BONNEVILLE POWER ADMINISTRATION

A Multiple Watershed Approach to Assessing the Effects of Habitat Restoration Actions on Anadromous and Resident Fish Populations

Technical Report 2003 - 2004	March 2004	DOE/BP-00012481-1

This Document should be cited as follows:

Marmorek, David, Ian Parnell, Marc Porter, Christine Pinkham, Clint Alexander, Calvin Peters, Joel Hubble, Charles Paulsen, Timothy Fisher, "A Multiple Watershed Approach to Assessing the Effects of Habitat Restoration Actions on Anadromous and Resident Fish Populations", 2003-2004 Technical Report, Project No. 200300300, 448 electronic pages, (BPA Report DOE/BP-00012481-1)

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This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

A Multiple Watershed Approach to Assessing the Effects of Habitat Restoration Actions on Anadromous and Resident Fish Populations

Innovative Project 34008
BPA Contract # 2003-003-00

FINAL REPORT

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March 19, 2004

Citation: **Marmorek, D.R., I.J. Parnell, M. Porter, C. Pinkham, C.A.D. Alexander, C.N. Peters, J. Hubble, C.M. Paulsen and T.R. Fisher.** 2004. A Multiple Watershed Approach to Assessing the Effects of Habitat Restoration Actions on Anadromous and Resident Fish Populations. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. 420 pp.

Executive Summary

Habitat protection and restoration is a cornerstone of current strategies to restore ecosystems, recover endangered fish species, and rebuild fish stocks within the Columbia River Basin. Strategies featuring habitat restoration include the 2000 Biological Opinion on operation of the Federal Columbia River Power System (FCRPS BiOp) developed by the National Marine Fisheries Service (NMFS), the 2000 Biological Opinion on Bull Trout developed by the US Fish and Wildlife Service (USFWS), and Sub-Basin Plans developed under the Fish and Wildlife Program of the Northwest Power and Conservation Council (NWPCC). There is however little quantitative information about the effectiveness of different habitat restoration techniques. Such information is crucial for helping scientists and program managers allocate limited funds towards the greatest benefits for fish populations. Therefore, it is critical to systematically test the hypotheses underlying habitat restoration actions for both anadromous and resident fish populations.

This pilot project was developed through a proposal to the Innovative Projects fund of the NWPCC (ESSA 2002). It was funded by the Bonneville Power Administration (BPA) following reviews by the Independent Scientific Review Panel (ISRP 2002), the Columbia Basin Fish and Wildlife Authority (CBFWA 2002), the NWPCC and BPA. The study was designed to respond directly to the above-described needs for information on the effectiveness of habitat restoration actions, including legal measures specified in the 2000 FCRPS BiOp (RPA 183, pg. 9-133, NMFS 2000). Due to the urgency of addressing these measures, the timeline of the project was accelerated from a duration of 18 months to 14 months.

The purpose of this pilot project was to explore methods for evaluating past habitat restoration actions and their effects on fish populations. By doing so, the project will provide a foundation of retrospective analyses, on which to build prospective, multi-watershed designs for future habitat restoration actions. Such designs are being developed concurrently with this project by several other groups in the Columbia Basin (RME Workgroup 2003, NMFS 2003, Hillman and Paulsen 2002, Hillman 2003). By addressing questions about habitat restoration and monitoring (in coordination with other related efforts), we hope that this project will catalyze a shift in the Basin's paradigm of habitat restoration, moving from implementation of individual watershed projects towards rigorously designed and monitored, multi-watershed, adaptive management experiments.

The project involved three phases of work, which were closely integrated with various related and ongoing efforts in the region:

1. *Scoping*. We met with a Core Group of habitat experts and managers to scope out a set of testable habitat restoration hypotheses, identify candidate watersheds and recommend participants for a data evaluation workshop.
2. *Data Assembly*. We contacted over 80 scientists and managers to help evaluate the suitability of each candidate watershed's historical data for assessing the effectiveness of past restoration actions. We eventually settled on the Yakima, Wenatchee, Clearwater, and Salmon subbasins, and began gathering relevant data for these watersheds at a workshop with habitat experts and managers. Data assembly continued for several months after the workshop.
3. *Data Analysis and Synthesis.* We explored statistical approaches towards retrospectively analyzing the effects of restoration 'treatments' at nested spatial scales across multiple watersheds (Chapters 2–5 of this report). These analyses provided a foundation for identifying existing constraints to testing restoration hypotheses, and opportunities to overcome these constraints

through improved experimental designs, monitoring protocols and project selection strategies (Chapters 6 and 7 of this report). Finally, we developed a set of recommendations to improve the design, implementation, and monitoring of prospective habitat restoration programs in the Columbia River Basin (Chapter 8).

Results of Retrospective Analyses

Effects of Screening on Irrigation Diversions in the Yakima River Sub-basin (Chapter 2)

The Bonneville Power Administration and Bureau of Reclamation have funded construction of improved fish screens at major irrigation/power diversions within the Yakima Subbasin, WA. Localized monitoring indicated that the screens functioned as intended, roughly doubling the survival of spring chinook smolts at a major irrigation canal. We extended these data into an index of the improving cumulative survival of smolts past all screened Yakima canals (Sc). To test if improvements in Sc contributed to increased subbasin productivity of spring chinook (adult returns/spawner or smolts/spawner), we developed a series of log-linear regression models based on Ricker-type-stock-recruitment relationships and environmental covariates, using other stocks as controls in a BACI design. Surprisingly, Sc was either not correlated or negatively correlated with chinook productivity. Climate variability in both the freshwater and ocean phases of the life history, as well as possibly other stressors within the watershed (e.g., changed hydrology), appear to have swamped any detectable fish screening benefits to overall productivity. A longer period of pre-implementation monitoring and greater spatial / temporal contrasts in implementation of screens within the subbasin would have increased the chances of detecting an overall effect on productivity.

Using an index of egg-to-parr survival rate to detect the effects of habitat actions in watersheds of the Salmon River Sub-basin (Chapter 3)

The many habitat restoration projects implemented in the Salmon River sub-basin since the early 1980s provide few examples of project effectiveness in terms of increased salmon survival rates. This is due to a lack of coordinated implementation of projects and associated controls, as well as monitoring designs that fail to account for the high variability and confounding inherent in biological data. Multi-watershed retrospective models that explicitly account for the spatial and temporal pattern of projects and include project-independent data provide an opportunity to account for these shortcomings. We used historical data to develop a spring-summer chinook egg-to-parr survival rate index for several tributaries in the Salmon River subbasin with contrast in the pattern of habitat actions and tested the hypothesis that higher egg-to-parr survival rates are associated with more habitat actions. We used information-theoretic methods to rank a set of 52 log-linear multi-stock regression models that accounted for density dependence, common brood year effects, fecundity, seasonal flow, and habitat actions. The top four models included the habitat index, had similar coefficients (0.22–0.29), and accounted for 82% of the relative probability. Our results suggest that more habitat actions are associated with higher egg-to-parr survival rates, but do not provide insight about the relative effectiveness of particular classes of habitat actions.

Relationship of Parr to Smolt Survival Rates to the Number of Habitat Restoration Projects (Chapter 4)

Using eleven years of parr-to-smolt survival estimates from 32 sites in the Snake River, we demonstrate that, despite a number of confounding factors, higher numbers of past habitat actions are associated with higher juvenile survival of endangered spring/summer chinook. Information-theoretic weights were applied to help distinguish between statistical models based on their relatively plausibility. In the models with the highest weights among those estimated, habitat actions showed a clear, positive association with increased survival. However, because habitat actions are not sited randomly on the landscape, and because they may also influence other, potentially important covariates, it is difficult to separate their effects from those of other important factors.

Utility of Redd Densities for Detecting the Effects of Habitat Actions (Chapter 5)

Previous studies have suggested that several decades of data may be needed to assess the effects of habitat actions on salmonids. We used redd density (redds per mile of stream surveyed) of Snake River spring/summer Chinook spawning in Idaho and Oregon to try to detect the effects of past habitat actions, using very simple stock-recruit estimates, since return-at-age information is not readily available for most of the spawning aggregations. Using recruits per spawner as the dependent variable, we employed information-theoretic methods to select the best-fitting models. The top-weighted models either did not include habitat actions or, if they were included, the estimated coefficients did not differ significantly from zero. The habitat variables were never significant in any of the models where they were used. The lack of age-at-return data likely limited the statistical power to detect effects. It is also possible that insufficient time has elapsed to detect what may very well be large effects on R/S. Finally, effects may in fact be present, but small.

Results of Review of "Blue Ribbon" Action Effectiveness Studies (Chapter 6 and Appendix 1)

We undertook a review of "blue ribbon" studies of action effectiveness of relevance to the Columbia Basin and representative of the various actions listed under RPA 183. "Blue ribbon" studies are examples with relatively strong experimental designs and time series of data with adequate duration for detecting the impacts of habitat restoration actions on salmon and steelhead survival. While many of these studies are outside of the Columbia Basin, they are all within the Pacific Northwest and offer guidance for future monitoring studies and potentially relevant data on outcomes. Some of the key messages that emerged from this review are listed below.

- Existing research and monitoring is generally inadequate for all restoration techniques.
- There is a need for comprehensive physical and biological evaluations of most watershed restoration strategies.
- While there is probably no need more studies on benefits of active stream restoration on coho and steelhead abundance; there is a need to know more about survival benefits of all actions (e.g. smolts/spawner; R/S) for all species (especially chinook, steelhead, bull trout).
- It is important to extend existing successful adaptive management experiments to learn more about the longer term benefits of those actions (e.g., longer term benefits of instream structures / fertilization on steelhead at Keogh River).

Lessons Learned from Retrospective Analyses *(Chapter 7)*

1. *We need better information on past and current habitat restoration projects*, including: # projects for each specific type of action; location of project activities; whether a project was actually implemented, and if so, over what period of time; area (e.g., m^2 of watershed restored, or length of stream restored); location/repository of biological or habitat data collected for the project (or relevant data from the same vicinity or time frame); and the intended benefits of the project for fish (testable hypotheses).
2. *Few restoration projects have explicitly stated hypotheses and structured monitoring to test them.* For example, only 3 of the 20 Blue Ribbon studies that we reviewed were adaptive management experiments with well-designed monitoring, and occurred within the Columbia River basin.
3. *It takes a lot of effort to find project, habitat and biological data required for retrospective tests of action effectiveness.* Habitat and fish data have been collected by multiple agencies, but

generally not for the purpose of evaluating past restoration projects. Data and descriptions of methods must often be obtained from unpublished reports and contacts with state and tribal biologists. Without the efforts of these contacts our retrospective analyses would not have been possible.

4. *Drawing inferences across multiple scales requires more planning than has occurred historically.* Historical data rarely allow inferences at multiple spatial scales (i.e., project, tributary, population, and subbasin scales). Effects of restoration actions are diluted as the spatial and temporal scale increases by such factors as hydrosystem passage, variable climatic and ocean conditions, and different ecoregions. Noise from these factors can be filtered out (e.g., by using covariates), but project signals become weaker at larger scales. To allow inferences at multiple scales, we must develop common and scalable indices of habitat restoration actions.
5. *More attention needs to be paid to where restoration projects and reference areas are located.* Most habitat actions have taken place where habitat conditions are bad, and no systematic attempt has been made to maintain and monitor control sites in areas with poor habitat conditions. As a result the areas with few to no habitat actions tend to be in wilderness areas (e.g., Salmon subbasin). Even if restoration actions have increased fish survival, it will be difficult to detect this effect due to a lack of monitored controls in areas with poor habitat. More precise monitoring will not reduce this confounding.
6. *More attention needs to be paid to the timing of restoration projects.* The apparent responses to treatments depend strongly on when the treatment is applied (e.g. Yakima screens were implemented just after a period of relatively high recruitment, leaving no apparent benefit). Staggered implementation of restoration treatments would reduce the risk that treatment effects are masked by common year effects. Formal staircase designs (e.g., Walters et al. 1988) for treatment implementation could reduce this problem.
7. *Strengths of applying a multi-watershed approach to historical data:* For some types of performance measures there are enough data for enough streams to estimate common year effects in juvenile survival indices, which increases the precision of estimated habitat effects and the power of statistical tests.
8. *Weaknesses of applying a multi-watershed approach to historical data.* The application of habitat actions across the landscape has not been random, so results cannot be easily extrapolated to prospective actions. There are typically various problems with the time series of available data: it may be too short for many of the habitat actions to have exerted their full potential effect; pre- and post-implementation monitoring period was insufficient for reasonable statistical power; designs were unbalanced (varying years of monitoring before/after impact); and/or there are missing data points. Monitoring methods may differ between streams creating different biases for what is ostensibly the same performance measure (e.g., smolts/spawner). Finally, in retrospective analyses data are generally being used for a different purpose than that for which they were collected.

Recommended Future Directions

Exploration of alternative multi-watershed designs

The above lessons highlight the urgency for improved experimental designs to determine the effectiveness of habitat restoration actions. A valuable component of this process will be to simulate multi-watershed, staircase-type designs under two sets of assumptions:

1. assume a scientific approach, in which control areas with poor-quality habitat are left untreated and unmonitored, while other poor-quality areas are treated intensively, and monitored using the same protocols; vs.
2. assume the status quo approach to assignment of treatments, in which all poor quality areas receive the same level of treatment, and the only control areas are those with high-quality habitat.

While the advantages of proper experimental design are well documented, the details of any particular design will depend on the hypothesis being tested, the performance measures being monitored, the magnitude of the process and sampling error associated with that performance measure, and the analytical method used to test for effects. We reviewed growing literature on statistical power analysis of monitoring and experimental designs in fisheries management (Chapter 7). This review yielded some valuable insights.

- Before-After-Control-Impact (BACI) designs are not always better than Before-After (BA) type designs; the results depend on the degree of covariation in performance measures.
- Spatial replication can greatly reduce the number of years required to detect effects for BACI designs.
- PIT tagging allows for the detection of relatively small changes in parr-to-smolt survival rates.
- BA/BACI designs with few spatial replicates and less direct measures of survival rates (e.g., recruits/spawners) can require a decade or more to detect even large changes.

Useful general principles for the design of experiments to evaluate habitat restoration actions are outlined in recent reports developed concurrently with this project (Hilman 2003, Jordan et al. 2003).

Importance of Tradeoff Analyses

We recognize that the ideals of proper experimental design may often be at odds with the reality of managing large ecosystems where there are many competing demands for limited budgets. Thus we recommend that the experimental design process explicitly consider tradeoffs between scientific objectives (e.g., high statistical power) and management objectives (e.g., work within budgets, achieve environmental improvements quickly).

Decision analysis (Peterman and Anderson 1999, Clemen 1996,) can be used to explicitly evaluate these tradeoffs (e.g., statistical power vs. cost of monitoring). Some decision problems have a relatively narrow set of objectives that can be addressed within the context of a unified and quantitative modeling framework (e.g., MacGregor et al. 2002, Peters and Marmorek 2001). Other decision problems must consider a broader set of objectives that are addressed by unrelated criteria measured on different quantitative or qualitative scales (e.g., Marmorek and Parnell 2002, Parnell et al. 2003). Such multi-attribute decision problems are most likely to be the case for evaluating tradeoffs in the design of large-scale experimental evaluation of habitat restoration programs.

Decision analysis has been shown to be a powerful tool for the design of large-scale monitoring and experimental programs (e.g., Parnell 2002, MacGregor et al. 2002, Walters and Green 1997, Keeley and Walters 1994, Peterman and Antcliffe 1993, Antcliffe 1992, McAllister and Peterman 1992a, b). These studies often show that the optimal design, over all objectives, is not necessarily the design with the highest statistical power.

Recommendations for Columbia Basin coordination efforts

How can the insights gained from our study and others that we've reviewed be incorporated into Columbia Basin management? Below we outline in point form a series of recommendations.

Regional planning of restoration projects

We believe there would be a benefit of having a core team of scientists with expertise in experimental design, fisheries and habitat restoration work with managers to develop both *extensive* approaches and *intensive* approaches to evaluating effectiveness of actions. Specific steps would include:

1. Complete analyses that explore statistical power, alternative experimental designs, and decision analyses of the learning-cost tradeoffs of different designs.
2. Initiate a series of meetings with fish and wildlife managers to present the results of this work in simple language — i.e. demonstrate the opportunities that exist to improve rates of learning and save money through better intra and inter-subbasin planning of restoration projects.
3. Explore with the managers what cost and benefit sharing mechanisms could be instituted to ensure equitable fish and wildlife benefits across subbasins.
4. Use the sub-basin planning process more specifically to co-ordinate when and where projects are implemented to increase learning from broader-scale monitoring both within and across sub-basins,
5. Ensure that funding agencies (paying for restoration projects) insist on coordinated multi-watershed designs and thorough monitoring and evaluation.
6. For individual projects focus on the proper design of reach scale analyses, but recognize that some indices and methods used to measure them should be scalable to allow broader scale comparisons (e.g., collect reach specific information in a way that could be expanded to tributary and sub-basin scales).

Database of projects

- Develop a single centralized database of new habitat projects (and the subset of past projects for which effectiveness evaluations are worthwhile) which includes geo-referenced information on project locations, activities, timing, intensity, etc. as discussed above. This should include all project activities regardless of who sponsored them. At present there are multiple databases maintained by different sponsoring agencies, using different project classification methods and often with different project location coordinates for the same project.
- The database should include the expected magnitude and timing of responses in key performance measures (habitat indicators, salmonid abundance, survival and/or distribution). These will form pre-project hypotheses that can be tested in a subset of cases.
- Where appropriate, organize a GIS database to improve the efficiency of associating independent data sets (biological and habitat monitoring) with ongoing or future habitat actions. While recent projects generally have GPS coordinates, this is not the case for older projects, whose locations must be inferred from topographic maps and general project descriptions.

Implementation monitoring

Post-project implementation monitoring should be a pre-requisite for funding. For longer duration actions (e.g. riparian restoration, erosion control) this will involve revisiting the site 5 or 10 years after implementation.

Monitoring protocols

- Develop *action indicators* that can incorporate estimates of the scale, intensity and magnitude of an action, for use in extensive analyses of action effectiveness (i.e. a 100m revegetation project is less likely to have an effect than a 1 km integrated erosion control, revegetation and instream channel project).
- Develop a common set of habitat and biological *response indicators* that are measured in all *intensive* projects to facilitate multi-project, multi-tributary and multi-basin comparisons. Efforts are being made to move in this direction through:
    - guidelines for action effectiveness studies (Paulsen et al. 2002);
    - consistent monitoring protocols (Johnson et al. 2001);
    - collaborative monitoring and evaluation approaches within the Columbia Basin and beyond;[1]
    - effectiveness evaluations using habitat and fish monitoring protocols applied to randomly selected sets of reaches;[2]
    - pilot projects in the John Day, Wenatchee and Salmon subbasins (NMFS 2003); and
    - work by the USFWS Recovery Monitoring and Evaluation Group (RMEG) for bull trout.[3]
- Have a smaller set of *response indicators* that are measured in all projects used for *extensive* studies. Smolts/spawner is probably the best integrative measure of cumulative benefit of freshwater restoration actions. It eliminates the noise contributed by other parts of life cycle. However, recruits / spawner indices also integrate over the entire life cycle, and therefore indicate the cumulative effect of all restoration efforts. The best approach is therefore to use both measures.
- Determine a reasonable set of core habitat measurements that can be used for matching treatment-control pairs. The cost of measuring many habitat parameters (and doing better matching) must be weighed against other components of the experimental design (sample size, precision of biological measurements, etc.).

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[1] Progress towards this objective is being made by CBFWA's Collaborative Systemwide Monitoring and Evaluation Project (CSMEP, www.cbfwf.org/rme/) and the Pacific Northwest Aquatic Monitoring Partnership (PNAMP).

[2] e.g. Washington's Salmon Recovery Funding Board, www.iac.wa.gov/srfb/docs.htm.

[3] See columbiariver.fws.gov/programs/bulltrout.htm

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Acknowledgements

We would like to thank the many scientists and managers who provided their insights, contacts, time and data for this study. Their contributions were absolutely essential to our progress, and we are very grateful for their many forms of assistance. We also thank Dr. Carl Schwarz, Chairman of the Statistics Department at Simon Fraser University, who provided very useful recommendation on analytical methods. Finally we thank Ms. Jessica Wilcox, our Contract Officer's Technical Representative (COTR) at the Bonneville Power Administration (BPA), who gave us enthusiastic support and helpful guidance.

