaries with HOBO monitors; not sure of placement).

8) ***Habitat***: Baseline instream and riparian data were collected in 1994 by a multi-agency effort. The entire main stem and Big Springs Creek, as well as the lower 14 km of Hayden Creek, were inventoried. This was intended as a coarse-resolution inventory and not as a rigorous survey for monitoring. Data were taken by measuring habitat units in a continuous manner moving downstream and intensely sampling substrate and other instream and riparian variables every tenth unit. Results were used to implement riparian improvements in the upper Lemhi. Local personnel feel that bank stability has likely increased there as a consequence. However, there has been only one year of flushing flows (1997), so instream habitat is likely unchanged. These data will be spot-checked this summer.

Table A.1. Proposed Lemhi River habitat conservation measures to be implemented (March 2005 draft).

Conservation Measure	Title	Geographic Area	Objective	Description
HCM 1 – 01	Lemhi River Tributary Reconnects	Lemhi River Tributaries	Fish Passage	Provide hydraulic and ecological connectivity between the Lemhi River and tributaries
HCM 2 – 01	Fish Passage Protection in the Lemhi River and Tributaries	Basinwide	Fish Passage	Identify and improve fish passage and entrainment problems throughout the Lemhi River basin
HCM 2 – 02	Eliminate Ditch Return (backdoor) Threats	Basinwide	Fish Passage	Prevent fish from entering irrigation ditches from the downstream end that do not provide adequate fish spawning and rearing habitat
HCM 2 – 03	Riparian Grazing Management in the Lemhi Mouth Reach	Basinwide	Riparian Habitat Protection	Improve riparian zones along the Lemhi River and tributaries to rehabilitate fish habitat
HCM 2 – 04	Side Channel and Secondary Channel Rearing Enhancement	Middle Reach Upper Reach	Stream Habitat Conditions	Provide fish access to side channels to enhance spawning habitats and juvenile rearing capacity
HCM 3 – 01	Maintenance of 35/25 cfs at L6	Lower Reach	Fish Passage	Minimum continuous stream flows at the L6 diversion to maintain adequate fish passage for access to the middle and upper river reaches and tributaries
HCM 3 – 02	Changes in Channel Morphology	Lower Reach	Fish Passage	Installation of structures that increase water depth to minimize fish passage delays
HCM 5 - 01	Manage Flow/Habitat in the Upper Lemhi River	Upper Reach	Stream Habitat Conditions	Develop a process to adaptively manage stream flow and other habitat parameters to maintain or enhance spawning and rearing in the upper river
HCM 5 - 02	Stream Channel and Substrate Maintenance Flows	Upper Reach	Stream Habitat Conditions	Provide high volume stream flows to reproduce the natural hydrograph and maintain stream channel complexity and rehabilitate fish habitat
HCM 6 – 01	Maintain fish passage in the lower reaches of Hayden Creek	Hayden Creek	Fish Passage	Provide fish passage conditions that allow fish to migrate through mouth of Hayden Creek

Appendix 6A: Original List of Questions Generated by the Hatchery Subgroup

What are the principal CSMEP questions to be addressed?
(Priority level for each question is characterized as High (H), Moderate (M) or Low (L))

To what extent can hatcheries be used to assist in meeting harvest management goals while keeping impacts to natural populations within acceptable limits?

Objective	Priority	
HA 1	H	What are optimum rearing and release, marking, and hatchery management strategies to maximize harvest management opportunities and minimize impacts to natural populations?
HA 2	H	What are annual harvest contributions and catch distribution of hatchery produced fish?
HA 3	H	To what degree does the hatchery program meet harvest objectives?
HA 4	H	What is the impact of incidental harvest and mortality on viability of natural populations?
HA 5	H	What is the magnitude and distribution of hatchery strays into natural populations?
HA 6	H	What is the impact of hatchery strays on viability of natural populations?
HA 7	H	What are the impacts on viability of natural populations resulting from ecological interactions at the juvenile life stage?
HA 8	L	What are the impacts of hatchery facility operations (water withdrawal, weir effects, water quality effects, etc.) on natural populations?
HA 9	M	What are the factors which influence the cost-effectiveness of the hatchery program?
HA 10	H	What are the most precise and accurate methods to forecast escapement of hatchery and natural fish?
HA 11	H	What are the disease agents and pathogens in hatchery fish, and what are the impacts due to transmission to wild fish?

To what extent can hatcheries be used to enhance viability of natural populations while keeping impacts to non-target populations within acceptable limits?

Objective	Priority	
S 1	H	What is the ratio of recruits per spawner for hatchery produced and natural produced fish?
S 2	H	What is the relative reproductive success of natural spawning hatchery and natural fish?
S 3	H	What is the spawning distribution of hatchery and natural origin fish and how do they differ?
S 4	H	What is the annual spawning distribution, how much does it vary annually, and how has it changed in supplemented populations?
S 5	H	What are the effects of hatchery supplementation on productivity and abundance of natural populations?
S 6	M	What are the life stage specific survival rates of hatchery and natural fish and how do they differ?
S 7	H	What are the effects of supplementation on adult life history diversity in supplemented natural populations?