This project, #2003-003-000, was funded by BPA through the Innovative Projects fund of the Northwest Power and conservation council's Fish and Wildlife Program, in response to proposal 34008 by ESSA Technologies Ltd. Work on Chapters 4 and 5 were funded by BPA though contacts to Paulsen Environmental Research and Fisher Fisheries.

1.0 Introduction

1.1 Background

Habitat protection and restoration is a cornerstone of current strategies to restore ecosystems, recover endangered fish species, and rebuild fish stocks within the Columbia River Basin. Strategies featuring habitat restoration include the 2000 FCRPS Biological Opinion (BiOp) developed by the National Marine Fisheries Service (NMFS), the Biological Opinion on Bull Trout developed by the US Fish and Wildlife Service (USFWS), and Sub-Basin Plans developed under the Fish and Wildlife Program of the Northwest Power and Conservation Council (NWPCC). There is however little quantitative information about the effectiveness of different habitat restoration techniques. Such information is crucial for helping scientists and program managers allocate limited funds towards the greatest benefits for fish populations. Therefore, it is critical to systematically test the hypotheses underlying habitat restoration actions (Figure 1.1), for both anadromous and resident fish populations.

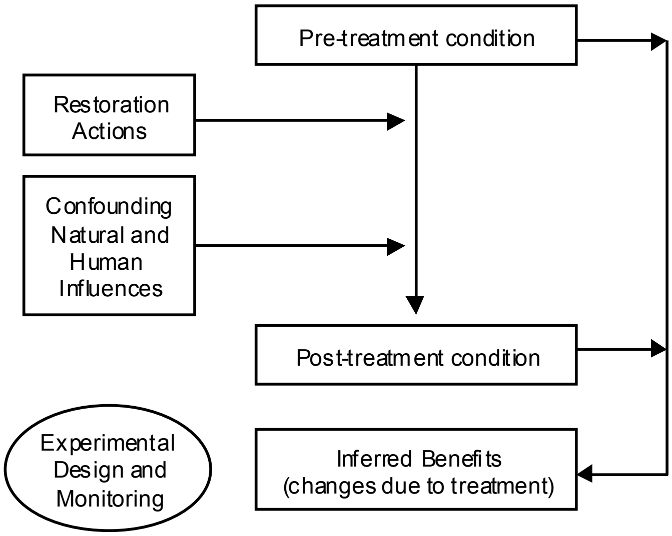

Figure 1.1. A framework for testing restoration hypotheses. Inferred benefits are affected by the strength of restoration actions, the pre-treatment condition, natural and human confounding influences, the experimental design (spatial and temporal contrasts in treatments) and the monitoring protocols employed.

This project was developed through a proposal to the Innovative Projects fund of the NWPCC (ESSA 2002). It was funded by the Bonneville Power Administration (BPA) following reviews by the Independent Scientific Review Panel (ISRP 2002), the Columbia Basin Fish and Wildlife Authority (CBFWA 2002), the NWPCC and BPA. The project was designed to respond directly to the above-described needs for information on the effectiveness of habitat restoration actions, including legal measures specified in the 2000 FCRPC BiOp (RPA 183, pg. 9-133, NMFS 2000).

1.2 Issues related to detecting effects of habitat actions

The often-unstated hypotheses underlying habitat restoration activity is that restoration actions will have some effect on physical variables, which in turn will have some effect (presumably positive) on fish survival rates and abundance (Figure 1.2).

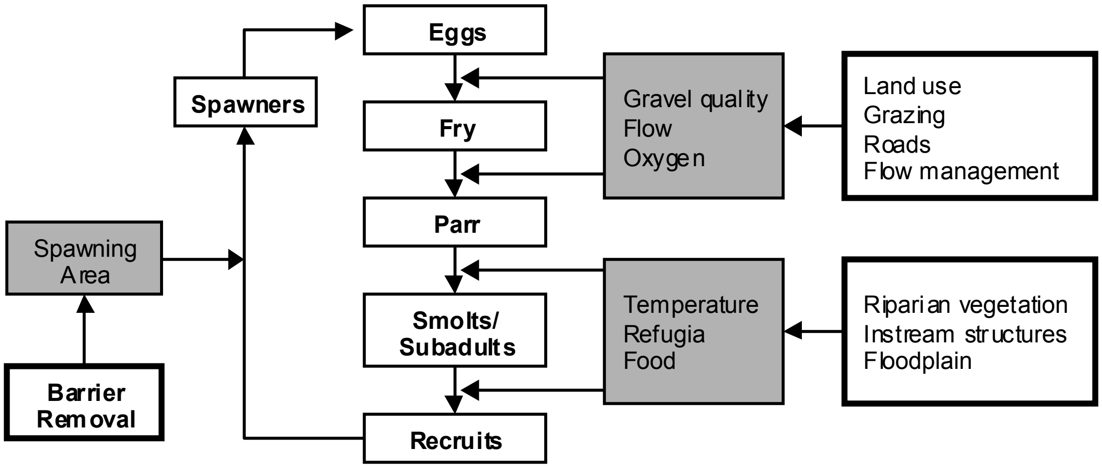

Figure 1.2. Generalized flow-chart or impact hypothesis showing examples of the influence of habitat restoration actions (thick boxes) on various physical habitat variables (gray boxes) that affect the survival of various life-history stages of salmon populations (in bold).

However, actually detecting such effects, particularly on fish survival and abundance, can be difficult. A number of factors (discussed below) determine what can be learned about the effectiveness of habitat restoration actions from biological data sets. These factors in many cases will determine what kinds of analyses are possible, given the spatial and temporal scale of the actions implemented and the biological data available.

1. Kinds of actions implemented and variables monitored.

Common habitat restoration actions include restoring in-stream flow, nutrient enhancement, barrier removal, diversion screens, sediment reduction, riparian buffers and vegetation, and in-stream structures. Because these actions can act through different mechanisms on different habitat features and life stages, detecting their effects requires looking at the appropriate physical and biological performance measures. Moreover, because often several of these actions are implemented concurrently, aggregate measures of fish survival at the tributary scale (e.g., recruits/spawner, smolts/spawner) will reflect the aggregate effects of multiple habitat actions. For this reason it is likely that, in most retrospective studies, it will be possible only to evaluate sets of simultaneous habitat actions rather than individual actions in isolation. Well-designed evaluations of habitat actions (e.g. Ward et al. 2002) can assess the effects of individual and multiple actions at both the reach and tributary scale; such studies are however very rare (Bayley 2002).

2. Starting habitat condition

Starting habitat condition and trends also affect our ability to detect the effects of habitat actions. An example is shown in Figure 1.3. Actions in areas where conditions are initially poor may cause the same magnitude of improvement as actions where initial conditions are good, but if only the end condition is monitored it may not appear to be having any benefit. Similarly, habitat conditions implemented where survival rates are on a downward trend may be sufficient to stabilize survival rates, but this benefit would not be readily apparent in a comparison of starting and ending survival rates. These difficulties point to the need for good experimental designs in any analyses (e.g., before/after comparisons, and the use of controls to adjust for regional trends in survival).

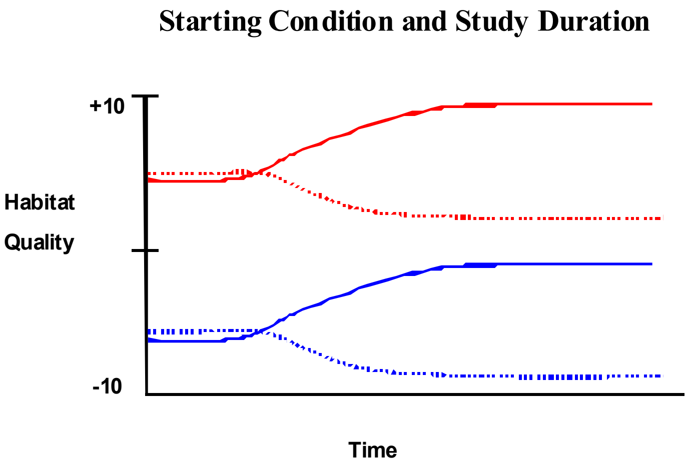

Figure 1.3. Example effect of habitat actions on habitat quality in two areas (blue versus red lines) with differing initial habitat conditions.

3. Spatial scale of the action and monitoring

Often the spatial scale of the action and biological monitoring are different. For example, biological data has generally been collected on a population scale, which covers a large geographical area such as a watershed. However, most habitat actions have been implemented on smaller spatial scales (reach or sub-reach). The comparability of spatial scales for habitat actions and the biological data with which to evaluate them may dictate what kinds of retrospective analyses can be undertaken, as well as the interpretations that can be drawn from such analyses (Figure 1.4).

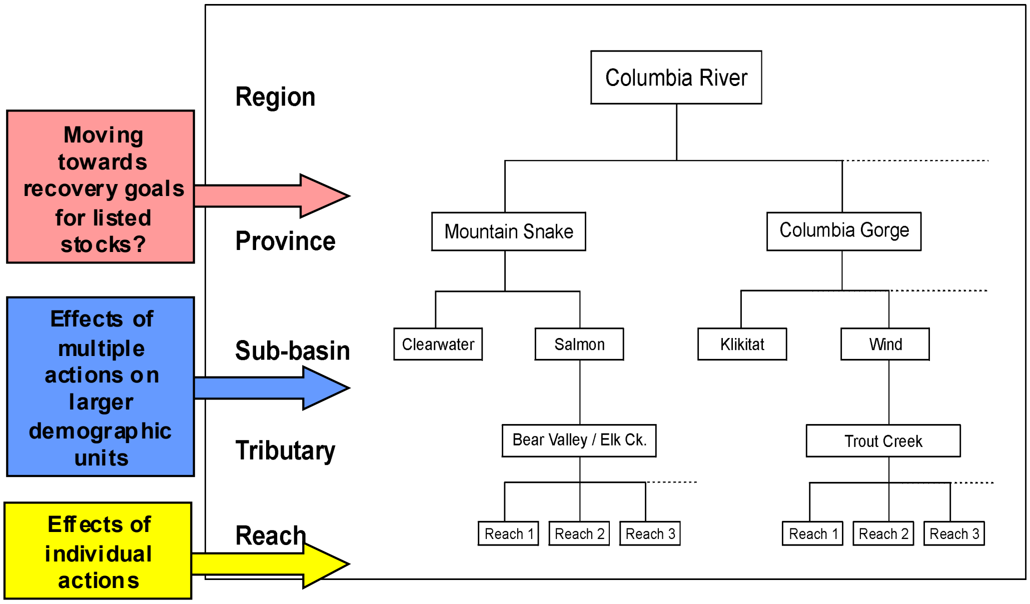

Figure 1.4. Spatial scales of actions and monitoring.

4. Temporal duration of monitoring

Habitat restoration actions such as restoring riparian vegetation may require 10 to 15 years before it is reasonable to expect to see some biological benefit in juvenile production via reduced erosion, improved stream temperatures and/or better sediment composition of spawning gravels. Evaluating the biological benefit of these types of habitat actions will therefore require long time series of biological data.

1.3 Project design

The purpose of this pilot project was to explore methods for evaluating past habitat restoration actions and their effects on fish populations. By doing so, the project will provide a foundation of retrospective analyses, on which to build prospective, multi-watershed designs for future habitat restoration actions. Such designs are being developed concurrently with this project by several other groups in the Columbia Basin (RME Workgroup 2003, NMFS 2003, Paulsen et al. 2002, Hillman 2003). By addressing questions about habitat restoration and monitoring (in coordination with other related efforts), we hope that this project will catalyze a shift in the Basin's paradigm of habitat restoration, moving from implementation of individual watershed projects towards rigorously designed and monitored, multi-watershed, adaptive management experiments.

The project involved three phases of work (Figure 1.5), each of which was closely integrated with various related and ongoing efforts in the region:

1. We met with a Core Group of habitat experts and managers to scope out a set of testable habitat restoration hypotheses, identify candidate watersheds and recommend participants for a data evaluation workshop.
2. We contacted over 80 scientists and managers to help evaluate the suitability of each candidate watershed's historical data for assessing the effectiveness of past restoration actions. We began gathering relevant data for a subset of these watersheds at a workshop with habitat experts and managers. Data assembly continued after the workshop.[4]
3. We explored statistical approaches towards analyzing the effects of restoration 'treatments' at nested spatial scales across multiple watersheds (Chapters 2-5 of this report). We identified existing constraints to testing restoration hypotheses, and opportunities to overcome these constraints through improved experimental designs, monitoring protocols and project selection strategies (Chapters 6 and 7 of this report).

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[4] We had originally contemplated organizing these data into one relational database (ESSA 2002). However, the large diversity of data types and formats made this objective impractical and infeasible, particularly given that the primary focus of this project was on data analysis, not data organization. To assist others interested in examining the data we used, we compiled inventories of all the data sets utilized in our analyses, including contact information (see Appendices to Chapters 2 and 3).

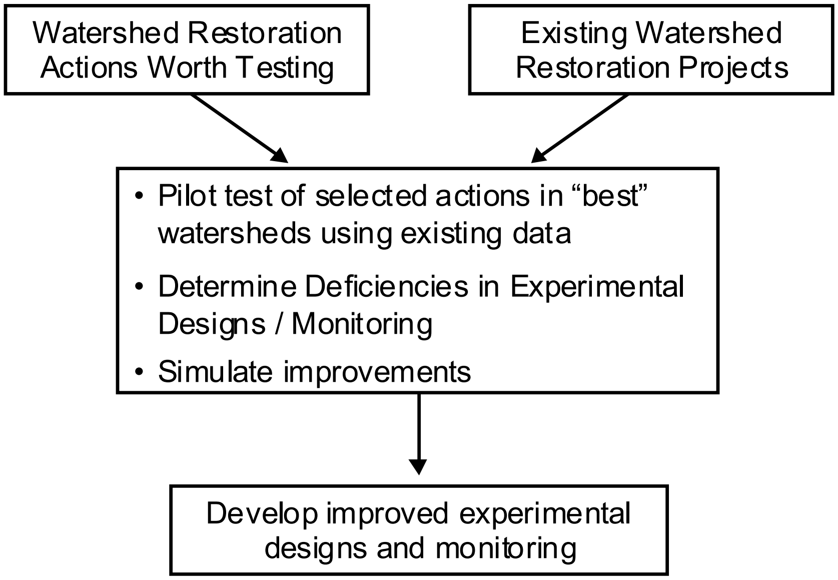

Figure 1.5. Steps involved in a multiwatershed approach for improving rates of learning.

1.4 Sub-basin selection

A Core Group[5] held a scoping meeting on February 24–25, 2003, and developed the following set of criteria for selecting subbasins appropriate for retrospective analyses:

1. have past or ongoing habitat restoration projects relevant to RPA 183 in the 2000 FCRPS BiOp;
2. possess either anadromous or resident fish populations of interest to NOAA Fisheries, BPA, USFWS (i.e., salmon, steelhead, bull trout);
3. have relevant datasets (i.e., estimates of spawners, parr, smolts, recruits) for development of survival or abundance indices and statistical tests of restoration hypotheses (either deliberate or opportunistic before/after, treatment/control contrasts);
4. share similarities/differences with other test 'watersheds' (i.e., similar physical attributes but different magnitude/timing of restoration actions (including no restoration). In general, look for tributaries in the same ecoregion of 4–6th order HUC code, (may vary by species and area), which span three classes:
    i undisturbed (relatively pristine control);
    ii) previously disturbed, but with limited restoration efforts (relatively degraded control); and
    iii) previously disturbed, with past/current restoration efforts (treatment).
5. share population measures and habitat treatments on comparable spatial/temporal scales;
6. have documentation (e.g., presentations, papers) indicating that planned restoration treatments were in fact implemented;

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[5] Participants included Laura Gephart (CRITFC), David Marmorek (ESSA), Kelly Moore (OWEB) , Charlie Paulsen (PER), Calvin Peters (ESSA), Ron Rhew (USFWS), Bruce Rieman (USFS), Jessica Wilcox (BPA). See Appendix 4 for contact information.

7. be represented by researchers and managers that are supportive of the project, and willing to share their data; and
8. have had restoration projects in place long enough for actions to potentially have an effect.

Many habitat restoration projects have been undertaken within the Columbia Basin, but biological data is more sparse and varies widely in quality, spatial scope, and duration. Given this, the Core Group informally adopted two general principles for identifying potential watersheds:

1. We should use studies that specifically examined biological responses to habitat restoration actions wherever possible, but since such studies are rare it is necessary to be more "opportunistic" in identifying relevant watersheds. That is, we should look for watersheds where habitat actions have coincided with collection of potentially useful biological data, even if that data were not collected specifically for the purpose of evaluating ongoing habitat restoration actions. By matching biological data to restoration actions, we should develop larger datasets for hypothesis tests than by concentrating solely on specific habitat restoration evaluation studies.
2. Since biological data are more scarce than habitat restoration actions, the most efficient approach to identifying potential watersheds will be to first identify sub-basins that have reasonably good biological data (i.e., good spatial coverage, consistent monitoring methods over long periods of time, easily accessible), then look upstream within those sub-basins for watersheds and sites with relevant restoration actions to evaluate. Ultimately, the goal is to define a set of hypotheses that could be tested given the biological data and actions occurring in a set of comparable watersheds. This process is illustrated in Figure 1.6.

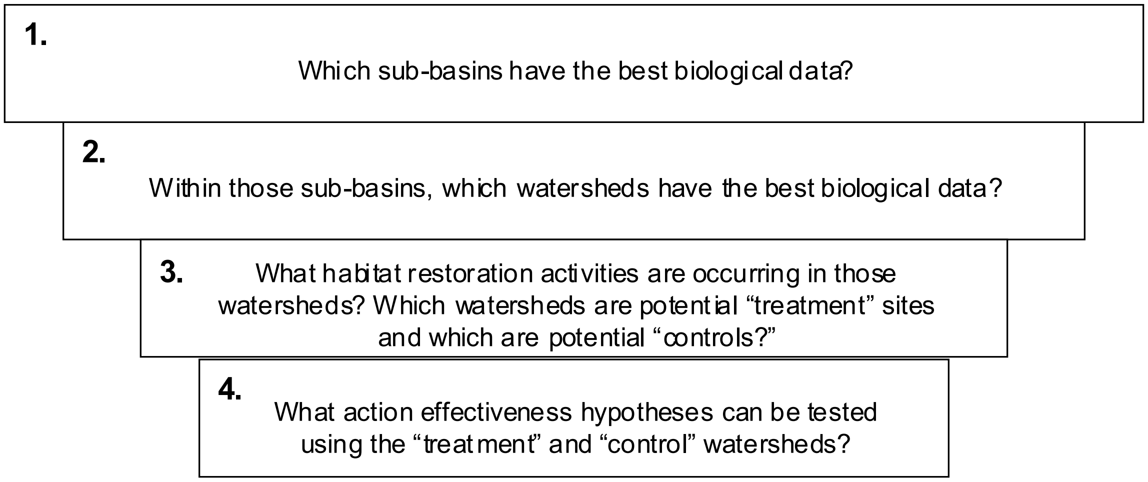

Figure 1.6. Filtering process for identifying potential watersheds and hypotheses.

Step 1 in the filtering process was initiated at the Core Group scoping meeting (February 2003) by reviewing the status (amount and quality) of biological data in various subbasins in the Columbia Basin. Based on initial review of the data, seven Columbia subbasins were selected for further exploration: Salmon River (South and Middle Forks), Clearwater, Grande Ronde, Flathead, Yakima, Deschutes and Wenatchee. Local fish experts and habitat managers from each of these subbasins were invited to a 3-day workshop on March 17–19th, 2003,[6] where the intent was to complete Steps 2 to 4 of the filtering process shown in Figure 1.6. Based on representation at the workshop and continued assessment of available datasets, the pilot project subsequently focused on just four subbasins: the Wenatchee, Yakima, Clearwater, and Salmon subbasins (Figure 1.7). There are ample opportunities for retrospective studies in subbasins other than the four we chose to examine.

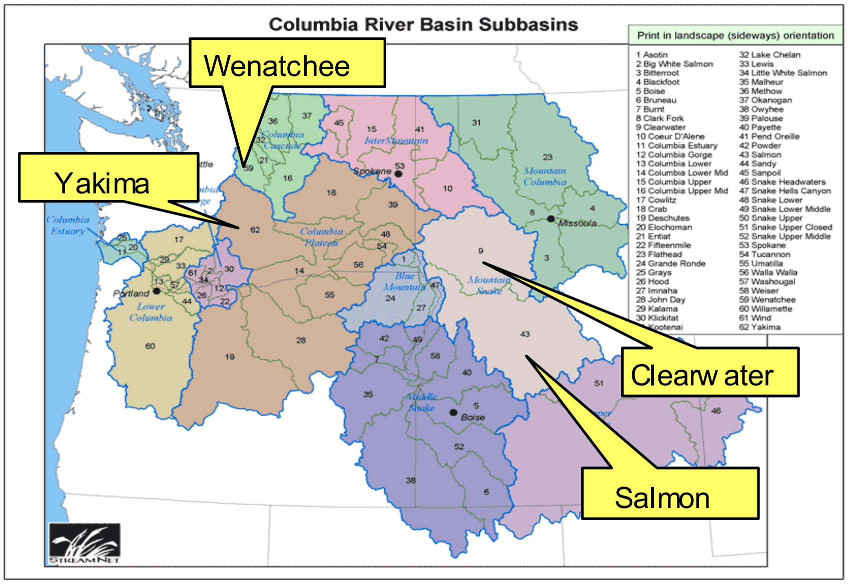

Figure 1.7. Locations of subbasins which were selected for retrospective analyses of action effectiveness.

1.5 Evaluation of projects and biological data

Agency experts at the March, 2003 workshop provided detailed information on habitat restoration projects that had/were being undertaken in each of the candidate watersheds, as well as the type and extent of biological monitoring datasets that were available for analyses. During the period of March–July 2003, historical datasets and supporting documentation describing restoration projects and biological inventory/monitoring within each of the four subbasins were obtained from various fisheries agencies operating in the Columbia. Project information from each subbasin was assembled and catalogued as in Table 1.1.

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[6] Participants included: Pete McHugh, Charlie Petrosky, Russ Keifer, Tim Fisher, Felix McGowan, Rebecca Lloyd, Nate McLennan, Steve Clayton, Jody Brostrum, Charlie Paulsen, Howard Schaller, Joel Hubble, Tracy Hillman, Chuck Peven, Laura Gephart, Dale McCullogh, Steve Katz, Tom Cooney, Jessica Wilcox, Steve Waste. See Appendix 2 for contact information.

Table 1.1. Project information assembled for subbasin restoration data inventory.

1. Location (basis, sub-basin) of the project activities (HUC code, latitude, longitude)
2. Type of project (e.g. riffle construction, LWD addition, etc.) and period of implementation
3. Fish species of interest
4. Hypotheses that could be tested (theorized effect on specific life stages of fish populations)
5. What biological/habitat indicators were measured
6. Where indicators were measured (w/, w/o treatment)
7. How indicators were measured (sampling protocols)
8. Frequency at which these measurements were taken
9. How data could be analyzed (e.g., statistical evidence/trends that would provide inferences on the effectiveness of actions in improving survival)
10. Classification variables (e.g., ecoregion, physiographic province, valley/channel characteristics)
11. Pointers to actual physical, chemical, biological datasets relevant to the project

The information in Table 1.1 was compiled into a Data Analysis Plan (ESSA 2003). This plan was reviewed by a select group of fisheries scientists and biostatisticians with expertise in Columbia basin fish monitoring studies as well as in large-scale experimental design, at a Data Analysis workshop convened on July 15–16, 2003.[7] The general intent of the Data Analysis workshop was to further assess the quality of the available subbasin data and refine possible approaches for statistical analysis. Specific goals of the July, 2004 workshop included:

1. review of relevant historical data for appropriate parts of the four candidate subbasins identified at the earlier meetings (and others if they arise);
2. determine what kinds of pilot tests of restoration action effectiveness are most promising, and identify challenges;
3. prioritize planned analyses both among and within sub-basins; and
4. make arrangements for any required further “data mining” activities.

Based on deliberations at the Data Analysis workshop it was concluded that it would be best to undertake a few statistical analyses in the most thorough manner possible, rather than doing a larger suite of potential ‘quick and dirty’ analyses. It was perceived that the greatest value in this pilot project was in exploring what level of effort might be required to get interpretable results from such retrospective studies. Proper implementation would assist in developing criteria for determining what data are necessary and what designs/analyses are most appropriate.

Workshop participants recognized that there are a number of reasons why one might not detect a positive effect of restoration actions on fish survival rates:

a) the actions weren’t actually implemented, or were implemented poorly;
b) the system was very degraded to begin with, and therefore has shown little response;
c) the actions did not address the key factors limiting survival’
d) the actions haven't had enough time to create survival benefits,
e) the actions did not affect a sufficient fraction of the total reach length or watershed area above the fish sampling point;

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[7] Participants included Tim Fisher, Joel Hubble, Chris Jordan, Steve Katz, Russ Kiefer, Dave Marmorek, Dale McCullough, Ian Parnell, Marc Porter, Charlie Paulsen, Charlie Petrosky, Ron Rhew, Carl Schwarz, Earl Weber, Jessica Wilcox.

e) some confounding factor affected the treatment and/or control site (e.g. droughts, flood);
f) low statistical power (fish response measures can have high process and measurement error); and/or
g) fish survival would have declined without the action, but merely stayed constant (only applies to a Before/After study; Before/After/Control/Impact designs should control for this).

These factors are not mutually exclusive. Should the retrospective analyses produce a negative result, identification of the key factors most likely responsible in each case will help to distinguish between weak experimental designs and ineffective actions.

The Data Analysis workshop identified a few locations of restoration activities that could provide thorough tests of action effectiveness. These activities (listed below) subsequently became the focus for detailed analyses included as part of this pilot project:

1. the program of Phase I fish screening projects on irrigation/power diversion canals in the Yakima Subbasin (Chapter 2);
2. erosion reduction programs in the Salmon River Subbasin (Chapter 3); and
3. cumulative effects of habitat restoration projects in both the Salmon and Clearwater Subbasins (Chapter 4 and 5).

In addition, it was considered valuable as part of this pilot project to undertake a review of relatively well designed action effectiveness studies ("blue ribbon studies") that have either been undertaken in the Columbia Basin, or have relevance to the situation in the Columbia. The purpose of this review was to more fully establish best practices for analyses of this nature. The complete review is in Appendix 1, and key lessons learned are summarized in Chapter 6.

Participants at the Data Analysis workshop also recommended that any qualitative weaknesses in the datasets or statistical designs used for the retrospective analyses undertaken in this project should be well documented, to allow comparisons of the reality of undertaking retrospective analyses for the Columbia Basin versus what might be recommended by an assessment of the "blue ribbon" studies. Finally we intend to synthesize results into priorities for further retrospective analyses and the development of a basis for more powerful and better designed effectiveness evaluations (Chapter 7).

2.0 Effects of Screening on Irrigation Diversions in the Yakima River Sub-basin

(M. Porter, D.R. Marmorek, J. Hubble, C.A.D. Alexander)

2.1 Abstract

There is little quantitative information about the benefits of past restoration projects for salmon survival. The Bonneville Power Administration and Bureau of Reclamation have funded construction of improved fish screens at major irrigation/power diversions within the Yakima Subbasin, WA. Localized monitoring indicated that the screens functioned as intended, roughly doubling the survival of spring chinook smolts at a major irrigation canal. We extended these data into an index of the improving cumulative survival of smolts past all screened Yakima canals (*Sc*). To test if improvements in *Sc* contributed to increased subbasin productivity of spring chinook (adult returns/spawner or smolts/spawner), we developed a series of log-linear regression models based on Ricker-type-stock-recruitment relationships and environmental covariates, using other stocks as controls in a BACI design. Surprisingly, *Sc* was either not correlated or negatively correlated with chinook productivity. Climate variability in both the freshwater and ocean phases of the life history, as well as possibly other stressors within the watershed (e.g., changed hydrology), appear to have swamped any detectable fish screening benefits to overall productivity. A longer period of pre-implementation monitoring and greater spatial / temporal contrasts in implementation of screens within the subbasin would have increased the chances of detecting an overall effect on productivity.

2.2 Introduction

Habitat protection and restoration is a cornerstone of current strategies to restore ecosystems, recover endangered fish species, and rebuild fish stocks within the Columbia River Basin. Strategies featuring habitat restoration include NMFS' 2000 Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), the USFWS Biological Opinion on Bull Trout, the overall NWPPC Fish and Wildlife Program, and Subbasin Plans developed under the NWPPC Program. Common habitat restoration actions include restoring in-stream flow, nutrient enhancement, barrier removal, sediment reduction, riparian re-vegetation, in-stream structures and installing or improving diversion screens. The FCRPS BiOp specifically mandated that studies be carried out to assess the effectiveness of these restoration actions (RPA 183, pg. 9–133 NMFS 2000).

The often-unstated hypothesis underlying habitat restoration activity is that the restoration actions will have some ultimate effect (presumably positive) on overall fish survival and abundance. There is however little quantitative information about the large-scale effectiveness of different habitat restoration techniques. A recent review by Bayley (2002) of 441 salmonid habitat studies concluded that current freshwater-based monitoring programs either: (1) fail to indicate an improvement associated with stream habitat restoration in terms of smolt recruitment, returning adults, or population size increase at the watershed scale; or (2) indicate an improvement but fail to demonstrate which and how habitat changes were responsible so that subsequent restoration policy could be made more cost-effective (summarized in Appendix 1 Blue Ribbon Studies). Such information is crucial for helping scientists and program managers allocate limited funds towards the greatest benefits for fish populations. It is therefore critical to systematically test the hypotheses underlying habitat restoration actions, for both anadromous and resident fish populations.

Since the mid 1980s, the Bonneville Power Administration (BPA) and the Bureau of Reclamation (BoR) have funded construction of and improvements to fish passage and protection facilities at irrigation diversions within the Yakima River Subbasin, WA. The program is designed to mitigate the impact of irrigation in the Yakima River Subbasin and provides offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin (Neitzel et al. 1985). The underlying assumption for the continuing fish screening program (now into Phase II of a two phase program) is that entrainment into poorly screened irrigation diversions has been a major source of mortality for migrating salmonids in the Yakima Subbasin and has contributed to reduced smolt production. A 1990 study of screening mortality for the Yakima Basin's Naches River supported this contention and estimated that about 6% of the Naches River spring chinook smolts were lost at the Wapatox canal diversion prior to installation of new fish screens (Yakima River Subbasin: Salmon and Steelhead Production Plan 1990, Appendix 2.2).

The initial focus (Phase I) of the BPA program was to replace older 1940s era fish screens existing on the Yakima Subbasin's largest irrigation canal diversions with newer generation screens that would more safely divert fish back into mainstem rivers and greatly reduce mortality to juvenile fish associated with canal entrainment and screen impingement (Blanton et al. 1998). This Phase I screening construction was completed for the major Yakima River diversions over the time period of 1985 to 1989, while new screening on large diversions in the Yakima's Naches River tributary was installed in 1993. General construction costs for each of the Phase I screening projects ranged from about \$0.3 to \$11.1 million (U.S.) with a total cost of about \$40 million (Anon 2001a).

Most of the Yakima Phase I screening facilities were evaluated for project level effectiveness by the Pacific Northwest National Laboratory (PNNL) between 1985 and 1990. PNNL reports consistently indicated that new fish screens significantly reduced velocity conditions in canals that had, in the past, seriously impinged fish on screen mesh surfaces (Neitzel et al. 1985; Abernathy et al. 1989; Neitzel et al. 1990a; Neitzel et al. 1990b). The PNNL reports also indicated that smaller mesh sizing on the new screens effectively eliminated occurrences of fish entrapment within the irrigation canals, and any associated migration delays at the canals appeared to have been reduced. Smolt passage data compiled by the Yakama Nation's Fisheries Program for the Chandler canal additionally indicated that measured smolt survival rates through the canal diversion had roughly doubled after installation of Phase I screening in 1987 (Neeley 1998). To date, however, no formal analysis has examined whether the Phase I fish screens had a significant and detectable effect at improving long term population trends for salmon at the larger subbasin scale. This paper explores whether rates of salmon production in the Yakima Subbasin, as indicated by a time series of subbasin wide smolt/spawner or adult recruits/spawner productivity indices, showed an improvement relative to 'control' populations following reductions in smolt mortality at screened irrigation canals.

2.3 Methods

To undertake this analysis of Phase I fish screening actions we adopted a retrospective inter-basin BACIP (Before-After-Control-Impact-Paired) approach (Underwood 1993). We set out to assess changes in productivity for the Yakima Subbasin in relation to quasi-control watersheds that are in the same or a nearby ecoregion, but have experienced far less watershed restoration efforts. A BACIP design compares sampling values estimated simultaneously at Treatment and Control sites on multiple occasions through time, to provide a time series both Before and After the treatment of interest has occurred. The design is intended to isolate sources of natural spatial and temporal variation from the treatment impact; treatment being defined within our analyses as the program of Phase I fish screening in the Yakima Subbasin. A positive change in historical salmonid productivity in the Yakima Subbasin that differs significantly over time from the patterns demonstrated by control watersheds would indicate a detectable and beneficial effect of the screening actions. To isolate the possible effects of fish screening on overall productivity we first developed a series of log-linear regression models explaining the spawner and recruitment data for spring chinook (salmon species with the most complete historical time series for the Yakima and control subbasins and largest spatial distribution) based on Ricker-type-stock-recruitment relationships and a range of potential environmental covariates that might partially explain any observed trends in fish survival data (as in Deriso et al. 2001; Thompson and Lee 1999). We then developed an index of fish screening related survival that could be included as a time-dependent term in each of our regression models. Finally we adopted an information-theoretic approach (Burnham and Anderson 1998) to assess the plausibility of the various models at explaining changes in spring chinook production over time. Evaluation of the fish screening term in the selected "best" models explaining changes in salmon productivity allowed us to determine if a significant and positive effect could be attributed to Phase I fish screen construction within the Yakima Subbasin.

2.3.1 Yakima River Subbasin (treatment site)

The Yakima Subbasin is described in detail in the Yakima Subbasin Summary (Anon 2001a), from which the following summary information is drawn. The subbasin is located in south central Washington (Figure 1), and drains an area of 15,900 km^2. This large subbasin spans four ecoregion classifications (Omernik 1987; Omernik 2002): North Cascades and Cascades in the headwaters, Eastern Cascade Slopes and Foothills, and the Columbia Plateau in the lowest part of the subbasin. Originating near the crest of the Cascade Range above Keechelus Lake, the Yakima River flows 344 km southeastward to its confluence with the Columbia River. The Yakima Subbasin has been heavily impacted by agriculture (Mobrand Biometrics 1999) and is one of the most intensively farmed areas in the United States. Six major reservoirs in the headwaters form the storage component of the federal Yakima Project, managed by the Bureau of Reclamation. Most of the irrigation water sustaining the agricultural industry is transported to the lower subbasin during the summer and early autumn when the river would otherwise be approaching base flow. Six low-head diversion dams are located on the main stem of the Yakima (Figure 1) and two on the Naches River, the largest tributary to the Yakima. Each of these diversion dams maintains screening structures that were installed to prevent upstream migration of adults or downstream entrainment by juvenile salmonids into the irrigation systems. There are also three small-scale hydroelectric projects at Roza, Chandler and Wapatox (Figure 1).

Water regulation and withdrawals for irrigation cause both dewatering and elevated flows relative to the Yakima River's historic discharge regime. During the summer, temperatures of the lower Yakima River and many tributaries (even at higher elevations) can frequently exceed levels suitable for salmonids. Large irrigation diversions at Sunnyside and Wapato (Figure 2.1) typically divert approximately one half of the entire river flow during the irrigation season, from May to October, while Prosser (Chandler canal) can divert flow throughout the year, both for irrigation and power production. The Yakima Subbasin currently supports natural production of spring and fall chinook, coho and summer steelhead, with spring and fall chinook displaying the greatest abundances. Endemic coho stocks were extirpated about 1980 although naturalized production from released hatchery smolts have been documented since 1989. Endemic summer chinook were last observed in the early 1970s and are now considered extirpated. Sockeye were historically abundant, but were extirpated following the completion of impassible storage dams below all natural rearing lakes in the early 1900s.

Salmonids have been enumerated since 1982 at adult counting facilities at Roza and Prosser (Chandler) Dams and from a juvenile monitoring facility operated at Chandler Canal, as well as through complete redd counts for spring chinook on the Yakima and Naches rivers. We selected spring chinook as the focal species for our analyses of fish screening effects. Their extended spawning and rearing distribution (Figure 2.2) into the upper reaches of the Yakima Subbasin requires that they must pass most of the screened irrigation canals at some point in their smolt outmigration (unlike fall chinook which spawn and rear downstream of most screened irrigation canals).

Figure 2.1. Map of the Yakima Subbasin showing major storage, diversion, and hydroelectric dams (*Source*: Draft Yakima Subbasin Summary, 2001).

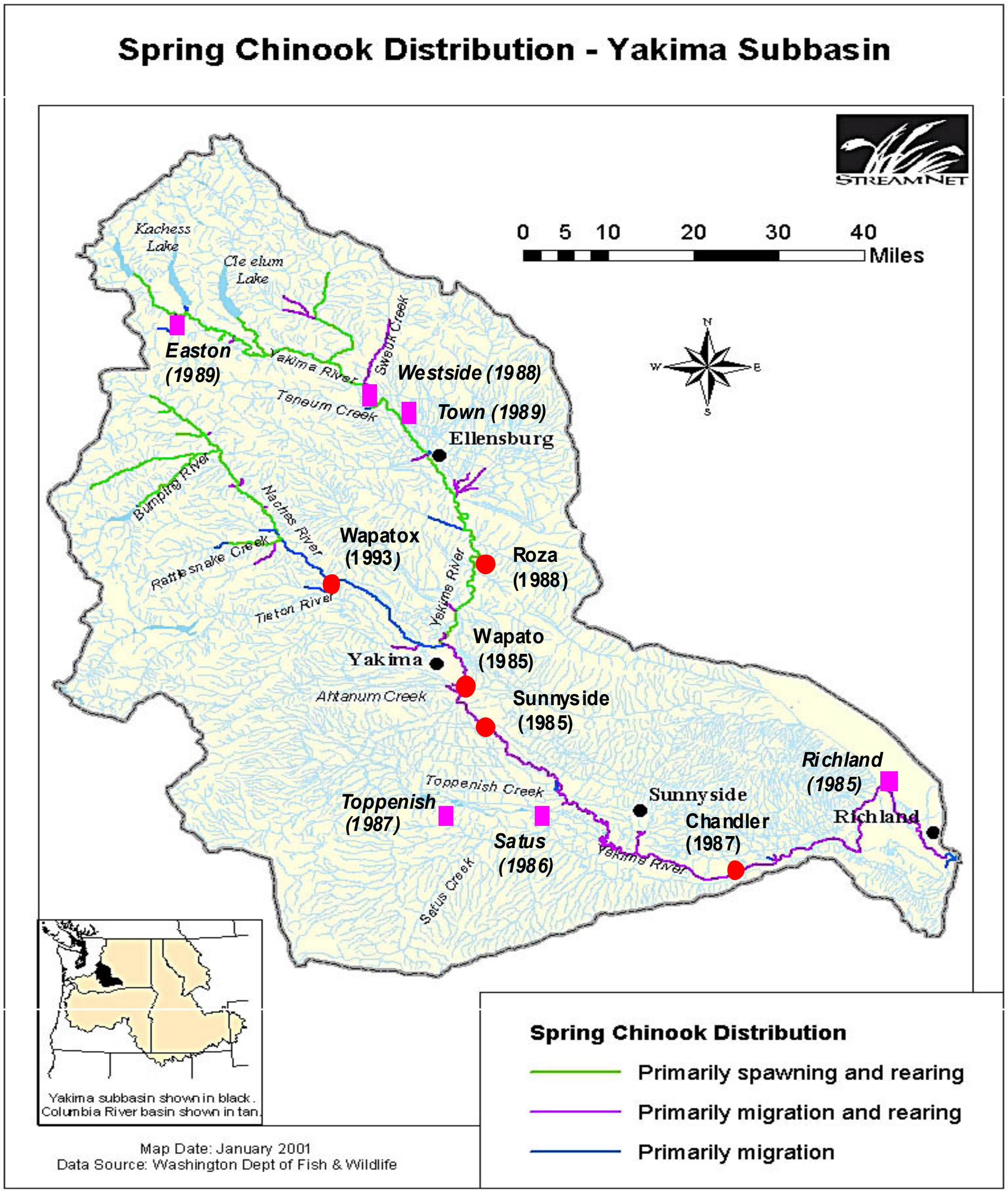


Figure 2.2. Locations (red dots) of the five irrigation/power canals (Roza, Sunnyside, Wapato, Chandler and Wapatox) in the Yakima Subbasin considered to be major sources of fish mortality. Purple squares represent other Phase I screened canals that are considered to represent only minor sources of fish mortality and were not used in our analyses. Bracketed dates indicate the timing of fish screen installation at each site. Canals are shown in relation to the distribution of spring chinook within the Yakima Subbasin (*Source*: Draft Yakima Subbasin Summary, 2001).