Objective	Priority	
S 8	H	What are the effects of supplementation on juvenile life history diversity in supplemented natural populations?
S 9	M	What is the degree and rate of change in genetic characteristics of supplemented populations?
S 10	H	What are the genetic characteristics of hatchery and natural fish in supplemented populations and how do they compare?
S 11	H	What are the adult life history characteristics of hatchery and natural fish and how do they differ?
S 12	H	What are the smolt migration characteristics of hatchery and natural smolts and how do they differ?
S 13	H	What are the proportions of natural spawning stray hatchery fish in non-target natural populations?
S 14	H	What are the distribution of strays and stray rates of hatchery fish?
S 15	H	What are the most precise and accurate methods to forecast escapement of hatchery and natural fish?
S 16	H	What are the catch contribution and catch distribution of hatchery fish?
S 17	H	What are the effects of alternative hatchery production strategies on juvenile characteristics, survival rates, adult life history characteristics, and spawner distribution?
S 18	H	What disease agents and pathogens occur in natural and hatchery fish, and what are the impacts to natural fish?
S 19	H	What is the spawning carrying capacity, and how does spawner abundance compare to the capacity?
S 20	H	What are the effects of status and trends of habitat on supplemented populations?
S 21	H	What are the status and trends in naturally produced juvenile and smolt abundance of supplemented populations?
S 22	H	What are the effects of the hydrosystem on productivity and survival of supplemented populations?

Appendix 6B: CWT Tagging Rates for Columbia/Snake River Basin Hatchery Programs

		Brood Year*					
Region - River/release site	Hatchery	1998	1999	2000	2001	2002	2003
Spring Chinook - Central Columbia River (CECR)							
Wind River	Carson NFH	0.05	0.05	0.08	0.04	0.09	0.05
Little White Salmon River	Little White Salmon NFH	0.07	0.07	0.07	0.07	0.14	0.18
Hood River	Round Butte	0.99	0.99	1.00	1.00	1.00	1.00
Klickitat River	Klickitat	0.21	0.29	0.98	1.00	1.00	0.97
Deschutes River	Round Butte	0.98	0.96	0.95	0.99	0.99	0.95
Deschutes River	Warm Springs	0.93	0.97	0.94	0.99	0.92	0.96
Umatilla River	Umatilla, Bonneville, Little White Salmon NFH, Willard NFH	0.26	0.37	0.20	0.23	0.22	0.33
Spring/Summer Chinook - Snake River (SNAK)							
Tucannon River	Tucannon	1.00	1.00	1.00	0.99	0.99	0.97
Clearwater River - Dworshak Hatchery	Dworshak	0.12	0.38	0.11	0.12	0.12	0.13
Clearwater River - Clear Creek	Kooskia	0.21		0.19	0.19	0.16	0.16
Clearwater River - Newsome Creek, Walton Creek, Lolo Creek, Crooked River, Crooked Fork Creek, Powell Acc. Pond	Clearwater, Nez Perce Tribal, Dworshak	0.67	0.95	0.94	0.97	0.98	0.41
Salmon River - Rapid River Hatchery	Rapid River	0.13	0.45	0.11	0.15	0.11	0.04
South Fork Salmon River - Knox Bridge	McCall	0.38	0.31	0.31	0.32	0.45	0.25
South Fork Salmon River - Stolee Meadows Acc. Pond, Johnson Creek	McCall		0.97	0.97	0.97	0.97	0.97
East Fork Salmon River, Pahsimeroi Acc. Pond	Sawtooth, Pahsimeroi	0.98	0.97	0.97	0.97	0.26	0.11
Grande Ronde River - Catherine Creek, Lookingglass Creek, Upper Grande Ronde R., Lostine R.	Lookingglass, Irrigon	0.99	0.99	0.95	0.99	0.98	0.90
Imnaha River	Lookingglass	0.96	1.00	0.99	0.99	0.29	0.50
Spring Chinook - Upper Columbia River (UPCR)							
Upper Yakima River	Cle Elum	0.81	0.96	0.95	0.97	0.99	0.95
Wenatchee River - Icicle Creek	Leavenworth NFH	0.12	0.15	0.29	0.59	0.58	0.53
Wenatchee River - Chiwawa River	Eastbank	0.97		0.99	0.99	0.97	0.98
Entiat River - Entiat NFH	Entiat NFH	0.30	0.48	0.36	0.49	0.50	0.50
Methow River - Twisp River, Chewuch River, Upper Methow River, Methow Hatchery	Methow	0.95	0.99	0.97	0.97	0.98	0.97
Methow River - Winthrop NFH	Winthrop	0.97	0.98	1.00	0.95	0.89	0.96
Summer Chinook - Upper Columbia River (UPCR)							
Wenatchee River, Dryden Acc. Pond	Eastbank	0.97	0.98	0.97	0.99	0.96	0.98