2.3.2 Spring Chinook populations in the Yakima Subbasin

Historically, spring chinook spawned in the upper reaches of the mainstem Yakima and Naches Rivers, most of their larger tributaries and in the three largest lower river tributaries, Satus, Toppenish and Ahtanum Creeks. Except for streams rendered inaccessible or unusable by unladdered dams (the upper Cle Elum River and the North Fork Tieton River) or by excessive irrigation diversions or releases (Taneum, Manastash and Wenas Creeks; the lower Tieton River), the current distribution of spring chinook spawning areas (Figure 2.3) is the same as it was historically, although at only about 1.5 to 8.5% of their historical abundance (Anon 2001a).

Current trends in abundance and productivity of Yakima Subbasin spring chinook represent a small fraction of historical values. Estimates of the size of historical Yakima spring chinook returns range from ~50,000 to 284,000. Table 2.1 summarizes recent annual smolt production and productivity for Yakima spring chinook. The Yakima Subbasin and the surrounding region as a whole experienced drought or near-drought conditions from 1986 to 1993, consistent with low adult recruitment rates (Table 2.1).

Table 2.1. Recent annual basin-wide smolt and adult productivity of Yakima Subbasin wild/natural spring chinook (*Source*: Yakama Nation Fisheries Program, Yakima River Run Reconstructions database – SpCkDataBase.xls). The years of major fish screen installations (Phase 1 screens on the Upper Yakima and the Wapatox Canal on the Naches River) are shown in the far right column.

Brood year	Smolt year	Spawners[a]	Smolts[b]	Smolts per spawner	Smolt to adult survival[c]	Adult recruitment rate[c]	Major fish screen installations
1982	1984	1,281	365,755	286	1.7%	4.9	
1983	1985	1,159	140,755	121	3.2%	3.8	
1984	1986	1,935	218,321	113	1.7%	1.7	
1985	1987	3,242	252,165	78	1.8%	1.3	Wapato ^{Y} Sunnyside ^{Y}
1986	1988	7,571	260,932	34	1.6%	0.6	
1987	1989	3,517	72,460	21	3.2%	0.6	Chandler ^{Y}
1988	1990	3,292	134,162	41	4.2%	1.6	Roza ^{UY}
1989	1991	3,761	104,405	28	2.4%	0.7	
1990	1992	3,601	123,041	34	0.9%	0.3	
1991	1993	2,732	87,844	32	0.6%	0.2	
1992	1994	4,138	162,989	39	2.0%	0.8	
1993	1995	3,674	168,471	46	2.1%	1.0	Wapatox ^{NA}
1994	1996	1,253	207,365	165	0.5%	0.9	
1995	1997	463	49,524	107	3.9%	3.5	
1996	1998	2,599	278,706	107	6.9%	7.6	
1997	1999	2,098	258,751	123	4.9%	6.3	
1998	2000	1,217	61,531	51		4.4	
1999	2001	742	96,734	130		4.9	
2000	2002	15,387	367,013	24		3.8	
2001	2003	16,860					
2002	2004	10,539					

a. Estimates for spawners do not include jacks

b. Estimated as the sum of "spring smolts", counted from March 1 through the end of the outmigration, and one half of the "winter migrants" – subyearlings passing Prosser the winter preceding the spring of outmigration.

c. Figures for brood year '96 estimated: the historical proportion of age-5 to age-4 returns was assumed.

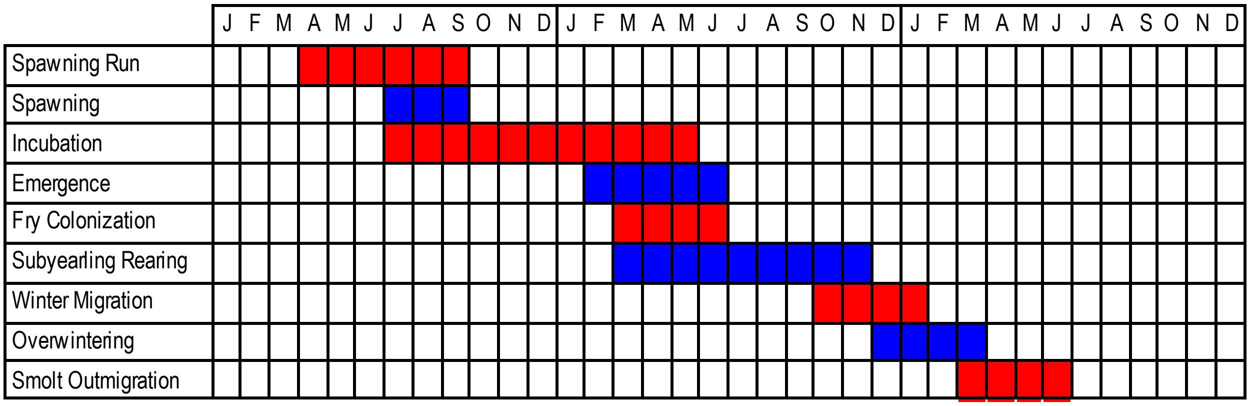
UY – on Upper Yakima River above Naches River confluence

NA – on Naches River

Y – on Yakima River below Naches River confluence

Three genetically distinct stocks of spring chinook have been identified in the Yakima Basin: the upper Yakima, the Naches, and the American River stocks (Anon 2001a). These three stocks differ in ocean age, mean fecundity and spawning timing, but are considered similar in their timing of spawning runs, smolt outmigration and emergence, as well as in pre-smolt migration patterns and smolt age. All stocks of Yakima spring chinook smolt as yearlings after about one year of rearing (Table 2.2).

Table 2.2. Mean timing of successive freshwater life stages of Yakima Subbasin spring chinook (*Source*: Draft Yakima Sub-basin Summary, 2001).



	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Spawning Run				🟥	🟥	🟥	🟥	🟥	🟥																											
Spawning							🟦	🟦	🟦																											
Incubation							🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																			
Emergence														🟦	🟦	🟦	🟦																			
Fry Colonization															🟥	🟥	🟥																			
Subyearling Rearing															🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦													
Winter Migration																						🟥	🟥	🟥	🟥											
Overwintering																								🟦	🟦	🟦	🟦									
Smolt Outmigration																											🟥	🟥	🟥	🟥						

Juveniles from all stocks redistribute themselves downstream during the spring and summer after emergence, with the highest summer densities well below the major spawning areas, but above Sunnyside Dam. The lack of fish below Sunnyside Dam is attributed to excessive summertime water temperatures. Most spring chinook pre-smolts migrate to the lower Yakima mainstem when water temperatures fall sharply in the late fall (Anon 2001a, pg. 43), usually reaching Wapatox and Roza dam in October/November and Prosser Dam during December (Figure 1). Although 10-35% of the juveniles from a given brood year migrate below Prosser Dam during the winter, most fish overwinter in the deep, slackwater portion of the mainstem Yakima between Marion Drain and Prosser Dam (Figure 1), and begin their smolt outmigration from the lower river the following spring.

The timing of Yakima spring chinook smolt outmigration is quite variable (Figure 2.3); outmigration can be 90% complete as early as April 28 or as late as June 1. Anon (2001a) report that while the migration rate of actively migrating smolts is positively correlated with flow the overall timing of the outmigration seems to be a function of water temperature the winter preceding smoltification.

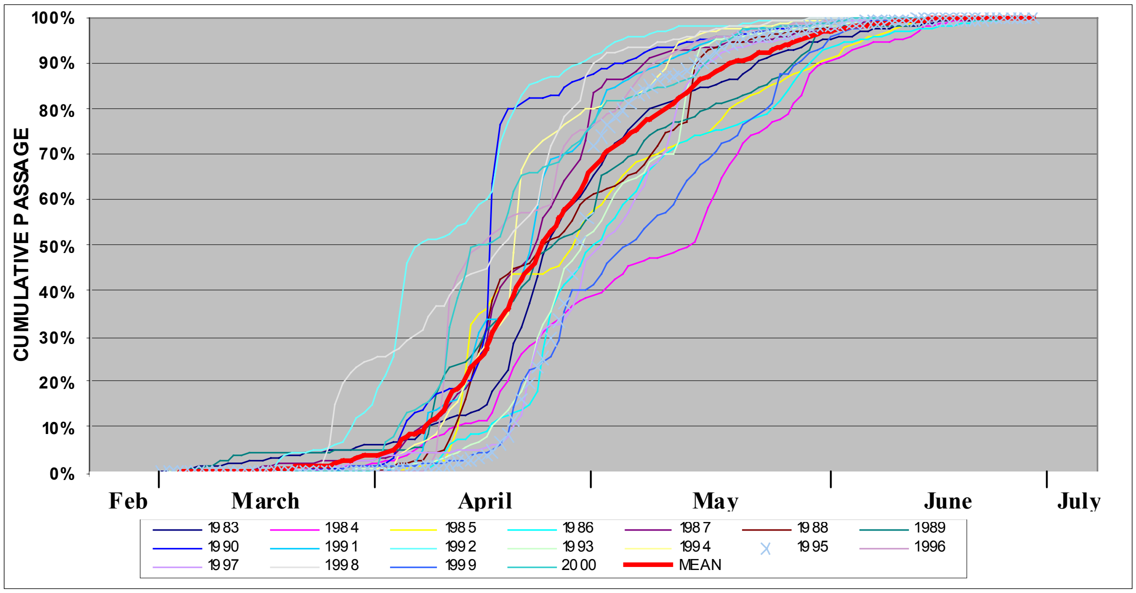


Figure 2.3. Cumulative outmigrant passage measured at Chandler Canal (*Source*: Draft Yakima Sub-basin Summary, 2001).

Primary data on spring chinook populations in the subbasin is collected and processed by the Yakama Nation's Fisheries Program. Annual estimates of the number of spawning adults (based on adult counts at Prosser and Roza dams, redd count estimates and the numbers harvested by the Tribe in the Yakima River), in addition to age determinations of sampled fish in the spawning areas, are used to generate historical run reconstructions for separate chinook stocks within the Yakima Subbasin. The current run reconstructions provide annual, age specific estimates of chinook spawners for brood years 1982 through 2001, to the mouth of the Yakima River. A detailed breakdown of the methodological steps used by Yakama Nation fisheries biologists to calculate these yearly estimates is provided in Appendix 2.A.

The Yakama Nation's run reconstructions can be used to generate estimates of annual adult recruits/spawner for two separate genetic stocks of spring Chinook within the Yakima Subbasin: an Upper Yakima stock and a combined Naches/American stock. Although run reconstructions are available for the American River as a separate stock, a limited number of spawner surveys for age composition in this system and extensive straying among different redd count areas suggest that aggregating American River data with the Naches River is most reliable (E. Weber, pers. comm.).

Spring chinook smolts migrating out of the Yakima system are additionally captured and enumerated at a juvenile monitoring facility located at the Chandler Canal. Juveniles entering the bypass pipe at Chandler are efficiently diverted into a livebox at subsampling rates controlled by facility operators, based on river flow and migration numbers. The monitoring facility is in continuous operation (24 hours a day, seven days a week) from November 1st of each year until late June or mid July (end of migratory period). Juvenile counts, in conjunction with the historical run reconstructions, allows an estimate of annual juvenile productivity within the Yakima system (expressed as smolts/spawner). The Chandler Canal Juvenile Monitoring Facility, however, is located below the confluence of the Upper Yakima and Naches Rivers, so that captured smolts represent a combination of juveniles from all upriver stocks. The estimates of smolts/spawner used in our analyses therefore apply to a pooled Yakima Subbasin stock, as opposed to the more discrete separation into Upper Yakima and Naches/American stocks that is possible for estimates of adult recruits/spawner.

2.3.2 Control sites

Control sites are required both to provide contrast in the treatment of interest (major fish screens) and to account for regional-scale temporal trends in climate which could confound the effect of interest. We therefore compared trends for spring chinook in the Yakima Subbasin with reference populations in other, similar subbasins where there has not been as much change in habitat due to human activity (either restoration or deterioration). Control sites were intended to: 1) be close enough geographically that they were likely to have been subjected to the same climatic regime (preferably in the same or similar ecoregion); 2) have had little habitat manipulation over the period of interest (i.e., neither degradation or improvement); and 3) have long term spring chinook population data. Participants at a series of workshops convened to discuss these issues suggested that only two watersheds fulfilled these criteria: the Wenatchee River (similar ecoregions, little habitat manipulation, long term adult recruit/spawner data) and the Warm Springs River (partly similar ecoregions, little habitat manipulation, long term smolt/spawner data).

1. Wenatchee River

The Wenatchee Subbasin is directly north of the Yakima Subbasin in Washington State, and drains an area of approximately 3550 km^2, from the high Cascades (North Cascades ecosystem) east to the Columbia River (East Cascade Slopes and Foothills ecoregion (Omernik 1987; Omernik 2002) (Figure 2.4). Four large tributaries (the Chiwawa River, White River, Little Wenatchee River and Nason Creek) join at or near Wenatchee Lake to form the Wenatchee River, which flows 85 kilometers to the Columbia River. Snowmelt in the upper watershed is the principal source of water for the subbasin's larger streams and provides over 80% of the total runoff from the watershed.

While irrigation (e.g., Dryden Diversion), mining and forestry have had some impacts (Anon 2002), the Wenatchee Subbasin is, in general, considered to be a much less disturbed system than the Yakima, with better connectivity and cooler water temperatures. Fisheries restoration work on the mainstem Wenatchee has also been minimal relative to the intensive activities that have occurred within the Yakima watershed (one Phase 1 screen at the Dryden Diversion). We believe that the Wenatchee Subbasin is a good control for the Yakima, being in a relatively pristine state and favorably located within similar ecoregions. Fish population data for the Wenatchee include historical run reconstructions for spring chinook that can be used to calculate yearly adult recruits/spawner numbers for comparison with the Yakima Subbasin. Methods for spring chinook run reconstructions in the Wenatchee are outlined in (Cooney 2002) and details of spawning enumeration methods through redd counts are described in Mosey and Murphy (2002). There are however no long-term data on smolt outmigration from the Wenatchee River that would allow us to contrast juvenile productivity with stocks from the Yakima Subbasin.

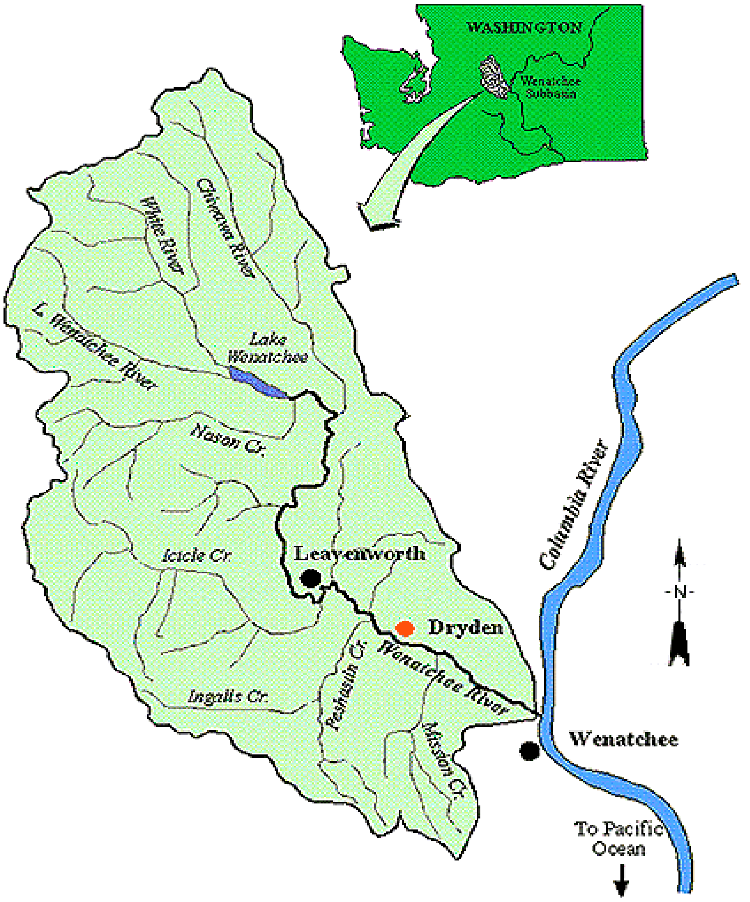


Figure 2.4. Map showing the location of the Wenatchee Subbasin, the one Phase 1 screened diversion at Dryden (*Source*: PacNorthLabs).

2. Warm Springs River

The Warm Springs River is a tributary of the lower Deschutes River in Oregon, draining approximately 1362 km^2 before entering the Deschutes River (Figure 2.5). The Warm Springs watershed is generally much drier than the Yakima Subbasin, and spans three Level III ecoregions: Cascades, East Cascade Slopes and Foothills and Blue Mountains; the first two are similar to ecoregions found in the Yakima Subbasin (Omernik 2002). Despite some history of resource extraction and agriculture, overall impacts to fish habitat are much less than within the Yakima Subbasin (Bob Spateholts, pers. comm.). Wild spring chinook salmon spawn in the Warm Springs watershed, most of which is managed by the Confederated Tribes of the Warm Springs (CTWS). CTWS monitors smolt out-migration from the system, and also conducts spawning surveys annually for spring chinook salmon, summer steelhead, and bull trout (Anon 2001b). Smolt monitoring on Warm Springs between 1975–2000 was undertaken using a 5 foot screw Humphey Scoop trap; this changed in 2001 to use of a 8-foot screw Heath Screw Trap. The smolt traps operate from Monday to Friday (5 days, 4 nights) during each week of the primary migration periods (March–June and September–December) (B. Spateholts, pers. comm.).

On the Warm Springs Reservation a watershed restoration program has been in place since the 1970s, including instream works and some diversion screen improvements (Anon 2001b). However, the extent of this program is very small relative to the large restoration programs undertaken within the Yakima Subbasin. The Warm Springs watershed cannot be considered a true control for the Yakima, as it has a much drier climate, though in similar Level III ecoregions. We can consider Warm Springs to represent at least a "quasi-control" system for our Yakima analysis. The smolt out-migration monitoring undertaken by the CTWS represents a valuable concurrent time series of juvenile production data that can be used for smolt/spawner comparisons with the Yakima.