		Brood Year*					
Region - River/release site	Hatchery	1998	1999	2000	2001	2002	2003
Columbia mainstem - Turtle Rock Hatchery **	Turtle Rock	0.72	0.97	0.99	0.71	0.39	
Columbia mainstem - Wells Hatchery **	Wells	0.97	0.98	0.98	0.98	0.98	0.90
Methow River, Carlton Acc. Pond	Wells	0.99	1.00	0.99	0.99	0.99	1.00
Similkameen River - Similkameen Acc. Pond	Wells	0.96	0.97	0.99	0.99	0.99	0.99

* juveniles released as yearlings; Release Year = Brood Year + 2
** juveniles released as yearlings and/or as sub-yearlings

Appendix 6C: Protocol Used to Query RMIS for Columbia Basin Spawning Ground CWT Recovery Data in Order to Estimate Hatchery Stray and Non-stray Rates

1. Log in to RMIS

2. Click "All Recoveries" under Recoveries, enter Species code of interest (see below), select the beginning and ending Recovery Years, and enter 54 as the Fishery code = spawning ground recoveries

   Species

1	Chinook
2	Coho
3	Steelhead
4	Sockeye
5	Chum

3. Click Recovery Location Name; select Columbia River - GO, select region – GO; select Basin – GO; select all Location Codes (only data for Fishery=54 locations will be returned) – RETRIEVE

4. Choose Report – select HTML; Send To - click Browser; CSV/HTM Data Field Chooser – click (>>) to select all fields (or, select a subset of data types of interest); click RUN

5. Copy and Paste Special (as Text) data into an Excel sheet 1 ("Recoveries"),
   Then set cell format: Font Size=8, Row-Autofit, Column-Autofit,
   Delete unneeded columns
   Then sort by tag_code; delete recovery data lacking a tag_code (most of these entries are for snouts lacking tags; only a very small inconsequential percentage of these entries will be for tags which were unread or lost),
   Then sort by Sampled_Run, delete unwanted run data (see below)

   Run

1	Spring
2	Summer
3	Fall
4	Winter
5	Hybrid
6	Landlocked
7	Late Fall
8	URB L-Fall

6. Copy & Paste Tag_Code column into 2nd sheet ("Tag Code")

   Then in an adjacent column, create a list of unique tag codes from the recovery data: in the Data tab, click Filter – Advanced; select "Copy to another location", and in the "Copy to" box type in cell number (or click on empty cell) – OK. Or, if using Microsoft Excel 2007: select the Tag Code column; click Remove Duplicates in the Data Tools window; click OK

RMIS requires all tag codes to be 6 digits, so select those codes with only 5 digits; go to the Number Format tab; click "Custom"; in Type" type "0#####"; OK (will place a 0 in front of all 5 digit codes)

7. Return to RMIS, click "Tagged Releases" and within the "Tag Code or Release ID" window, copy/paste the 6-digit unique tag code list – Retrieve

8. Choose Report – select HTML; Send To - click Browser; CSV/HTM Data Field Chooser – click (>>) to select all fields (or, select a subset of data types of interest); click RUN

9. Copy and Paste Special (as Text) data into an Excel sheet #3 ("Releases"),
   Then set cell format: Font Size=8, Row-Autofit, Column-Autofit,
   Delete unneeded columns

10. To calculate the overall CWT tagging rate for each release group: insert a column between "non_cwt_2nd_mark_count" and "counting_method"; label it % CWT Tagged; and insert/fill down the formula: SUM(cwt_1st_mark_count, cwt_2nd_mark_count) / SUM(cwt_1st_mark_count, cwt_2nd_mark_count, non_cwt_1st_mark_count, non_cwt_2nd_mark_count) – Note: these counts have already been corrected for estimated tag loss rates

11. Merge this Release information with the initial Stream Recovery data following the procedure below:
    Data – Import External Data – New Database Query
    (Microsoft 2007: Data – From Other Sources – From Microsoft Query)
    Excel Files* - OK
    Select file - OK
    Click on appropriate Sheets (Recoveries, and Releases) and data column(s) - > - Next
    Click OK to message saying that "the Query Wizard cannot …"
    Link corresponding data columns (Tag_Code)
    File – Return Data to Microsoft Excel
    Choose cell A1 in sheet #4 ("Merged") within Excel file, where merged data will be "pasted"

12. If needed, sort by Sampled_Run, and cut and paste run-specific data into separate sheets

13. Sort by Run_Year, Release_Location_Name, and Tag_Code

14. insert 2 new columns behind "% CWT Tagged", and label them "#/Recovery" and "Expanded #/Recovery"

15. in the #/Recovery column, enter the formula =1/% CWT Tagged (and Fill Down the whole column) to expand the value of each CWT recovery for the proportion tagged)

16. Insert 5+ rows between each Run-Year's group of recoveries

17. Below each Run_Year's list of data, calculate number and sum the #/Recovery data for all, total, non-strays, in-basin strays, and out-of-basin strays

18. Now, obtain metadata for the sampling and escapement for each Run_Year by going back to RMIS; select Catch/Sample under Other; enter Species code, beginning and ending Catch_Year (= Run_Year), and Catch Location Name – Retrieve

19. Choose Report – select HTML; Send To - click Browser; CSV/HTM Data Field Chooser – click (>>) to select all fields (or, select a subset of data types of interest); click RUN

20. Copy and Paste Special (as Text) data into an Excel sheet #5 ("Catch/Sample"), Sort by Sampled_Run, and delete any run information which is not of interest

21. Within in this table, "Number_Caught" is equivalent to the total escapement estimate for the Run_Year, and "Number_Sampled" is equivalent to the number of carcasses sampled for presence of a CWT (Note: one must presume that the carcasses chosen for CWT scanning represents a random sample of the spawning escapement, e.g., that an accurate count was retained of all carcasses examined for an adipose fin clip, and that snouts for all fin clipped fish were taken for CWT scanning)

22. A summary table is created in a subsequent sheet within the spreadsheet file, which provides actual and expanded numbers for the CWT recoveries – total and by type (non-stray, in-basin stray and out-of-basin stray) per run year. These numbers are then divided by the associated "Number_Sampled" to obtain stray and non-stray ratios. The Number_Sampled minus the expanded total number of CWT recoveries represent the number on non-adipose clipped fish of presumed natural origin.

23. Inclusion of the "Number Caught" and further expansion of the estimated number of CWT recoveries will provide estimates of the total number of CWT tagged (total and by type) and non-tagged fish within the escapement.

Appendix 6D: Summary of Stray Rate Estimates for Columbia Basin Spring and Summer Chinook Salmon Using Methods Described in Appendix 6C

Queries were performed on spawning ground data for all Columbia River basin stream/river recovery locations upstream of Bonneville Dam, for the period from 1990 to 2005 (2005 being the most recent run year for which CWT data may be complete) using the methods described in Appendix 2.5.C. Results are summarized below, including average stray rates average strays rates calculated for the period 2000 to 2005).

Spring Chinook - CENTRAL COLUMBIA RIVER (CECR)

Wind River

A total of 29 recoveries reported for the Wind, occurring in run years from 1994 to 2003; 100% were of Carson NFH harvest augmentation fish released in the Wind River, and would thus be considered as in-basin strays.

Klickitat River

Only 4 reports for CWT recoveries, occurring in run years 1992-1994; 3 were non-strays (fish released from the Klickitat Hatchery supplementation program) and 1 was an out-of-basin stray from the Imnaha River.

Deschutes River

Only 2 reports for CWT recoveries - both from 2001 and neither with tag code information.

John Day River

Data for a total of 24 recoveries is reported in RMIS, occurring in run years from 2000 to 2005; as there are no hatchery programs operating within the John Day basin, 100% of these recoveries represent out-of-basin strays.

2004 is the only year with several (n=12) recoveries, which when expanded to represented 21.3, and 53% of the 40 fish indicated at the Number_Sampled.

The Catch/Sample information for 2004 and 2005 indicate the “Number_Caught” is the same as the “Number Sampled …?

Release location and number for these 24 strays is:

Release River	Number
Hood	1
Deschutes	1
Grande Ronde	13
Imnaha	2
Salmon	7

Umatilla River

Natural origin spring Chinook in the Umatilla basin are derived from a reintroduction/ supplementation program initiated in 1983; since the 1990's, smolts are released from Bonifer Springs, Thornhollow and/or Imeq-C-mem—ini-kem acclimation ponds.

RMIS contains 2249 reports of CWT recoveries (with tag code information) for the period 1990 to 2005.

However, there are <u>no</u> corresponding Catch/Sample data with which to calculate straying proportions.

Of the 835 recoveries since 2000, only 2 (<<1%) were out-of-basin strays (1 from the Tucannon, and 1 from the Rogue River-Cole Rivers Hatchery)

HOWEVER – this is likely a gross underestimate of the actual out-of-basin stray rate. Carcass sampling during spawning ground surveys is decidedly biased – snouts are obtained almost exclusively for ventral-clipped carcasses (to obtain information for cohort analysis of returning Umatilla smolt releases) – snouts from adipose clipped carcasses (but without a ventral clip) are only occasionally collected for CWT recovery; in the Umatilla program for spring Chinook hatchery releases, smolts in which a CWT is implanted are also ventral clipped, while smolts without a CWT are adipose clipped – as such, the adipose clipped in-basin non-strays and out-of-basin stray carcasses are not proportionately represented among the CWT recoveries

Spring Chinook - UPPER COLUMBIA RIVER (UPCR)

Yakima River

The Yakima basin has a spring Chinook supplementation program operated at the Cle Elum Hatchery, with smolts released from the Easton, Clark Flat and Jackson Creek acclimation ponds; smolt production from this program began in 1997.