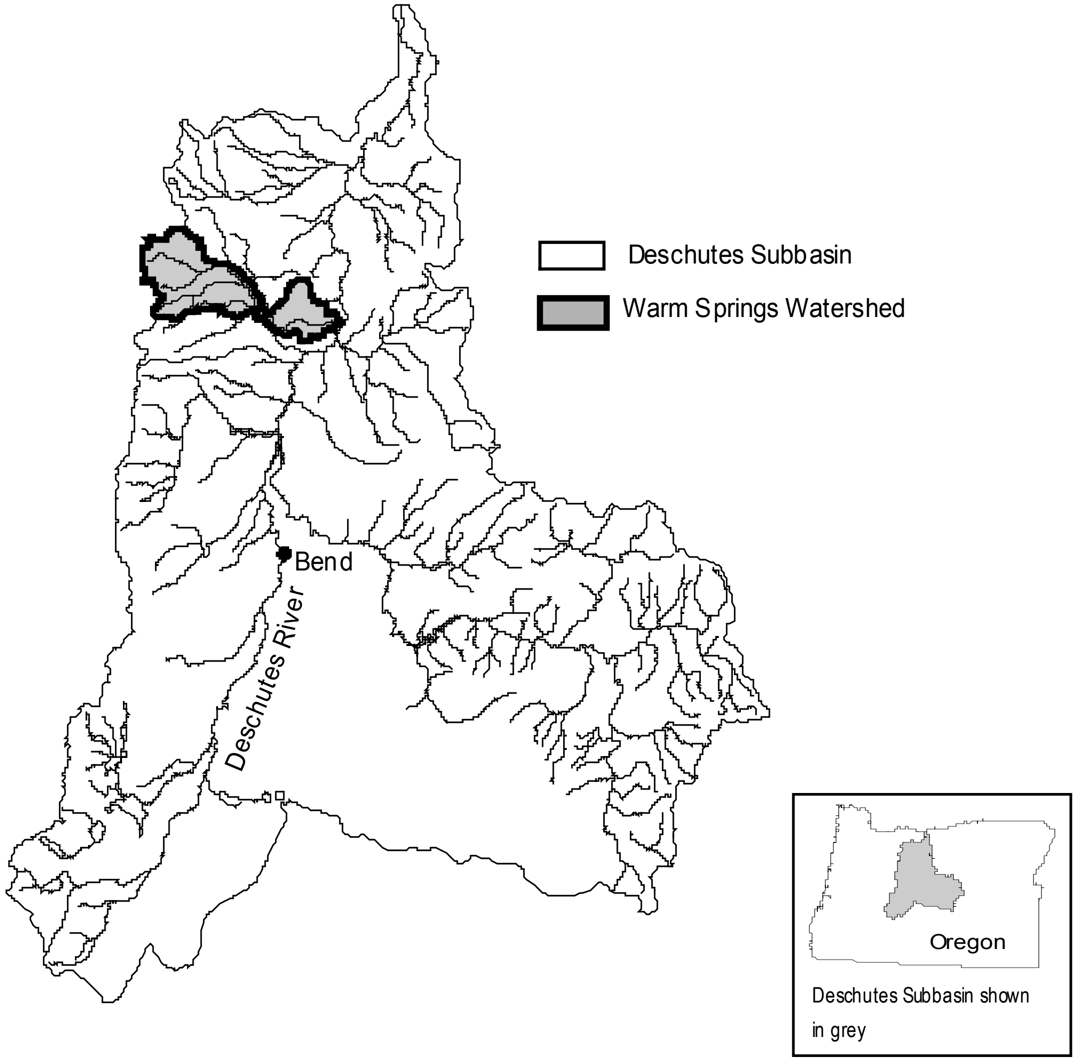


Figure 2.5. Map showing the location of the Warm Springs River within the larger Deschutes Subbasin, OR (*Source*: State of Oregon: Oregon Geospatial Data Clearinghouse).

2.3 Fish screens in the Yakima Subbasin

The Yakima River and its tributaries have been heavily diverted for irrigation and power production. Installation of improved fish screens (e.g., Figure 2.6) on these diversion canals has been the focus of intensive mitigation efforts by the BPA and BoR within the subbasin.

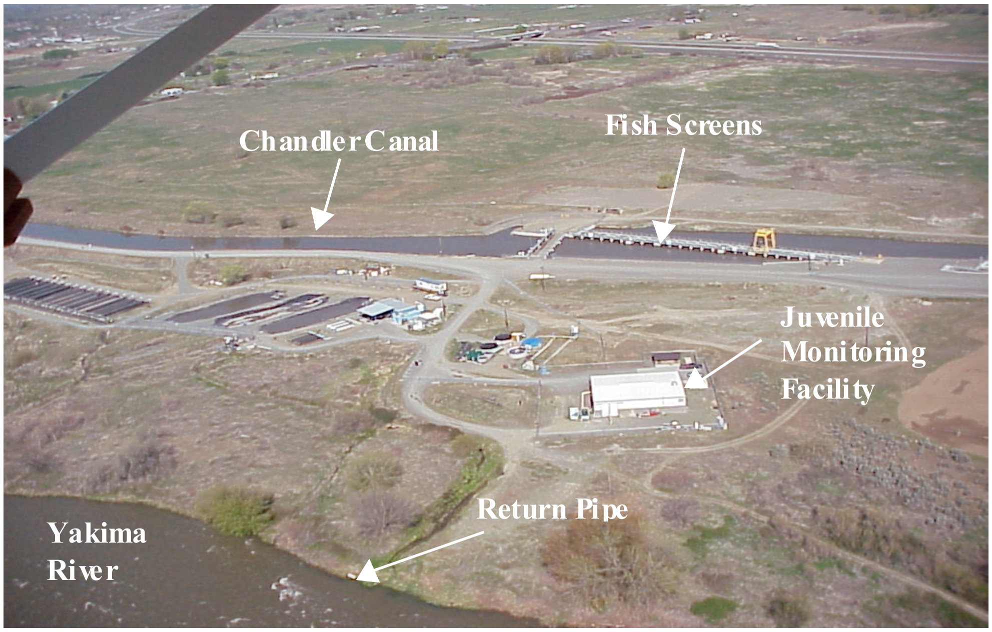


Figure 2.6. Chandler Canal Fish Screen and Juvenile Monitoring Facility on the Yakima River. Photo courtesy of Yakama Nation.

Phase I of the BPA/BoR fish screening program targeted the ten largest irrigation canals (Figure 2.2) and involved installation of improved fish screens in these canals over a four year period (1985 to 1989). Phase II screening was initiated by the BPA in 1993 (and remains ongoing), targeting the remaining smaller irrigation canals throughout the subbasin. Consultation with Yakama Nations Fisheries biologists suggested that only four of the Phase I canals (Roza, Wapato, Sunnyside and Chandler) would have been considered major sources of fish mortality historically. Impacts to fish at other Phase I canals were considered to be relatively minor due to a combination of better canal/mainstem configurations, smaller amounts of river flow actually diverted into the canal, or (in some cases) canal locations being well upstream of the primary spring chinook spawning/rearing areas.

One of the Phase II canals (i.e., Wapatox canal on the Naches River) was, however, identified by Yakama Nations Fisheries biologists as being another major mortality source prior to installation of its new screen in 1993. The Yakima River Subbasin Salmon and Steelhead Production Plan (1990) suggested that mortalities at this canal were historically responsible for the loss of about six percent of Naches River system spring chinook smolts. Consequently we also incorporated Wapatox Canal as a fifth target canal in our analyses of fish screening impacts (Figure 2.2).

Information from fish sampled at the Chandler Juvenile Monitoring Facility provides annual estimates (both before and after installation of new fish screens) of three critical components that we used to develop a Fish Screen Survival Index (Sc) for use in our analyses:

1. an estimate of daily juvenile outmigration past the Chandler Canal;
2. an estimate of daily fish entrainment rate into Chandler canal; and
3. an estimate of daily survival rate for fish that are entrained within Chandler Canal.

‘Entrainment’ rate is the proportion of those fish passing Prosser dam that enter (are entrained into) Chandler Canal (and does not refer to ‘entrapment’ behind the fish screen). Canal survival is the proportion of those entrained fish that survive entrainment within the canal to be counted at the Juvenile

Monitoring Facility located at the bypass leading back to the river. Details of how these estimates were obtained for Chandler Canal are provided in a series of Yakama Nation Chandler Certification reports (e.g., Neeley 1998; Neeley 2002; also see BPA 1985).

The Yakama Nation estimates of daily entrainment rates and canal survival rates in Chandler Canal are derived from the proportions of paired releases of marked fish (freeze branded in earlier years, later PIT tagged) that are detected at downstream sampling sites. One of the paired releases is made into Prosser Dam's forebay on the right bank approximately 0.8 km upstream of the dam (providing information for the entrainment rate estimate), and the other release is made into Chandler Canal itself below the headgates (providing information for the canal survival rate estimate). These estimates of canal entrainment and survival rates are used in combination with total counts of migrating smolts subsampled at the Chandler Juvenile Monitoring Facility downstream of the screens to generate an index of estimated daily juvenile outmigration past the Prosser Diversion Dam.

Outmigration Index

The outmigration index (O_j) used by the Yakama Nation to estimate juvenile numbers on day j at Prosser Dam is represented by the equation (Neeley 1998):

$$\sum_{j} o_j = \sum_{j} \frac{c_j}{er_j \ cs_j \ sr_j} \qquad \text{(Eq. 1]}$$

where:

c = count of fish subsampled at the juvenile monitoring facility;
er = estimated juvenile entrainment rate into Chandler Canal
cs = estimated canal survival rate
sr = estimated subsampling rate

It is not possible to make releases of marked fish on each day. During certain periods when flows are high, many fish may pass the dam, but few are entrained into the canal. Thus the mark recapture data may not be representative of actual conditions on non-sampled days. To overcome this problem the Yakama Nation developed predictive models, relating estimates from the release days to predictor variables that are available on a daily basis. The model and daily predictor variables are used to generate entrainment estimates for days when no releases were made (Neeley 2002).

Canal Entrainment Rate

The predicted entrainment rate (*er*) of juveniles into Chandler Canal is based on a function of the canal diversion rate (*cd*); the percentage of daily river flow that is diverted into the canal (Neeley 1998). Derivation of this logistic expression (Figure 2.7) for *er* is described in following section (Development of a Fish Screen Survival Index).

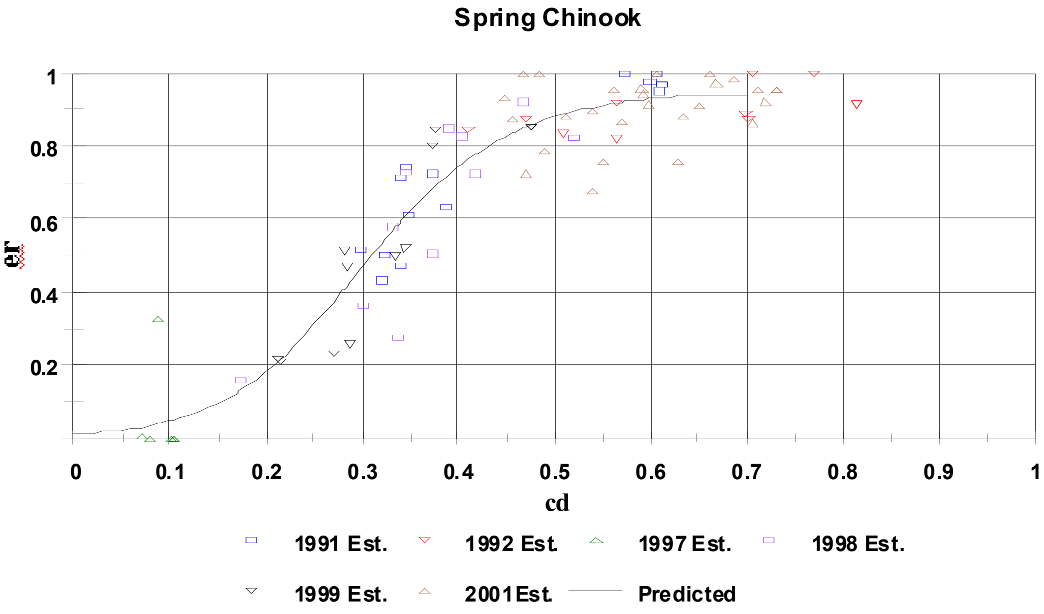


Figure 2.7. The proportion of spring chinook migrants passing Prosser dam that enter (are entrained into) Chandler Canal. The entrainment relationship is based on the proportion of mainstem Yakima flow diverted daily (cd) into Chandler Canal (*Source*: Chandler Certification Report. 2002).

Canal Survival Rate:

Figure 2.8 illustrates the precipitous decline in canal survival rates for spring chinook smolts post May 20th. Canal survival rates become 1 when the canal becomes closed following the irrigation season and mainstem flow is no longer diverted into the canal.

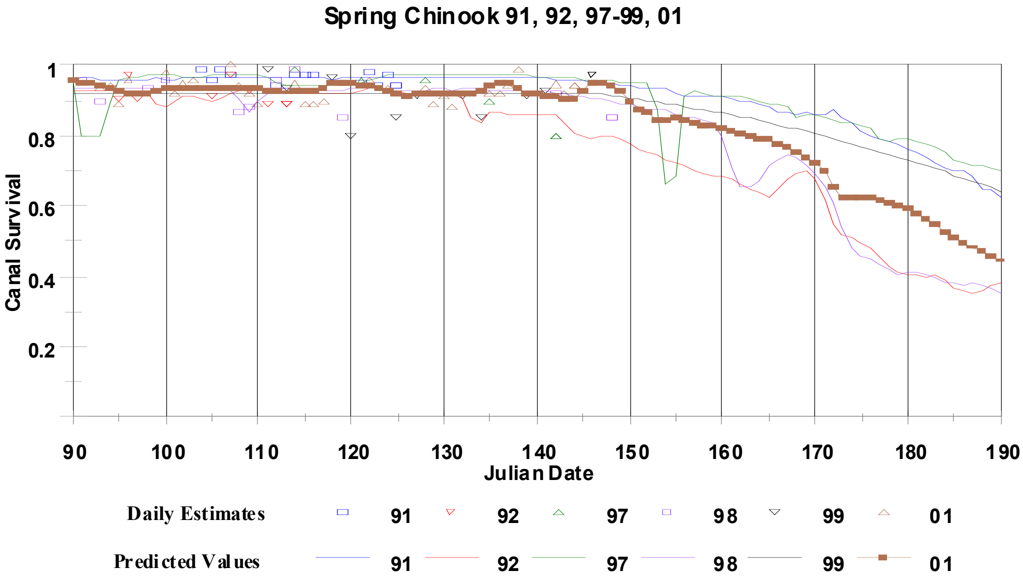
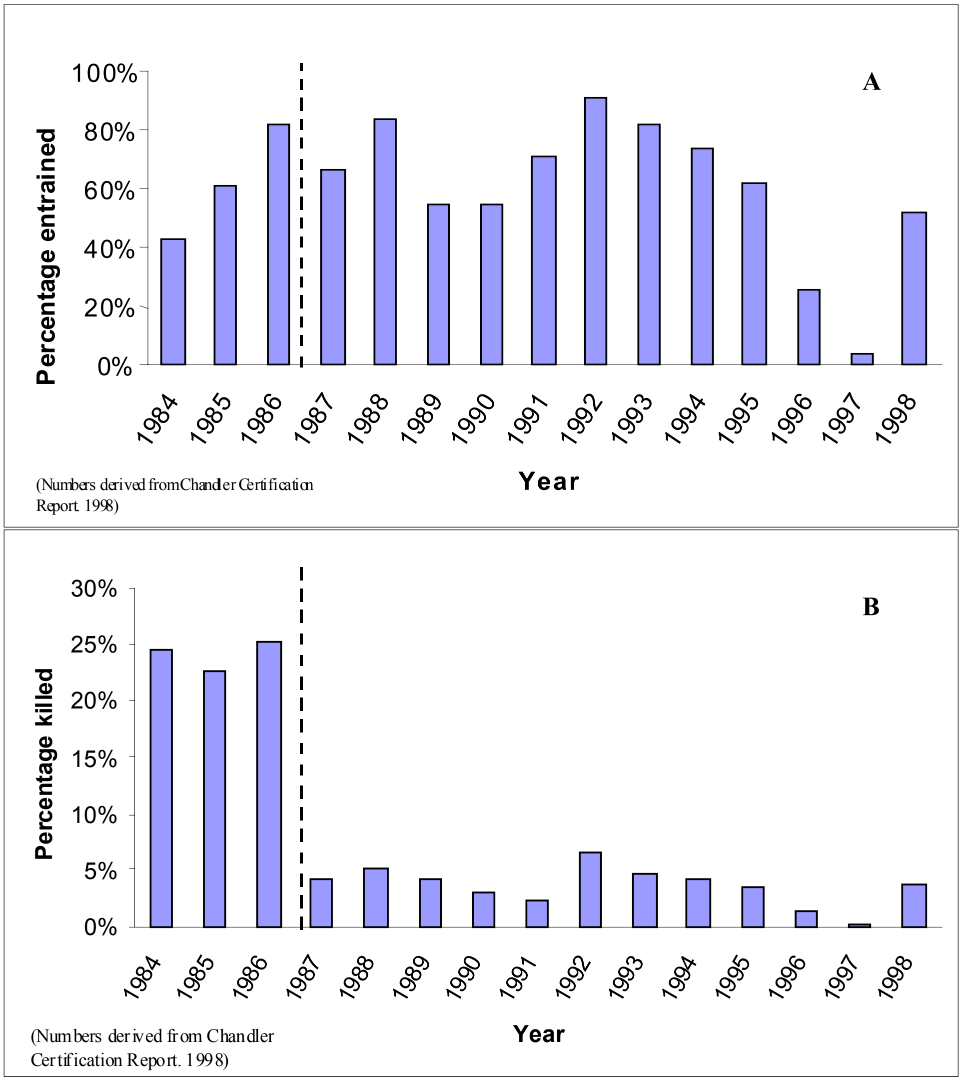


Figure 2.8. Daily estimates of Chandler canal survival (1991–2001) and logistic predicted canal survival rates (*Source*: Chandler Certification Report. 2002).

Base estimates of canal survival rates for juveniles at Chandler Canal in the years preceding installation of the new Phase I screens are considerably lower than in post installation years. Chandler canal daily survival rates in early spring of 1984, 1985 and 1986 (the first complete years for which this data is available) were estimated at 0.47, 0.71 and 0.75 respectively (Neeley 1998), whereas in the years after the Phase I screen installation daily canal survival rates in early spring have consistently been estimated at 0.92 or greater (Neeley 1998, 2002).

Figure 2.9 illustrates that while installing the new fish screen facilities at Chandler canal had little effect on the numbers of fish entrained in the canal (expressed as the proportion of the year's smolt run entrained within Chandler canal) it had a major effect on mortality rates occurring within the canal. The Chandler Canal Certification Reports indicate that up to 25% of the migrating spring smolt population may have been killed in some years at Chandler prior to construction of the Phase I screen, while mortality rates drop well below 5% for most years after construction.



(Numbers derived from Chandler Certification Report. 1998)

(Numbers derived from Chandler Certification Report. 1998)

Figure 2.9. Estimated percentages of annual chinook smolt migration entrained (A) and killed (B) at Chandler Canal. Dashed line indicates the year of new Phase I fish screen construction.

2.4 Development of a fish screen survival index

The annual estimates of smolt outmigrant numbers, canal entrainment and canal survival at Chandler Canal documented by the Yakama Nation provide the opportunity to create a broader index of fish screen survival that might be applied to the other four major canals targeted within the Yakima Subbasin. Unfortunately, comparable information on smolt passage or entrainment are not available for other canals, requiring assumptions to be made that general entrainment and survival relationships from Chandler can be applied to the other canals. Consultation with Yakama Nation Fisheries biologists suggested that given the lack of any useable information to the contrary, we could justifiably make this assumption for the Wapato, Sunnyside and Wapatox canals. However it was felt that with the generally better configuration of Roza canal (in terms of alignment with the mainstem and smaller canal length), entrainment at Roza would most likely be less than for Chandler and survival rates likely higher, though this difference has not been empirically measured. We therefore assumed that survivals at Roza would only be half as much as would be calculated based on Chandler survival and entrainment rate relationships (Joel Hubble, pers. obs.). That is, if we originally estimated that 100 juveniles would be killed at Roza Canal on that day, we reduced our estimate to only 50 juveniles killed.

The estimates of daily smolt outmigration, daily canal entrainment and canal survival derived for Chandler canal allowed development of a broader fish screen survival index that could be applied to each of the canals through the following steps:

1. Daily estimates of smolt emigration at Chandler provide an estimate of the proportion of that year's total smolt run passing by Chandler Canal on any particular day of the run. By back timing the smolt run by 3 days to both Wapato and Sunnyside, and by 4 days to Roza and Wapatox (based on average smolt run times between the canals suggested by Joel Hubble, pers. obs.) and also by assuming generally equal smolt proportions for Upper Yakima and Naches stocks running each day, it is also possible to estimate the proportion of the total smolt run passing each of the other four canals (Wapato, Sunnyside, Roza and Wapatox) on any day of the year.
2. Flow information from USGS and USBOR gauging stations (available for download from the Internet) located at each of the canals and at adjacent Yakima and Naches River mainstem sites allowed an estimate of daily mainstem flow diverted (*cd*) into any of the other four canals on any day during the smolt run. We then applied the logistic entrainment rate algorithm developed for Chandler Canal in relation to *cd* (assuming that a similar relationship at all canals) to estimate the proportion of each day's smolt run that would be entrained within each of the other four canals. We then extended this procedure to cover the entire year's smolt run.
3. The daily survival rates estimated at Chandler canal in each year were used to estimate the survival of entrained fish at each of the other canals on any particular day. Greatly improved canal survival rates were estimated at Chandler canal from the time of Phase I fish screen installation in 1987. However, the situation is complicated by the fact that new fish screens were installed earlier at Sunnyside and Wapato (1985) than at Chandler (1987), and were installed later at Roza and Wapatox (1988 and 1993 respectively). Consequently the yearly survival rate regressions developed at Chandler cannot always be applied directly to the other canals by years, as this could result in applying pre-screen survival functions in post-screening situations, and vice-versa. Instead we adopted a mixed approach where we matched pre- or post-annual Chandler canal survival functions to each canal as new screens came into operation. For years/screening that differed from the situation at Chandler we applied the average pre-screen or average post-screen survival relationship from Chandler, depending on which relationship would be most appropriate to use at any particular canal in any particular year.

4. The derived information described above allowed estimation of the number of chinook smolts killed in each canal on day j of the smolt run and (by extrapolation) the proportion of the year's total smolt run that is killed each day in each canal using the equation:

$$CANALMORT_j = PROPSM_j * ER_j * (1 - CS_j) \qquad \text{(Eq. 2)}$$

where:

$CANALMORT_j$ = proportion of the annual smolt run killed at the canal on day j;
$PROPSM_j$ = proportion of the annual smolt run passing the canal on day j;
ER_j = daily smolt entrainment rate into the canal;
CS_j = daily smolt survival rate at the canal

We also assumed that the proportion of presmolts in the total chinook run at Rosa, Wapato and Sunnyside is the same as that captured as winter outmigrants at Prosser canal (average = 23.5% between 1982 and 1999, Yakima River smolt trap). We assumed that this proportion of the chinook population experiences no canal related mortality as the canals are generally not in operation during those winter months. The temporal distribution of spring smolts (76.5% of total emigration) is divided across the days of the spring smolt run in the same proportions as determined at Prosser but backtimed to the other Yakima canals as described above. For Wapatox canal a more convoluted assumption was used as most of the fall outmigrant (presmolts) population in the Naches River migrates in the month of November and represents 60% of the total annual juvenile population (Joel Hubble pers. obs.). The remaining 40% of the migration represents smolts passing in the months of March, April, May and June (Yakima Subbasin Salmon and Steelhead Production Plan 1990). We assumed that the fraction of the smolts (40%) was divided across the days of the spring smolt run in the same proportions as determined at Prosser (but backtimed by 4 days to Wapatox). Both presmolts and smolts may be killed during passage by Wapatox as the canal is in operation year round for power production.

The reverse of the canal mortality rates is the proportion of the year's smolt run that survives passage by each canal, a proportion that changes each year at each canal with flow and smolt passage timing, and construction of fish screen installation. Appendix 2.B provides a detailed graphical and textual description of the algorithm components required to estimate the annual run survivals at the four Upper Yakima canals. Calculation of smolt survival at Wapatox canal on the Naches River is somewhat more complicated as fish entrained here historically (pre-new screen) could also be drawn into the power generation facilities. The Yakima River Subbasin Salmon and Production Plan estimated that (on average) 36% of entrained smolts could pass through the mesh of the old fish screens and be pumped through the turbines of the hydro-generation plant. It was estimated that approximately 88% of these smolts would subsequently be killed in the Wapatox turbines, while 12% would survive and be passed back to the mainstem to continue their downward migration. These additional elements of mortality/survival at Wapatox Canal are outlined in Appendix 2.C. After installation of new fish screens at Wapatox in 1993, it is assumed that the number of smolts entrapped behind the screens and pumped through the turbines was zero.

The product of the individual canal survival proportions as the fish move progressively down river represents our annual Fish Screen Survival Index (*Sc*) used in our regression models, computed for both Upper Yakima and Naches/American spring chinook stocks (Table 2.3).

Table 2.3. Annual canal survivals for spring chinook presmolt and smolt runs past all major Yakima River irrigation canal diversions (Roza, Wapato, Sunnyside and Chandler canals **Upper Yakima River**) and (Wapatox, Wapato, Sunnyside and Chandler canals for **Naches River**). The **Fish Screen Survival Index (Sc)** is the final product of the individual canal survival proportions as the fish move progressively down river. Sc is based on information from Chandler Canal on smolt passage and is adjusted to account for the 23.5% (on average) of the juvenile population that passes through the Upper Yakima system as pre-smolts when the canals are not in operation. Italicized years show survival at each canal after screen installation.

	Canal survival proportions (pre-smolts and smolts)					Cumulative Survival (*Sc*)	
Year	1 Roza	2 Wapato	3 Sunnyside	4 Chandler	5 Wapatox	*Sc* - Upper Yakima (1*2*3*4)	*Sc* - Naches (5*2*3*4)
1982	0.88	0.84	0.90	0.79	0.95	**0.52**	**0.57**
1983	0.83	0.92	0.93	0.89	0.70	**0.63**	**0.53**
1984	0.82	0.84	0.90	0.81	0.81	**0.51**	**0.50**
1985	0.92	*0.98*	*0.98*	0.83	0.67	**0.73**	**0.53**
1986	0.89	*0.97*	*0.97*	0.81	0.79	**0.68**	**0.60**
1987	0.91	*0.98*	*0.98*	*0.96*	0.78	**0.84**	**0.73**
1988	*0.99*	*0.98*	*0.98*	*0.96*	0.91	**0.91**	**0.84**
1989	*0.99*	*0.99*	*0.99*	*0.97*	0.72	**0.93**	**0.67**
1990	*0.99*	*0.99*	*0.99*	*0.98*	0.73	**0.94**	**0.69**
1991	*1.00*	*1.00*	*1.00*	*0.98*	0.75	**0.97**	**0.73**
1992	*0.99*	*0.99*	*0.99*	*0.95*	0.74	**0.92**	**0.69**
1993	*0.99*	*0.99*	*0.98*	*0.96*	*1.00*	**0.92**	**0.93**
1994	*0.99*	*0.98*	*0.98*	*0.97*	*0.99*	**0.92**	**0.92**
1995	*0.99*	*0.99*	*0.99*	*0.97*	*1.00*	**0.95**	**0.96**
1996	*0.99*	*1.00*	*1.00*	*0.99*	*0.99*	**0.97**	**0.97**
1997	*0.99*	*1.00*	*1.00*	*1.00*	*0.98*	**0.99**	**0.98**
1998	*0.97*	*0.99*	*0.99*	*0.97*	*0.99*	**0.92**	**0.94**
1999	*0.99*	*0.99*	*0.99*	*0.97*	*0.98*	**0.93**	**0.95**

2.5 Covariates in the regression models

Sc is an approximate index of the effect of the fish screening actions at improving juvenile survival across the major irrigation/power canals in the subbasin over time. Uncertainties in this index include estimation errors in the procedures used at Chandler Canal for determining entrainment and survival rates, and extrapolation errors in applying the Chandler survival relationships to the other canal systems where different processes might occur. We used the sequence of values for *Sc* as an independent variable in our inter-basin comparisons of Ricker-type-stock-recruitment models (Yakima stocks as treatment, Wenatchee or Warm Springs stocks as controls) to assess if our improving fish screen survival was correlated with observed trends in fish productivity (adult recruits/spawner or smolts/spawner).

There are however many factors other than screen survival which can affect stock productivity, particularly for an analysis of adult recruits/spawner (R/S). At a workshop convened to discuss these issues, agency biologists suggested such factors as changing predation pressures (birds and bass), lower river flows and temperatures experienced by migrating smolts within the subbasin, differences in mainstem dam spill, and changing ocean experienced by adult salmon. Each of these factors could have serious and variable impacts on smolt or adult survival that could impede our ability to discern an overall effect of improved fish screening. These potentially confounding factors were captured for both the

Yakima treatment basin and the Wenatchee and Warm Springs control basins where appropriate, and included as covariates in our regression models (Table 2.4).

Table 2.4. Environmental covariates included in the regression models developed for comparative analyses of spring chinook productivity in the Yakima Subbasin and control subbasins (Wenatchee or Warm Springs). Included is the expected timing of the effect on chinook life history and the relevant productivity metric for covariate analysis. The common year effect parameter is intended to account for a composite of common factors that affect all stocks within a given year such as regional changes in terrestrial climate and/or changes in marine survival rates. The stock covariate represents a stock specific Ricker *a* term, and captures the expected differences in natural productivity (recruits-per-spawner) between each subbasin at low numbers of fish. R/S = adult recruits/spawner, Sm/S = smolts/spawner.

Covariate	Expected Timing of Effect	Data Source	Productivity Metric
[1]Oyster Condition Index (OCI) (index for ocean productivity)	Annual	University of Washington	R/S
[1]Coastal Upwelling Index (CUI) (alternative index for ocean productivity	Annual	Pacific Fisheries Environmental Laboratory website	R/S
Common Year Effect*	Annual	Dummy coded	R/S
Stock**	Annual	Dummy coded	R/S
Avg. lower river flows (Q)	Smolt migration (March- July)	USGS and USBOR website	R/S, Sm/S
Avg. lower river temperatures (T) (air temperatures used as surrogate)	Smolt migration (March- July)	NOAA's National Climatic Data Center website	R/S, Sm/S
Avg. Columbia mainstem dam spills (M)	Smolt migration (March- July)	Columbia Fish Passage website i) McNary Dam (Yakima stocks) ii) Priest Rapids Dam (Wenatchee stock)	R/S
Fish Screening Survival Index (Sc)	Pre-smolt and smolt migration (Nov. – July)	Chandler Canal Certification Reports	R/S, SM/S

[1] Derivations of these ocean productivity indices are described in Hare and Mantua, 2000.

The covariates we used are the most likely factors affecting chinook survival and productivity, but are by no means the only factors one could explore. Other changes likely have occurred in the watersheds over the period of interest that are not captured by these covariates (e.g., site specific habitat changes). However, agency biologists believe that such changes were minor and likely had relatively small impacts on survival. In the Yakima Subbasin, hatchery and supplementation operations only began in 1997 (Joel Hubble, pers. obs.), at the very end of the period studied here, and therefore are not a confounding influence on screening effects. Hatchery juvenile releases and adult returns are in any case separately accounted for by the Yakama Tribe, so that data used in our analyses represented only wild and natural production.

2.6 Candidate models

Candidate models were structured as stock-recruitment, regression models with stock specific Ricker *a* values and a selection of theorized environmental covariates. We developed three base-case statistical log-linear models to assess changes in chinook productivity at the subbasin scale using two measures of stock productivity: ln(recruits/spawner) or ln(smolts/spawner).

(A) Adult Recruits/Spawner

Model 1:

$$\ln(R/S)_{t,i} = a_i - b_iS_t + cQ_{t+2,i} + dO_{t+2} + eM_{t+2} + fSc_{t+2} + gT_{t+2} \qquad \text{(Eq. 3)}$$

where:

a and b are Ricker growth model parameters,
t = year index (i.e. t = brood year, t+2 = smolt migration)
i = stock index (1=Wenatchee, 2=U. Yakima, 3=Naches/American)
R = recruits back to the mouth of the river system that originated from the spawners in year t (4, 5 and 6 year olds, 3-year old jacks (premature spawners) are excluded)
S = spawners which spawned in year t (excluding jacks)
Q = lower river flow to which smolts are exposed,
O = Oyster Condition Index (OCI) or Coastal Upwelling Index (CUI) to which smolts are exposed (alternative indicators of ocean productivity)
M = mainstem dam spill to which smolts are exposed
Sc = fish screen survival index to which smolts are exposed
T = lower river temperatures to which smolts are exposed

Model 2:

Similar to Model 1, but ocean productivity indicators are replaced by a measure of common years, δ_t, (as in Deriso et al. 2001). Each brood year's δ_t reflects relative changes in ln(R/S) that are common across all stocks in a given year; the mean value of δ_t across all years is zero.

$$\ln(R/S)_{t,i} = a_i - b_iS_t + cQ_{t+2,i} + eM_{t+2} + gSc_{t+2} + hT_{t+2} + \delta_t \qquad \text{(Eq. 4)}$$

(B) Smolts/Spawner

Model 3 examines smolts (Sm) instead of adult recruits as a measure of subbasin productivity, and therefore does not require covariates to explain variability that occurs after smolts are counted at Prosser dam (i.e. Q, O, M, δ):

$$\ln(Sm/S)_{t,i} = a_i - b_iS_t + cQ_{t+2,i} + gSc_{t+2} + hT_{t+2} \qquad \text{(Eq. 5)}$$

For **Model 3** which deals with Sm/S for an aggregate Yakima stock (Upper Yakima and Naches/American smolt combined), it was necessary to compute a spawner weighted average of the Screening Index (Sc_{Yakima}) for the two stocks:

$$Sc_{YAK,\ t+2} = (Sc_{UY,\ t+2} * S_{UY,\ t} + S_{NA,\ t+2} * S_{NA,\ t}) / (S_{UY,\ t} + S_{NA,\ t}) \qquad \text{(Eq. 6)}$$

where:

Sc_{YAK} = combined fish screen survival index for Upper Yakima and Naches stocks
Sc_{UY} = fish screen survival index for Upper Yakima stock
Sc_{NA} = fish screen survival index for Naches stock
S_{UY} = number of spawners in Upper Yakima River
S_{NA} = number of spawners in Naches River

Three of the canal projects (Wapato, Sunnyside, Chandler) are passed by both stocks; weighting has no effect on these survival values. However, since the Upper Yakima generally has more spawners than the Naches/American, improvements in the survival at Roza Canal on the Upper Yakima have a greater effect on Sc_{YAK} than do changes at Wapatox on the Naches/American. For Model 3 the stock index (i) is 1 = Yakima, 2 = Warm Springs.

Linear models describing stock-recruitment were generated using SYSTAT 9 software (SYSTAT 1999).

Model Selection

We used an information-theoretic approach (Burnham and Anderson 1998) for selection of the models that best explained the observed trends in R/S or Sm/S in our compared watersheds. We did so because this approach gives a formal accounting of the relative plausibility of the estimated models. Deriso et al. (2001) and Thompson and Lee (2002) have applied similar information-theoretic approaches to chinook spawner-recruit models, while Paulsen and Fisher (in review) have used this approach to explore habitat factors affecting survival of juvenile chinook.

The information-theoretic approach is described at length in Burnham and Anderson (1998). A concise outline of the steps involved is provided in Paulsen and Fisher (in review) and is reproduced here:

> "The method consists of the following steps: 1) Identify a candidate set of models *a priori*, using information on scientifically plausible relationships between candidate independent variables and the dependent variable of interest; 2) Estimate the regression models using the same dataset; 3) For each model, calculate the Akaike Information Criterion (AIC), (Aiaike 1973) corrected for the number of estimated parameters; 4) Among the candidate models, select the model with the lowest AIC. Subtract the lowest AIC from each of the candidate models, yielding a "delta" which will be zero by definition for the model with the lowest AIC; and 5) Calculate "AIC weights" for each model, using a simple exponential function of the deltas. The weights are normalized to sum to one, and their values can be interpreted as the relative probability of each model, given the data and the set of candidate models."

AIC is a relative ranking statistic. AIC values are interpreted in terms of the magnitude of the differences among candidate models rather than the magnitude of any particular value (Thompson and Lee 1999). It should be noted that calculated AIC values are specific to the data set that is used to compute them, and hence those computed from different data sets are not comparable.

For our analyses we have two distinct biological datasets relating to spring chinook productivity that can be explored within the subbasins: adult recruits/spawner and smolts/spawner. AIC comparisons of predictor variables (*Sc* and a range of additional covariates) are thus interpreted separately for these two distinct but related biological datasets.

The AIC statistic is defined as:

$$\mathrm{AIC} = n \ln(\mathrm{RSS}/n) + 2k, \qquad \text{(Eq. 7)}$$

where n is the number of observations, ln is the natural logarithm, RSS is the residual sum of squares and k is the number of estimable parameters in the model. When the number of observations is small ($n/k < 40$) it is recommended that a small sample adjustment (AICc) be used (Hurvich and Tsai 1989; Thompson and Lee 1999). Given the limited number of observations within our analyses we adopted the AICc statistic for our model comparisons. The AICc statistic is defined as:

$$AICc = AIC + 2k(k + 1)/(n - k - 1), \quad \text{(Eq. 8)}$$

and the "delta" AICc weights are calculated as:

$$\Delta AICc\ weight = \frac{e^{(-\Delta AIC_i/2)}}{\sum_{i=1}^{m} e^{(-\Delta AIC_i/2)}} \quad \text{(Eq. 9)}$$

where $\Delta AICc_i$ is the ΔAICc value for the ith model in a set of m candidate models. Thus the ΔAICc weights sum to 1 (Thompson and Lee 1999).

2.7 Results

2.7.1 Observed correlations among variables

Correlations between the natural logs of adult recruits/spawner in the Upper Yakima, Naches and Wenatchee subbasins and continuous independent variables used in our analyses are shown in Table 2.5. A key pattern evident from the matrix is that ln(recruits/spawner) is highly and positively correlated between each of the three subbasins (Upper Yakima, Naches and Wenatchee), with r values of 0.62, 0.75 and 0.91 between the three subbasins pairs. This strong correlation is further illustrated in Figure 2.10 where it is apparent that a changing recruits/spawner relationship is being tracked very similarly across the three subbasins over time.

Table 2.5. Pearson correlations between ln(recruits/spawner) and independent variables in the Yakima Basin (n = 15) from Model 1. All relevant correlations of approximately 0.5 or greater are bolded.

	LRSW	LRSUY	LRSN	SW	SY	SN	QW	QY	OCI	CUI	MPR	MMCN	ScUY	ScNA	MTW	JTW	MTY	JTY
LRSW	1.00																	
LRSUY	**0.91**	1.00																
LRSN	**0.62**	**0.75**	1.00															
SW	-0.16	-0.06	0.22	1.00														
SY	**-0.55**	**-0.53**	-0.44	0.35	1.00													
SN	-0.33	-0.32	**-0.58**	0.13	**0.73**	1.00												
QW	**0.59**	**0.52**	0.23	-0.30	-0.53	-0.18	1.00											
QY	**0.70**	**0.62**	0.34	-0.49	-0.74	-0.42	**0.89**	1.00										
OCI	0.21	0.24	0.33	-0.24	-0.16	-0.20	0.12	0.23	1.00									
CUI	-0.02	0.04	0.11	-0.02	-0.51	-0.22	0.13	0.27	-0.13	1.00								
MPR	**0.66**	**0.52**	0.13	**-0.61**	-0.61	-0.33	**0.78**	**0.86**	-0.01	0.10	1.00							
MMCN	**0.60**	**0.50**	0.24	**-0.59**	-0.72	-0.46	**0.76**	**0.95**	0.26	0.32	**0.87**	1.00						
ScUYAK	-0.16	-0.23	-0.71	-0.44	0.15	0.43	0.32	0.12	-0.17	-0.30	0.36	0.12	1.00					
ScNA	0.01	-0.05	-0.45	**-0.60**	0.03	0.22	0.41	0.37	0.32	-0.27	0.42	0.44	**0.75**	1.00				
MTW	-0.49	-0.46	-0.06	0.23	0.13	-0.13	-0.16	-0.34	0.03	-0.06	-0.45	-0.44	0.01	-0.10	1.00			
JTW	-0.35	-0.19	0.12	0.39	-0.03	-0.16	-0.31	-0.39	-0.23	0.47	-0.46	-0.47	-0.30	-0.58	**0.52**	1.00		
MTY	**-0.52**	**-0.52**	-0.24	0.03	0.18	-0.07	-0.04	-0.23	0.00	-0.09	-0.25	-0.27	0.26	0.18	**0.93**	0.34	1.00	
JTY	-0.31	-0.16	0.01	0.31	0.02	-0.15	-0.15	-0.24	-0.09	0.39	-0.31	-0.29	-0.05	-0.23	**0.51**	**0.86**	0.48	1.00

Variable descriptions:

LRSW = natural log of adult recruits/spawner for Wenatchee River spring chinook estimated for the smolt brood year (BY)
LRSUY = natural log of adult recruits/spawner for Upper Yakima River spring chinook estimated for the smolt brood year (BY)
LRSN = natural log of adult recruits/spawner for Naches River spring chinook in the smolt brood year (BY)
SW = number of spring chinook adult spawners in the Wenatchee River in the smolt brood year (BY)
SUY = number of spring chinook adult spawners in the Upper Yakima River in the smolt brood year (BY)
SN = number of spring chinook adult spawners in the Naches River in the smolt brood year (BY)
QW = average daily river flow (cfs) in the lower Wenatchee River for the migratory time period of March 01 to June 30 measured during the smolt migration year (BY + 2)
QY = average daily river flow (cfs) in the lower Yakima River for the migratory time period of March 01 to June 30 measured during the smolt migration year (BY + 2)
OCI = average Oyster Condition Index measured at Stony Point, Washington for the smolt migration year (BY + 2)
CUI = average Coastal Upwelling Index for the smolt migration year (BY + 2)
MPR = average daily Columbia mainstem dam spill (kcfs) at Priest Rapids Dam measured during the time period of March 01 to June 30 during the smolt migration year (BY + 2)
MMCN = average daily Columbia mainstem dam spill (kcfs) at McNary Dam measured during the time period of March 01 to June 30 during the smolt migration year (BY + 2)
MTW = average daily maximum May air temperature in the lower Wenatchee River sub-basin determined for the smolt migration year (BY + 2)
JTW = average daily maximum June air temperature in the lower Wenatchee River sub-basin determined for the smolt migration year (BY + 2)
MTY = average daily maximum May air temperature in the lower Yakima River sub-basin determined for the smolt migration year (BY + 2)
JTY = average daily maximum June air temperature in the lower Yakima River sub-basin determined for the smolt migration year (BY + 2)
ScUY = cumulative Fish Screen Survival Index for Upper Yakima stock determined for the smolt migration year (BY + 2)
ScNA = cumulative Fish Screen Survival Index for Naches stock determined for the smolt migration year (BY + 2)

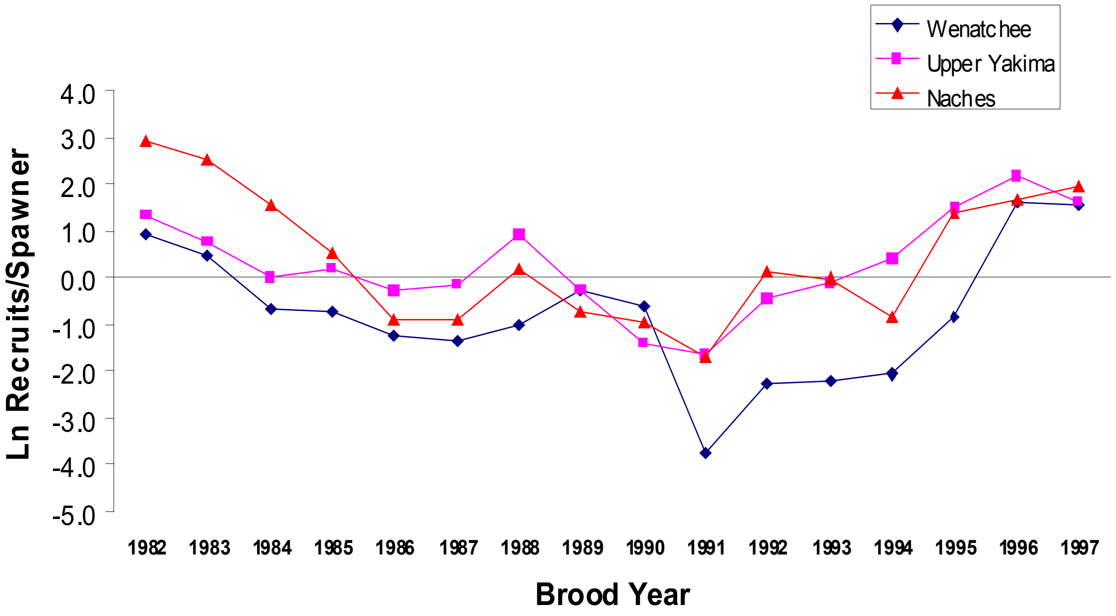


Figure 2.10. Recruits/spawner relationships for Upper Yakima, Naches and Wenatchee River spring chinook between brood years 1982 and 1997.

Other correlations of note in Table 2.5 are the positive and generally strong correlations across the subbasins among:

1. ln(recruits/spawner);
2. lower river water flows in the smolt migration year; and
3. amounts of water spilled at the Columbia mainstem dams in the smolt migration year.

Generally strong negative correlations are also evident between subbasin ln(recruits/spawner) and:

1. lower river water temperatures (especially during May) in the smolt migration year; and
2. spawner abundances in the brood year.

These correlations would suggest that differences in water quality and volume experienced by migrating smolts has an appreciable and detectable effect on overall measures of subbasin productivity as indexed by recruit/spawner estimates. The strong negative correlations between ln(recruits/spawner) and brood year spawner numbers in the Upper Yakima and Naches might additionally imply density dependent effects of spawner abundance on smolt production, though there was no significant correlation within the Wenatchee (possibly due to low spawner abundances). Generally, each of these correlations are in the direction that would be expected given our presumed understanding of factors affecting spring chinook life history, and justify their inclusion as covariates in our analysis of fish screening effects. Strong positive correlations evident between measures of flow and temperature for the Yakima and Wenatchee Rivers (Table 2.5) also provides additional justification for our use of the Wenatchee as a control subbasin: although the actual magnitudes of flow and temperature may/may not be different in the two subbasins, their patterns of change in these two parameters over time appear tightly linked.

Correlations in Table 2.5 that were not as expected relate to our measures of ocean productivity and, more critically for our analyses, our derived index of fish screening survival (*Sc*). Our two alternative indices of ocean productivity (OCI and CUI) show non-significant weakly positive correlations with ln(recruits/spawner), (r = 0.04 to r = 0.33 across subbasins, with r = -0.02 for CUI with recruits/spawner in the Wenatchee). This could indicate either that: 1) ocean productivity has not been a major factor affecting recruitment to these subbasins; or 2) our measures of ocean productivity were too crude to accurately represent changes in the nearshore systems that might effect fish survival. The second hypothesis is more likely, especially given that improvements in ocean conditions have been cited by NOAA Fisheries biologists (NOAA 2003) as a major contributor to the recent marked escapement increases for Columbia Basin chinook stocks (a data series beyond the temporal horizon of our analyses). Numerous studies have demonstrated strong relationships between overall salmon productivity indicators and ocean conditions (Mantua et al. 1997; Hare et al. 1999; Beamish et al. 2000; Welch et al. 2000).

As we expected from the outset that our measures of ocean productivity might not be tightly linked to fish productivity measures within the subbasins, we developed Model 2, which alternatively incorporated a common “year-effect”. The year-effect parameter would presumably better capture a range of poorly quantifiable factors that influence chinook survival in the marine environment, or freshwater factors not captured by other covariates.

A surprising result was the absence of any positive correlation between *Sc* and the annual recruit/spawner estimates (Table 2.5), especially given the marked improvement in canal survivals after Phase I screens were installed (Table 2.3). The correlations between *Sc* and subbasin ln(recruits/spawner) numbers were instead negative, and in the case of the Naches Subbasin quite strongly negative (r = -0.45). There are several possible reasons for this result, which we explore in the Discussion.

As in our comparison of recruits/spawner relationships in the Yakima and Wenatchee, ln(smolts/spawners) (Table 2.6) was positively correlated between the Yakima and Warm Springs subbasins. The strength of this correlation (r = 0.36) was, however, much weaker than was evident for the earlier Yakima/Wenatchee subbasin ln(recruit/spawner) comparisons; the data are illustrated in Figure 2.11. Similar to our recruit/spawner analysis there was also a fairly strong negative correlation between number of spawners and ln(smolts/spawner), indicative of density dependent effects in both the Yakima and Warm Springs subbasins. Both subbasins showed positive correlations between ln(smolts/spawner) and lower river flow (r = 0.42 and r = 0.53 for Yakima and Warm Springs respectively) as might have been expected, and weakly negative or non-existent correlations with lower river air temperatures. Lower river flow and monthly air temperatures showed strong correlations between the Yakima and Warm Springs subbasins (r = 0.70 for flow, and r = 0.89 and r = 0.93 for May and June temperatures respectively), providing some support for our use of Warm Springs as a quasi control. The correlation between ln(smolts/spawner) and *Sc* was, as in our recruits/spawner analysis, weak and negative. Possible reasons for this are considered in the Discussion.

Table 2.6. Pearson correlations between ln(smolts/spawner) and independent variables in the Yakima Basin (n = 18). All relevant correlations of approximately 0.5 or greater are bolded.

	LSSY	LSSWS	SY	SWS	QY	QWS	ScY	MTY	JTY	MTWS	JTWS
LSSY	1.00										
LSSWS	0.36	1.00									
SY	**-0.67**	-0.46	1.00								
SWS	-0.18	**-0.49**	0.42	1.00							
QY	0.42	0.44	-0.46	-0.43	1.00						
QWS	0.31	**0.53**	-0.40	-0.38	**0.70**	1.00					
ScY	-0.31	0.20	0.06	-0.70	0.22	0.10	1.00				
MTY	-0.27	-0.21	0.00	-0.09	-0.27	-0.13	0.27	1.00			
JTY	-0.10	0.03	0.00	0.33	-0.16	-0.02	-0.07	0.36	1.00		
MTWS	-0.07	-0.07	-0.19	-0.28	-0.13	-0.09	0.17	**0.89**	0.28	1.00	
JTWS	0.16	0.15	-0.29	0.13	0.00	0.08	-0.14	0.32	**0.93**	0.32	1.00

Variable descriptions:

LSS = natural log of smolts/spawner for Yakima River spring chinook estimated for the smolt brood year (BY)
LSSWS = natural log of smolts/spawner for Warm Springs River spring chinook estimated for the smolt brood year (BY)
SY = number of spring chinook adult spawners in the Yakima River (Upper Yakima and Naches/American stocks combined) in the smolt brood year (BY)
SWS = number of spring chinook adult spawners in the Warm Springs River in the smolt brood year (BY)
QY = average daily river flow (cfs) in the lower Yakima River for the migratory time period of March 01 to June 30 measured during the smolt migration year (BY + 2)
QWS = average daily river flow (cfs) in the lower Warm Springs River for the migratory time period of March 01 to June 30 measured during the smolt migration year (BY + 2)
MTY = average daily maximum May air temperature in the lower Yakima River sub-basin determined for the smolt migration year (BY + 2)
JTY = average daily maximum June air temperature in the lower Yakima River sub-basin determined for the smolt migration year (BY + 2)
MTWS = average daily maximum May air temperature in the lower Warm Springs River sub-basin determined for the smolt migration year (BY + 2)
JTWS = average daily maximum June air temperature in the lower Warm Springs River sub-basin determined for the smolt migration year (BY + 2)
ScY = cumulative pooled Fish Screen Survival Index for Yakima stocks determined for the smolt migration year (BY + 2)

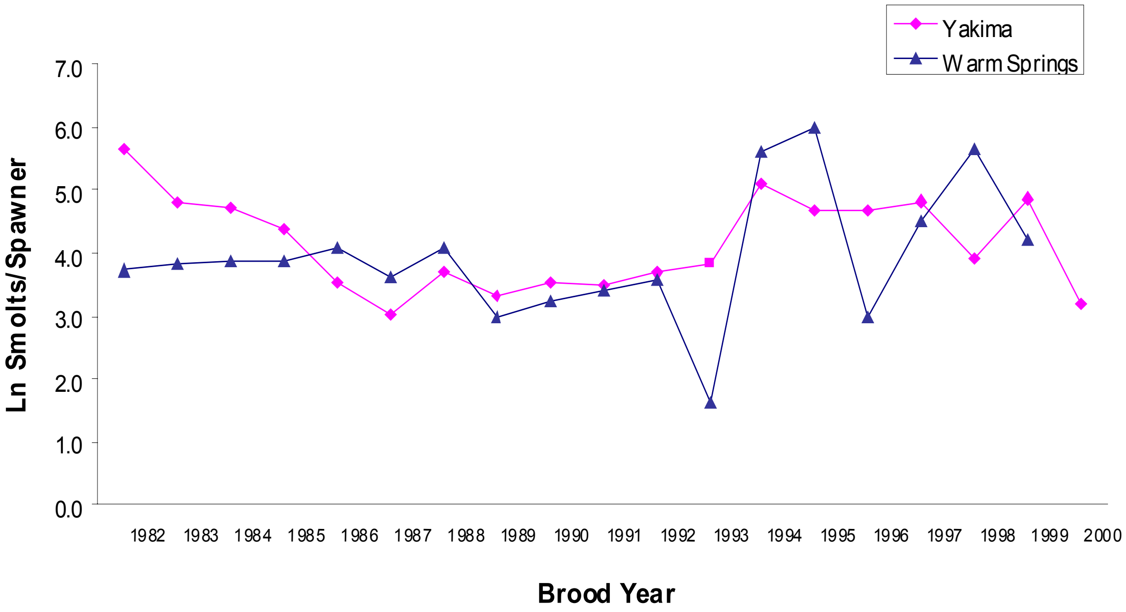


Figure 2.11. Smolts/spawner relationships for Yakima and Warm Springs spring chinook between brood years 1982 and 2000. r = 0.36.

2.7.2 Subbasin models

We developed 20 log-linear models exploring different combinations of covariates that might best explain variation in ln(recruits/spawner) in Yakima and Wenatchee subbasins over the available period of record (brood years 1982–1997) (Table 2.7). All models contained *Sc*, our parameter of prime interest in this analysis and employed separate Ricker *a* terms (denoted by the STOCK parameter). Only two models (bolded in Table 2.7) had the overwhelming majority of the AICc weighting (0.58 and 0.38 respectively), accounting for 96% of the probability among the models estimated. All the other models evaluated seem highly implausible; none had a probability exceeding 0.01 (Table 2.8). Both of the high probability models include a year effect common to all stocks (YR), while the second includes a measure of spawner abundance (S). Both have similar high R^2 values (Table 6). A model containing only the *Sc* term without additional covariates was among the lowest ranked models and had an R^2 of only 0.19.

Of 11 log-linear models we developed to explain ln smolts/spawner (Table 2.8) only two models (bolded in Table 2.8) have the overwhelming majority of the AICc weighting (0.64 and 0.22 respectively), accounting for 86% of the probability among the models estimated. Both these models include lower river flows (Q), while the highest ranked also includes a measure of spawner abundance (S). Explanatory value of the models is only moderate, with the highest ranked model having an R^2 of 0.39 while the second ranked model has a R^2 = 0.31. Again a model including only *Sc* and no additional covariates was among the lowest ranked models and had an R^2 of only 0.06.

Table 2.7. Predictor variables, AICc values, ΔAICc values, ΔAICc weights, and adjusted R-squares for the set of candidate models relating ln(recruits/spawner) to the migration year screening index (included in each model) and potential environmental covariates (n = 48). ΔAICc weights represent the relative degree of plausibility of each model given the data.

Predictor Variables	AICc	ΔAICc	ΔAIC$_c$ weight	Adjusted R-square
I, YR, Sc	**5.32**	**0.00**	**0.58**	**0.87**
I, S, YR, Sc	**6.14**	**0.82**	**0.38**	**0.88**
I, S, QY, QW, OCI, MPR, MMCN, Sc	12.69	7.37	0.01	0.60
I, S, QY, QW, YR, Sc	12.86	7.53	0.01	0.90
I, S, QY, QW, OCI, Sc	14.43	9.11	0.01	0.53
I, S, CUI, MPR, MMCN, Sc	15.82	10.50	<0.01	0.52
I, S, MPR, MMCN, Sc	16.70	11.38	<0.01	0.48
I, S, CUI, MPR, MMCN, QY, QW, Sc	16.92	11.60	<0.01	0.57
I, S, CUI, MPR, MMCN, QY, QW, MTY, MTW, Sc	19.01	13.69	<0.01	0.61
I, CUI, S, Sc	22.62	17.30	<0.01	0.38
I, OCI, S, Sc	25.29	19.97	<0.01	0.34
I, S, MTY, MTW, JTY, JTW, QY, QW, OCI, MPR, MMCN, Sc	25.58	20.26	<0.01	0.62
I, CUI, Sc	26.63	21.31	<0.01	0.28
I, S, MTY, MTW, JTY, JTW, QY, QW, CUI, MPR, MMCN, Sc	26.73	21.41	<0.01	0.61
I, OCI, Sc	27.87	22.54	<0.01	0.27
I, Sc	29.97	24.65	<0.01	0.19
I, S, MTY, MTW, JTY, JTW, Sc	32.63	27.31	<0.01	0.36
I, S, MTY, MTW, QY, QW, YR, YR, MPR, MMCN, Sc	42.04	36.72	<0.01	0.92
I, S, JTY, JTW, QY, QW, YR, MPR, MMCN, Sc	43.75	38.43	<0.01	0.91
I, S, MTY, MTW, JTY, JTW, QY, QW, YR, MPR, MMCN, Sc	59.39	54.07	<0.01	0.93

Table 2.8. Predictor variables, ΔAICc values, ΔAICc weights, and adjusted R-squares for the set of candidate models relating ln(smolts/spawner) to the migration year screening index (included in each model) and potential environmental covariates (n = 37). ΔAICc weights represent the relative degree of plausibility of each model given the data.

Predictor Variables	AICc	ΔAICc	ΔAIC weight	Adjusted R-square
I, S, QY, QWS, Sc	**-12.39**	**0.00**	**0.64**	**0.39**
I, QY, QWS, Sc	**-10.31**	**2.08**	**0.22**	**0.31**
I, S, Sc	-7.31	5.08	0.05	0.20
I, S, QY, QWS, JTY, JTWS, Sc	-6.69	5.71	0.04	0.40
I, S, QY, QWS, MTY, MTWS, Sc	-6.40	6.00	0.03	0.40
I, Sc	-4.10	8.29	0.01	0.06
I, S, MTY, MTWS, Sc	-3.11	9.28	0.01	0.22
I, JTY, JTWS, Sc	0.07	12.46	<0.01	0.08
I, S, QY, QWS, MTY, MTWS, JTYAK, JTWS, Sc	0.15	12.55	<0.01	0.41
I, MTY, MTWS, Sc	0.87	13.27	<0.01	0.06
I, S, MTY, MTWS, JTY, JTWS, Sc	1.99	14.38	<0.01	0.25

Variable definitions for Tables 2.7 and 2.8:

I: dummy coded descriptor for spring chinook stocks in each of Upper Yakima, Naches, Wenatchee or Warm Springs watersheds (separate Ricker *a* parameters)

S: number of spawning adults in each river system during the smolt brood year (separate Ricker *b* parameters)

QW: average daily flow (cfs) in the lower Wenatchee River between March 01 and June 30 (measured at Monitor, Washington) during the smolt migration year

QY: average daily flow (cfs) in the lower Yakima River between March 01 and June 31 (measured at Kiona, Washington) during the smolt migration year

QWS: average daily flow (cfs) in the lower Warm Spring River between March 01 and June 30 (measured at Kahneeta Hot Springs, Oregon) during the smolt migration year

MTY: average daily maximum air temperature in the lower Yakima Subbasin during the month of May (measured at Yakima airport, Washington) during the smolt migration year

MTW: average daily maximum air temperature in the lower Wenatchee subbasin during the month of May (measured at Wenatchee, Washington) during the smolt migration year

MAYTWS: average daily maximum air temperature in the lower Warm Springs subbasin during the month of May (measured at Dufur, Oregon) during the smolt migration year

JTY: average daily maximum air temperature in the lower Yakima Subbasin during the month of June (measured at Yakima airport, Washington) during the smolt migration year

JTW: average daily maximum air temperature in the lower Wenatche subbasin during the month of June (measured at Wenatchee, Washington) during the smolt migration year

JUNETWS: average daily maximum air temperature in the lower Warm Springs subbasin during the month of June (measured at Dufur, Oregon) during the smolt migration year

MMCN: average daily mainstem Columbia River spill (kcfs) at the McNary Dam between March 01 and June 30 during the smolt migration year

MPR: average daily mainstem Columbia River spill (kcfs) at the Priest Rapids Dam between March 01 and June 30 during the smolt migration year

OCI: The average annual Oyster Condition Index (OCI) determined at Stony Point, Willapa Bay, Washington during the smolt migration year (measure of ocean productivity)

CUI: The average annual North Pacific Coastal Upwelling Index (CUI) for the US Coast 45 deg latitude, 125 deg longitude in the smolt migration year (measure of ocean productivity)

YR: dummy coded descriptor for a common year effect reflecting the shared suite of factors that affect survival of all stocks

Sc: derived index of cumulative canal survival rates for Upper Yakima and Naches River irrigation/power canals in the smolt migration year (based on relative levels of screening effectiveness) – Fish Screen Survival Index

Table 2.9 shows parameter estimates for the two "best" ln(recruits/spawner) models plus the third best model that did not include a common year effect. In the two best models the *Sc* parameter has a negative but non-significant coefficient, while in the third less plausible model the *Sc* co-efficient is negative and significant. The common year effect is highly significant in both of the two best models.