Beyond a few entries for years prior to initiation of the supplementation program, the RMIS database contains recovery data only for the Easton Pond recovery location and for the 2000 and 2001 run years (representing returns from the first two release groups); however, there is no associated Catch/Sample data reported.

Also, there are no recovery data for other recovery locations within the basin, and no spawning ground recovery data whatsoever subsequent to 2001.

Of the 242 Easton Pond recoveries reported for 2000 and 2001, 100% were non-strays (supplementation releases from the Cle Elum hatchery), involving smolt releases from the Easton (n=75), Clark Flat (n=160), or Jackson Creek (n=7) acclimation ponds.

Wenatchee River

The long-established USFWS Leavenworth Hatchery, on Icicle Creek, operates a harvest augmentation program. Returning adults from this program are considered as in-basin strays.

Since 1989, the Wenatchee basin has also released juveniles from supplementation program operated on the Chiwawa River; broodfish for this program are capture at a trap on the Chiwawa, spawning and incubation/rearing occurs at Eastbank Hatchery, and acclimation and release of the smolts from a pond on the Chiwawa. Fish from this supplementation program are considered as “non-strays.”

CWT recovery data is reported in RMIS for several different streams/subbasins (Recovery Locations) within the Wenatchee basin; our initial analysis pools all of the data under Wenatchee River.

CWT recovery information is available in RMIS for the 1993 to 2005 run years (except for 1994 and 1999); annual abundance estimates for 2000 to 2005 (w/out 2003) averaged 1749 fish (901 to 3369).

Data for 2003 were not used, as the expanded estimate for the number of CWT fish exceeds the Number_Sampled for this year; this difference could be a result of error (an over-estimate) introduced by expansion of the number of Leavenworth in-basin strays; these fish were CWT tagged at only a 10-13% rate, creating an expansion factor per recovery of between 7.7 and 10.1, while Chiwawa supplementation recoveries for this run year were 94% or 99% CWT tagged, and had an expansion factor of only 1.06 or 1.01, respectively.

The total number of hatchery-origin fish accounted for an average of 65% (36% to 76%) of escapement for 2000 to 2005 (minus 2003), and consisted of (average and range):

- non-strays = 44% (20% to 74%)
- in-basin strays = 21% (<1% to 36%)
- out-of-basin strays = <1% (0% to 0.9%)

Summary survey data is also reported by WDFW in annual Spawning Ground memos; these memos indicate that in 3 of the 6 years for the period 2000 to 2005, the No. Examined exceeded by greater than 10% the figures for Number_Sampled in the Catch/Sample tables queried from RMIS (in the same years, the Estimated Population figures in the memos exceeded by a similar magnitude, the Number_Caught figures in RMIS) ; the reason for a difference is unclear, and was not due to a high number of snouts for which the CWT was reported in RMIS as unreadable or unread - this proportion was very low (about 1% in this case), as was generally the case for all queries performed as part of this study.

Recalculating the stray/non-stray ratios using the WDFW spawning ground memos indicated somewhat higher proportions of hatchery origin fish - an average of 76% (68% to 99%) of escapement for 2000 to 2005 (minus 2003), and consisted of (average and range):

- non-strays = 52% (44% to 98%)
- in-basin strays = 23% (<1% to 33%)
- out-of-basin strays = <1% (0% to 1.4%)

Total of 1989 CWT recoveries were reported for 2000 to 2005, of which only 11 (<1%) were out-of-Sin strays: 1 was from the Entiat, 1 from the Methow, 2 from the Similkameen, 1 from the Sandy, 5 from the Clearwater (3-Clear Creek, 1-Lochsa, 1-Powell Rearing Ponds), and 1 from the Salmon River (South Fork).

The following are summaries for the Wenatchee data organized by sub-basin within the Wenatchee basin (going generally from downstream to upstream):

- Peshastin Creek – 19 CWTs recovered during surveys in 2001, 2003 and 2004; 100% were in-basin strays (Leavenworth NFH)
- Icicle Creek – of 58 CWTs recovered during 2000 to 2005, 5 were for supplementation non-strays released from Chiwawa River and Dryden Pond (an acclimation pond used to some extent for spring Chinook prior to the Chiwawa Supplementation program), and 53 were in-basin strays (released from Leavenworth NFH in Icicle Creek)
- Wenatchee River - for the 2000, 2001, 2004 and 2005 run years, abundance estimates averaged 196 fish (138 to 344), of which an average of 66% (22% to 100%) were of hatchery origin:
    - non-strays = 53% (22% to 85%)
    - in-basin strays = 12% (0% to 38%)
    - out-of-basin strays = 0%
- Chiwawa River – for 2000 to 2005 run years, abundance estimates averaged 761 fish (349 to 1733), of which an average of 55% (35% to 72%) were of hatchery origin:
    - non-strays = 50% (26% to 72%)
    - in-basin strays = 5% (0% to 24%) – 2 fish in 2 of the 6 years
    - (note – the expansion factor for these fish was high – 8 for 3 fish and 20 for the 4th)
    - out-of-basin strays = <1% (0% to 0.3%) – 2 fish in 2001
- Nason Creek – average abundance for the 2000 to 2005 run years was 419 (202 to 598), of which an average of 43% (19% to 73%) were of hatchery origin:
    - non-strays = 31% (7% to 72%)
    - in-basin strays = 11% (1% to 27%)
    - out-of-basin strays = <1% (0% to 3.0%)
- Little Wenatchee River – recoveries were reported only in the 2001, 2002 and 2005 run years; abundance estimates for these 3 years were 118, 86 and 116, respectively, of which an average of 60% (50% to 73%) were of hatchery origin; of the total of 66 CWTs sampled, 64 were from non-stray Chiwawa releases, and 2 were in basin strays from Leavenworth NFH:
    - non-strays = 42% (25% to 57%)
    - in-basin strays = 18% (0% to 28%)
    - out-of-basin strays = 0%

- White River – as for the Little Wenatchee, multiple CWT recoveries were reported only for the 2001, 2002 and 2005 run years; abundance estimates were 158, 82 and 156, respectively, of which an average of 43% (22% to 68%) were of hatchery origin; of the total of 64 CWTs sampled, 61 were from non-stray Chiwawa releases, and 1 was an in-basin stray from Leavenworth NFH, and 2 were out-of-basin strays:
    - non-strays = 38% (18% to 68%)
    - in-basin strays = 3% (0% to 10%)
    - out-of-basin strays = 2% (0% to 4%)

Entiat River

A supplementation program is operated at USFWS Entiat Hatchery which releases approx. 400,000 smolts annually into the Entiat.

Only 28 CWT recoveries reported in RMIS: 3 in 1997, 2 in 2000, 12 in 2001, and 11 in 2002.

Among all recoveries (n=28): 10 (36%) were non-strays (in-basin releases), 16 (57%) were out-of-basin strays (8 from Chiwawa, 8 from Methow, and 1 each from Clearwater and Salmon rivers).

There was no Catch/Sample data reported in RMIS except for 1993 and 1994.

WDFW annual Spawning Ground memos report escapement and CWT recovery data only for 1999 and 2000.

Methow River

Supplementation programs are operated at both Winthrop NFH and Methow State FH, with additional acclimation ponds in the Twisp and Chewuch rivers.

RMIS contains Recovery and Catch/Sample data only for 2000, 2003, 2004 and 2005 run years.

Abundance during these 4 years averaged 1470 (714 to 1777), of which an average of 67% (57% to 82%) were of hatchery origin:

- non-strays = 66% (55% to 80%)
- in-basin strays = 0%
- out-of-basin strays = 1.4% (0.7% to 2.6%)

Of the 1192 CWT recoveries reported during 2000 to 2005, only 12 (1%) were out-of-basin strays: 3 were from the Entiat, 4 were from the Wenatchee (3-Chiwawa, 1-Icicle Creek), 1 from the Umatilla, 3 from the Clearwater (Dworshak Hatchery, Lolo Creek and Lochsa), and 1 from the Imnaha.

The following are summaries for the Methow data organized by sub-basin within the Methow basin (going generally from downstream to upstream):

- Chewuch River – of the 376 recoveries made in the Chewuch since 2000, 371 were non-strays and 5 were out-of-basin strays - 2 from the Clearwater (Dworshak and Lolo Creek), 2 from the Wenatchee (Chiwawa), and 1 from the Entiat; of the 371 Chewuch recoveries - 112 were released in the Chewuch, 27 in the Methow, 229 in the Methow+Chewuch, and 1 each in the Twisp, in Wolf Creek and in Lake Creek

- Twisp River – of the 67 CWT recoveries made in the Twisp since 2000, 64 were for non-strays, and 3 were out-of-basin strays - 1 each from the Entiat, Clearwater(Lochsa River) and Imnaha rivers; of the 64 non-strays, 59 were released in the Twisp, 4 in the Methow and 1 in the Chewuch
- Methow River - data includes recoveries in the Methow and at the outfalls of the Methow and Winthrop hatcheries; of the 730 recoveries made since 2000, 726 were for non-strays, and 4 were out-of-basin strays - 2 were from the Wenatchee (Icicle Creek and Chiwawa), and 1 each from the Entiat and the Umatilla; of the 726 non-strays, 362 were released in the Methow, 240 in the Methow+Chewuch, 90 in the Chewuch, 32 in the Twisp, and 2 in Wolf Creek

Chelan, Okanogan and Similkameen Rivers

There are no spring Chinook runs to these rivers.

Spring Chinook - SNAKE RIVER (SNAK)

(note: spring Chinook in this analysis = stream-type Snake River spring/summer Chinook)

Tucannon River

A supplementation program has been operated at the Tucannon State Fish Hatchery since 1985, with smolt releases occurring from the hatchery or the Curl Lake acclimation pond

RMIS contains Recovery and Catch/Sample data for the 1996 to 2004 run years.

Estimated escapement during 2000 to 2004 averaged 578 (239 to 906), of which an average of 36% (7% to 65%) were of hatchery origin:

- non-strays = 32% (7% to 56%)
- in-basin strays = n/a
- out-of-basin strays = 4% (0% to 11%)

Of the 234 CWT recoveries reported for 2000 to 2004, 15 were for out-of-basin strays - 1 from Lyons Ferry Hatchery, 8 were from the Umatilla, 3 from the Clearwater (Dworshak Hatchery, Powell Rearing Pond, Lochsa), 1 from the Salmon (Sawtooth Hatchery), and 2 from the Imnaha. HOWEVER, apparently some culling of ventral clipped Umatilla River strays occurs at the Tucannon weir, such that the 4% rate of out-of-basin straying is an underestimate relative to the stray rate to the river mouth.

Clearwater River

There is NO Catch/Sample data (Number_Sampled and Number_Caught) with which to calculate stray ratios.

There is a total of 428 CWT recoveries reported since 1990, with a substantial number (n>20) for the American River (S Fork Clwtr, n=58), Colt Killed Creek (Lochsa, n=20), Fishing Creek (Lochsa, n=54), Crooked Fork (Lochsa, n=202), Brushy Fork Creek (Lochsa, n=27), and Red River (Clwtr, n=42).

Of the total of 226 recoveries reported for the period 2000 to 2004, only 1 (<1%) was from an out-of-basin stray (Umatilla River).

Salmon River

RMIS contains data for a total of 881 CWTs recovered from fish in spawning ground surveys conducted in the Salmon River basin from 1995 to 2005.

Of these 881 reports, only 2 (<1%) were for out-of-basin strays (both Lookingglass hatchery releases, located in the Lostine River, a tributary to the Grande Ronde River).

Grande Ronde River

CWT recovery data available in RMIS only beginning with the 2002 run year.

Of the 480 recoveries reported for run years 2002 to 2006:.

- non-strays = 472 of 480 (98%)
- in-basin strays = 6 of 480 (1%)
- out-of-basin strays = 2 of 480 (<1%)

The non-strays were predominantly Catherine Creek releases, and secondarily upper Grande Ronde releases.

Of the 6 in-basin strays, 4 were Lookingglass Hatchery releases returning to Catherine Creek, 1 was a Lostine River release returning to Catherine Creek, and 1 was a Catherine Creek release returning to the upper Grande Ronde.

The 2 out-of-basin strays were both Imnaha River releases.

Imnaha River

CWT recovery data reported since 1990; however, there is NO Catch/Sample data (Number_Sampled and Number_Caught) with which to calculate stray ratios.

For the period 2000 to 2006, 1061 recoveries were reported, of which.

- non-strays = 1051 of 1061 (99%)
- in-basin strays = n/a
- out-of-basin strays = 10 of 1061 (1%)

The non-strays were predominantly Catherine Creek releases, and secondarily upper Grande Ronde releases.

Release location of the 10 out-of-basin strays: 7 from the Grande Ronde (4-Lostine, 2-Catherine Creek, 1-Lookingglass Creek), 2 from the Salmon (Rapid River Hatchery), and 1 from Youngs Bay/Clatskanie River.

Summer Chinook - UPPER COLUMBIA RIVER (UPCR)

Upper Columbia summer Chinook comprise populations occurring in the Wenatchee, Entiat, Chelan, Methow and Okanogan/Similkameen rivers, which join the Columbia between Rock Island and Chief Joseph Dams. Some spawning also occurs within the mainstem Columbia, although how much is unclear, due to difficulty in monitoring this activity. Supplementation programs for summer Chinook are operated in the Wenatchee, Methow, and Okanogan/Similkameen subbasins. Broodstock collection for the Wenatchee program now occurs exclusively at Dryden Dam within the Wenatchee. However, broodstock for the Methow and Okanogan/Similkameen programs continue to be collected at Wells Dam on the Columbia mainstem downstream of these two rivers, which compromises the management protocol for a supplementation program which dictates that broodstock are to be obtained from among in-basin returns. Three harvest augmentation programs are operated at Turtle Rock, Eastbank and Wells hatcheries along the Columbia mainstem. CWT tagging rates in all Upper Columbia summer Chinook programs is in the 95% to 100% range. In the analysis for stray ratios of summer Chinook, non-strays were defined as fish returning to the subbasin in which they were acclimated and released. As the supplementation summer Chinook smolts are released in the mainstem of these tributary rivers, and as there are no harvest augmentation releases in these tributaries, the category of “in-basin stray” is not applicable. All strays were from out-of-basin sources (either from one of the mainstem harvest augmentation programs, or from supplementation releases in a different tributary), and were defined simply as “Strays”. Average stray/non-stray ratios for Upper Columbia summer Chinook, for the period 2000 to 2005, are summarized in the table below, with the remainder presumed to be fish of natural origin:

Upper Columbia River (2000 to 2005)	% Non-Strays	% Strays	Remainder (natural origin)
Wenatchee	17%	1%	82%
Entiat			
Chelan	n/a	61%	39%
Methow	13%	20%	67%
Okanogan	31%	12%	57%
Similkameen	44%	<1%	55%

Wenatchee River

The Wenatchee supplementation program involves collection of broodstock at Dryden Dam (Rkm 26) and acclimation and release of smolts at the nearby Dryden Rearing Ponds.

Information is available in RMIS for the 1994 to 2005 run years; abundance estimates for 2000 to 2005 averaged 8570 fish (4,396 to 13,706).

Hatchery-origin fish accounted for an average of 18% (14% to 23%) of the escapement for 2000 to 2005), and consisted of (average and range):.

- non-strays = 17% (14% to 22%)
- strays = 0.8% (0.3% to 1.0%) - primarily Turtle Rock and Wells Hatchery River releases

Entiat River

This river has no supplementation program, and all hatchery origin fish are considered strays.

Recovery data is available in RMIS only for the 2002 run year and involves 55 CWT recoveries, although no Catch/Sample information for this run year (nor for any run year) is available in the RMIS database.

Of these 55 strays, 29 (53%) were releases from Turtle Rock Hatchery, 9 (16%) from Wells Hatchery, 17 (29%) from the Wenatchee River supplementation program, and 1 (2%) from the Similkameen River supplementation program.

Chelan River

The Chelan River has no supplementation program; thus, all hatchery origin fish are considered as strays.

Only a very short stretch of the Chelan River is available for summer Chinook spawning, due to the proximity to the Columbia River of the blockage which creates Lake Chelan; of note, the area in the Columbia mainstem adjacent to the confluence with the Chelan is one where spawning of summer Chinook is consistently observed.

The RMIS database has information for run years 2000 to 2005; population abundance estimations during this period averaged 566 (range 416 to 984); CWT recoveries totaled 407, representing an estimate of 421 hatchery origin strays, representing a stray ratio of 61% (35% to 80%) for the annual escapement.

Of the estimated 421 strays, the majority were harvest augmentation releases from Turtle Rock Hatchery and others indicated a Columbia River-General (52%), and from Wells Hatchery (31%); with the remainder from supplementation releases in the Wenatchee(12%), Similkameen (5%) and the Methow (<1%).

Methow River

Information is available in RMIS for the 1993 to 2005 run years.

Abundance estimates for 2000 to 2005 averaged 2879 fish (1200 to 4630), of which hatchery-origin fish accounted for an average of 33% (20% to 56%).

- non-strays = 13% (8% to 26%)
- strays = 20% (10% to 44%)

Non-strays are returns from the Methow supplementation program, which collects broodstock at Wells Dam, incubates and rears juveniles at Wells Hatchery, and acclimates and releases smolts from Carlton Rearing Ponds (Rkm 58).

Of the total of 1123 records representing an estimated 1153 stray returns to the Methow during the 2000 to 2005 period, 78% were augmentation releases – 39% each from Wells Hatchery and from Turtle Rock Hatchery, and 22% were supplementation releases – 21% from the Wenatchee River, and 1% from the Similkameen River.

Okanogan/Similkameen River

The Okanogan/Similkameen River system has a supplementation program which collects broodstock at Wells Dam, incubates and rears juveniles at Wells Hatchery, and acclimates and releases smolts from the Similkameen Acclimation Pond (Rkm 5); this pond is located in the 14 km stretch of river available for Chinook spawning between the confluence with the Okanogan River (Rkm 192 along the Okanogan)and the impassable Enloe Dam.

Okanogan River
Information is available in RMIS for CWT recoveries from surveys within the Okanogan River for the 1992 to 2004 run years.

Estimated abundance for the 2000 to 2004 period averaged 3497, comprised of:

- non-strays = 31% (12% to 45%)
- strays = 12% (4% to 22%)

Data for the strays during this period involved a total of 207 reports representing a return of approximately 214 fish; of these 43% each were from the Wells Hatchery and Turtle Rock harvest augmentation programs, 3% from the Methow supplementation program, and 10% from the Wenatchee supplementation program.

Similkameen River
Information is available in RMIS for CWT recoveries from surveys within the Okanogan River for the 1992 to 2005 run years.

Estimated escapement for 2000 to 2005 averaged 4865 *(3735 to 7723)*; this excludes data for 2003 (the estimate of 915 provided for this year is certainly erroneously low, e.g., the adult passage estimate at Wells dam, which did not indicate a dramatic decrease in 2003 relative to other years).

- escapement (2000 to 2005, excluding 2003) is comprised of:
- non-strays: 44% (15% to 65%)
- strays: <1% (0.3 to 0.8%)

Data for the strays during this period totaled only38 reports representing a return of approximately 39 fish; of these 32% each were from the Turtle Rock and 26% from the Wells Hatchery harvest augmentation programs, and 8% from the Methow River and 13% from the Wenatchee River supplementation programs.