Table 2.9. Parameter estimates for top 3 ΔAIC ranked ln(recruits/spawner) models. Parameters that are significant at 0.05 are bolded. ΔAIC_c shown at top (0.0 for best model).

Model ΔAIC_c	**Top-ranked 0.0**		**2nd ranked 0.82**		**3rd ranked 7.37**	
Parameters	**Estimate**	**Prob. > t**	**Estimate**	**Prob. > t**	**Estimate**	**Prob. > t**
Sc	-1.686	0.19	-0.422	0.76	**-3.998**	**<0.01**
S			0.001	0.08	0.001	0.59
I		**0.05**		0.45		0.25
QY					0.001	**0.01**
QW					0.001	0.81
MPR					**0.036**	**0.04**
MMCN					-0.012	0.18
OCI					**0.278**	**<0.01**
YR		**<0.001**		**<0.001**		

Table 2.10 shows the parameter estimates for the three "best" ln(smolts/spawner) models. In all three of these models our *Sc* parameter displays a nonsignificant, negative co-efficient.

Table 2.10. Parameter estimates for top 3 ΔAIC ranked ln(smolts/spawner) models. Parameters that are significant at 0.05 are bolded. ΔAIC_c shown at top (0.0 for best model).

Models **ΔAIC_c**	**Top-ranked 0.00**		**2nd ranked 2.08**		**3rd ranked 5.08**	
Parameter	**Estimate**	**Prob. > t**	**Estimate**	**Prob. > t**	**Estimate**	**Prob. > t**
SPAWNERS	**-0.001**	**0.04**	N/A	N/A	**-0.001**	**0.03**
QYAK	0.001	0.16	0.001	0.07	N/A	N/A
QWS	**0.003**	**<0.01**	**0.003**	**<0.01**	N/A	N/A
Sc	-1.991	0.20	-2.671	0.09	-2.031	0.40
I		0.09		0.26		0.39

2.8 Discussion

A wide variety of BPA and BoR funded fish habitat restoration projects have been undertaken throughout the Columbia basin as part of hydropower compensation and mitigation programs. Determination of the long term impacts of these projects on fish populations in the Columbia has generally been difficult, as the required experimental designs are generally lacking to isolate specific habitat effects at varied spatial and temporal scales. The program of Phase I fish screening construction in the Yakima River Subbasin offered a perhaps unique opportunity to quantify the effect of a specific habitat restoration activity at increasing salmon survival and production, both at the local project scale and at a subbasin scale. Unlike many habitat restoration projects, new fish screens constructed within the Yakima subbasin have undergone regular quality control (QA/QC) assessments to ensure that enhancements were indeed implemented, have remained in place, and are functioning as intended (i.e., Neitzel et al. 1985; Abernathy et al. 1989; Neitzel et al. 1990a, Neitzel et al. 1990b; McMichael et al. 2002). Annual monitoring of smolt passage at the Chandler Canal by Yakama Nation fisheries biologists (i.e., Neeley 1998; Neeley 2002) and basin level chinook run reconstructions have additionally provided a rare long term dataset of salmon productivity within the Yakima system.

Effectiveness monitoring at Chandler before and after the time of Phase I screen construction has provided strong evidence that Phase I screens have produced a measurable improvement in fish survival at the project level (marked improvements in chinook smolt survival rates within Chandler Canal after Phase I screen construction). At this project level scale the money invested in the Phase I screening program appears money well spent; a major smolt mortality factor has been considerably reduced and this effect is quantified on an annual basis. However, our analyses examining the impact of the Phase I program on spring chinook at the broader subbasin scale failed to detect any significant positive effect of fish screening on overall measures of productivity (recruits/spawner or smolts/spawner). Survival past fish screens was either not correlated with R/S and smolts/spawner indices in our analyses, or was instead negatively correlated (complete opposite of expected effect). It could be argued that density dependent effects on survival may have masked the effects of screening in these comparisons. However our covariate analyses, accounted for this, and still produced an *Sc* coefficient that was negative and non-significant.

Fish screens appear to do what they were designed to do at a localized scale: improve smolt survival at irrigation/power canals. The first question is, why did we fail to discern a larger overall effect for a restoration program that has obvious and demonstrable benefits to fish at the project scale? Secondly, why did there appear to be a weakly negative correlation of screen effects with fish productivity indices? There are a number of factors that could have interfered with the ability of our population analysis to detect the larger benefits of a restoration project or program. A listing of potential factors for our analysis could include:

1. Although immediately beneficial at the point of the restoration site**, the restoration activity did not actually address the larger factors limiting longer term survival**, or may have interacted with other stressors (such as a highly perturbed watershed hydrology) to have unintended effects. Although it might be argued that increases in smolt survival at screened canals could have a negligible effect on eventual recruitment given the range of mortality factors present within the complete life cycle of chinook, it seems unlikely that improved survival at canals could actually negatively impact recruitment. While it might be postulated that increased numbers of smolts surviving to the ocean might increase marine density dependent interactions, this seems unlikely given the extremely low abundances during this period relative to both historical and more recent time periods. Furthermore, density dependent effects were already considered through inclusion of spawners as a covariate.
2. **Combinations of random environmental factors** (e.g., drought, floods, poor ocean conditions) could affect treatment and/or controls and confound our ability to detect any effect. This possibility was the rationale for our covariate analysis that attempted to partition variation among potentially confounding factors. It was also the rationale for undertaking an analysis of smolts/spawner productivity using an alternative (although not ideal) control subbasin (Warm Springs). It was hoped that this would provide a more direct assessment of juvenile productivity within the subbasins, before the introduction of additional confounding influences affecting the migratory and adult chinook life stages. Weakly negative correlations between *Sc* and both ln(recruits/spawner and ln(smolts/spawners) could be due to similar factors, except that Columbia River mainstem and ocean survival factors are not at issue in our smolts/spawner analysis. Any unexplained variability in smolt survival would be occurring more locally at the intrabasin scale. There is an inherent inability in such analysis to fully quantify all environmental covariates that may be relevant; hence leading to low power to detect responses.
3. **Fish response measures are naturally highly variable** and there is inherent high measurement error. Given the degree of noise and uncertainty in the subbasin level data available for such a retrospective exercise as attempted here, detecting a signal (even when it exists) is likely to be difficult. Complete counts of returning spawners were performed at Rosa Dam on the Yakima at a well designed facility, so measurement error for spawners is low. Measurement errors in adult recruits are higher due to lack of aging data in some years. Measurement errors in smolt counts are also likely to be higher due to uncertainties in trap efficiencies and differing operating protocols at Yakima and Warm Springs juvenile counting facilities and smolt traps. Additionally, calibrated smolt entrainment and survival rates at Chandler Canal may have been somewhat biased in the early years of the Yakima dataset, due to the greater possibility of failing to detect freeze branded smolts versus those PIT tagged in subsequent years. It is likely that this potential degree of error is very small relative to other sources of variability in the data.
4. *Sc*, although quantified as best as possible from agency data compiled at Chandler Canal, is still based on modeled estimates and **extrapolation of Chandler results to other screened canals**. We may not have sufficiently captured the reality of conditions at all canals. We suspect, however, that these errors are minor compared to other factors.
5. Although *Sc* gradually improved with the installation of Phase 1 screens across a number of years, **a sharp contrast in before/after survival is not present within the analysis**. Some of this lack of contrast relates to the partial efficiency of the older screens that were present on the canals prior to Phase I implementation. Although markedly inferior in design they did appear to allow successful passage for at least 50% of entrained smolts, at least as documented at Chandler canal (Neeley 1998). So although the screening saw a progressive 2-fold improvement in survival of juveniles entrained within the canals (from approximately 50% survival to about 100%), this survival contrast may lack

sufficient signal strength to detect improvements in productivity at a watershed scale. Additional sensitivity analyses may provide greater insights into the degree of contrast in canal survival rates that might be required to statistically detect improvements in subbasin chinook productivity.

6. There may have been some level of increased localized predation of smolts as a result of passage through the canals. It has been noted (J. Hubble, pers. obs.) that high numbers of predatory pikeminnow congregate at the outflows of canal bypass pipes and feed on disoriented smolts. Although the extent of this predation has not been quantified, it is conceivable that improved survival though the canals may be negated somewhat by high levels of predation immediately subsequent to canal bypass.
7. **Unfortunate timing of our data set.** The Yakima had relatively high fish production in the first 3 years of a limited time series (particularly in brood year 1982) – coinciding with the primary pre-screening years available for our analyses. The Yakima sub-basin then went into a six-year period of major drought coincident with the timing of major fish screen implementation. The limited number of pre-screening years available for comparison could have obscured the detection of a real pattern (unbalanced design with insufficient temporal/spatial contrasts).

This last point is likely the most important factor creating a negative correlation between screening and fish survival indices in our analyses. Figure 2.12a illustrates the high ln(R/S) ratios in the first years of the time series for the Naches River coincident with lower values of *Sc* (this pattern is similar for the Upper Yakima). This sharp decline in recruits/spawner through the mid 1980s and early 1990s, despite increases in *Sc* values, contributes to the negative correlation of *Sc* and ln(R/S).

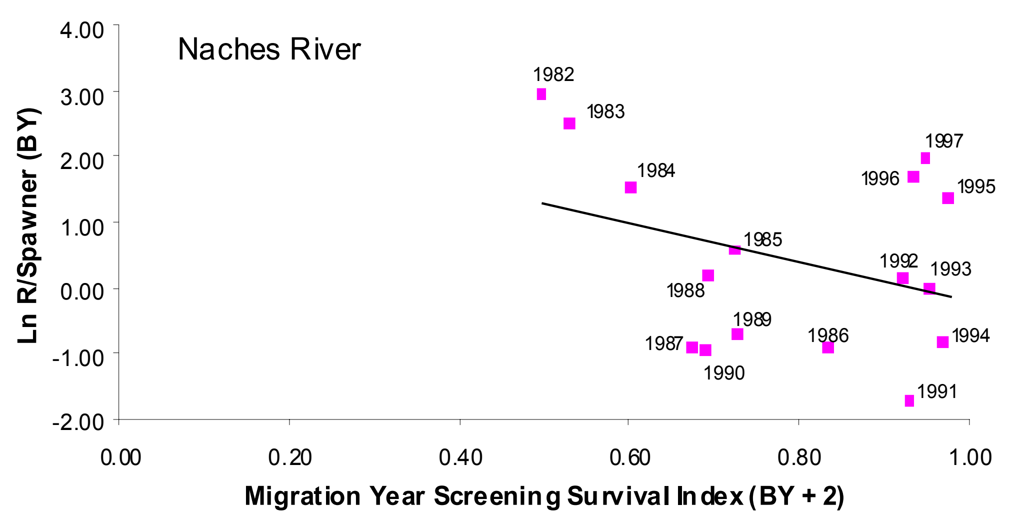


Figure 2.12a. Naches River ln(recruits/spawner) estimates for brood years 1982–1997 in relation to Fish Screening Survival Index (*Sc*) values estimated in the smolt migration years (BY + 2).

The same general negative trend is also apparent for ln(smolts/spawner) in the Yakima relative to an increasing *Sc* (Figure 2.12b). The most probable explanation for this (other than invoking an actual negative effect of fish screening) is that changes in smolt production within the Yakima sub-basin are driven by a suite of additional factors that may override the localized beneficial effects of improved screening, and prevent their easy detection at broader spatial scales.

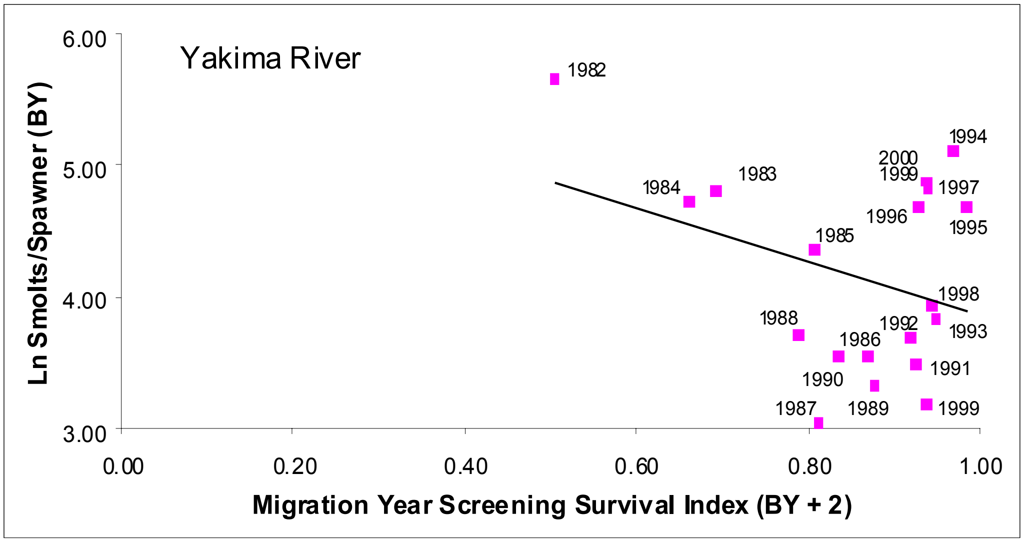


Figure 2.12b. Yakima Subbasin ln(smolts/spawner) estimates for brood years 1982–2000 (pooled Upper Yakima and Naches/American stocks) in relation to *Sc* values estimated for the smolt migration years (BY + 2). The screening index (*Sc*) for the Yakima is a weighted average for the two stocks (UY and NA), based on the estimated proportion of spawners in each system.

There was a strong correlation between lower river flow and both ln(recruits/spawner) and ln(smolts/spawner) in brood years 1982 to 1992 (see Figures 2.13 and 2.14). This tight tracking between productivity measures and flow was weakened in the Yakima River in brood years 1993 to 1996 as the Yakima system recovered from drought. Spring flow rates increased dramatically in the lower Yakima over these years, but without any comparable matching increase in sub-basin smolts/spawner production (Figure 2.13). By contrast the Warm Springs stock did show higher smolts/spawner coincident with increased flows (Figure 2.14). Given the limited number of treatment/control contrasts available within our analyses to buffer against the effects of sharp environmental fluctuations, the statistical interpretation of this result would be that an elevated *Sc* in the Yakima Subbasin was apparently suppressing the expected concomitant increase in productivity that would otherwise have occurred due to increased river flow.

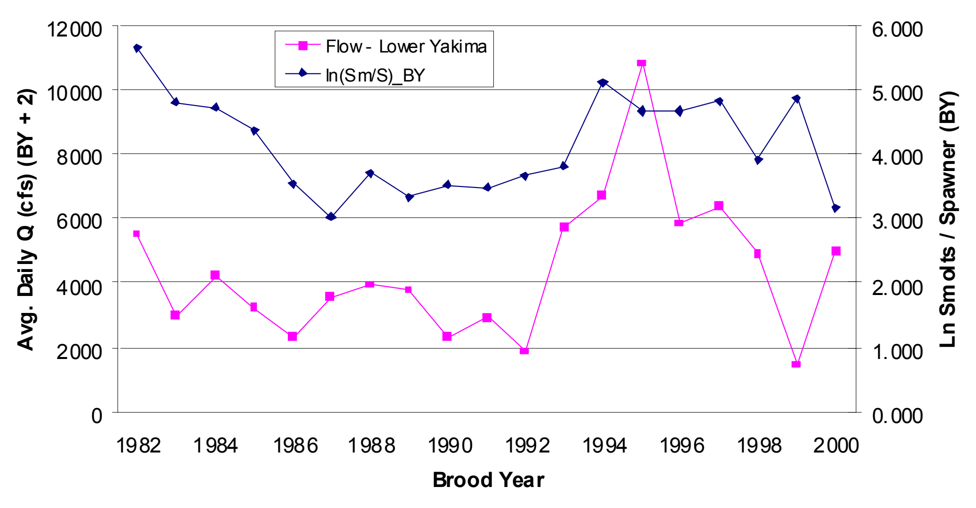


Figure 2.13. Changes in average daily spring/summer lower Yakima River flows and ln(smolts/spawner) ratios over the time period of record. Average daily flows are for the period March–June (prime migration window) during the associated smolt migration year (BY + 2).

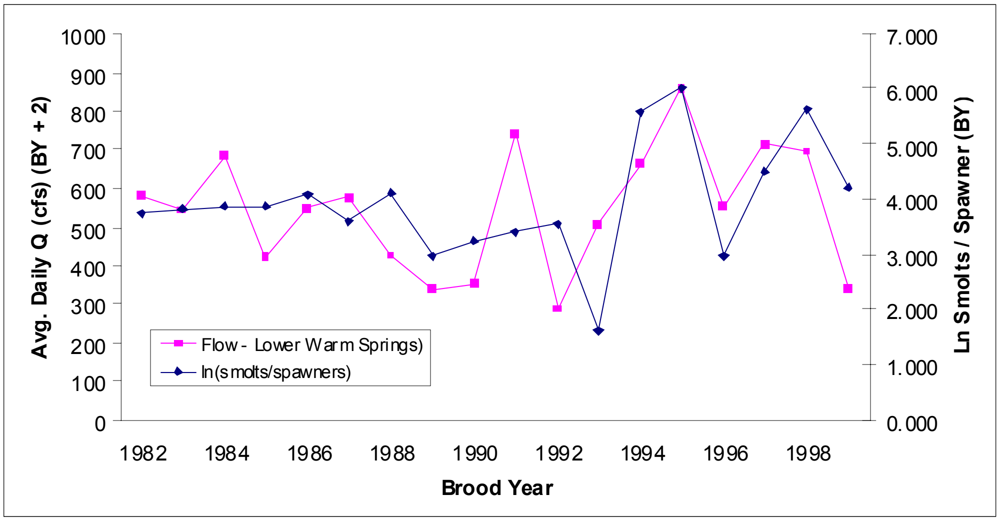


Figure 2.14. Changes in average daily spring/summer lower Warm Spring flows and ln(smolts/spawner) ratios over the time period of record. Average daily flows are for the period March–June (prime migration window) during the associated smolt migration year (BY + 2).

Improved smolt survival data for Upper Yakima spring chinook (Table 2.11) is now becoming available from PIT tag monitoring undertaken by the Yakama Nation Fisheries Program, although the time series for these data is too limited to incorporate into our analyses. This new dataset does indicate, however, that even in recent years (1999-2003) subsequent to installation of all major screens, overall smolt survival rates within the Upper Yakima are often quite low (0.31 to 0.83, with a mean of 0.50).

Table 2.11. Recent (1999 – 2003) survival data for PIT Tagged wild spring chinook smolts in the Upper Yakima River. The table indicates survival rates of tagged smolts from Roza Dam to Prosser (Chandler) Dam and from Roza Dam to the mainstem McNary Dam. (*Source*: Yakama Nation Fisheries Program and Charlie Paulsen).

Downstream migration year	Stage	Number tagged	Survival, Rosa to Prosser	Survival, Rosa to McNary
1999	Smolt	470	0.58	0.48
2000	Smolt	2105	0.83	0.53
2001	Smolt	2179	0.31	0.24
2002	Smolt	7710	0.38	0.25
2003	Smolt	7802	0.37	0.27

There is little doubt that factors besides irrigation/power canals strongly influence juvenile salmon survival in the Yakima system. The single overriding factor may be the river's inverted hydrograph (flip-flop water management) caused by irrigation releases from Upper Yakima storage reservoirs (Joel Hubble, pers. obs.). The Yakima Subbasin Summary (Anon 2001a) identified what was termed a "pernicious interaction" between the loss of habitat complexity and these non-normative flows in the river, and consequent losses of juvenile salmonids. Four general kinds of impact have been attributed to non-normative flows in the Yakima:

1. Channel-maintenance peak flows are much less frequent now, which has resulted in the gradual silting in of off-channel habitat.
2. Irrigation demand results in flows that are unnaturally high in the summer, while the need to refill reservoirs results in flows that are unnaturally low in winter. These high summer flows, combined with a lack of "velocity cover" formerly supplied by side channels and log jams, results in the downstream displacement of juveniles (Anon 2001a). It may be that some fish screens could contribute to this situation by confining juvenile fish to the mainstem Yakima during the summer period of unnaturally high flows, causing premature downstream movement to poorer habitat in the lower Yakima River. However, we have no direct evidence that this occurred with our assessed Phase I screens.
3. The scarcity of off-channel habitat and LWD has also resulted in a lack of slow, pool-type habitat, the "key habitat" for all of these life stages. The little structure that remains — perched LWD, riprap and the remaining side channels — is then rendered largely inaccessible when flow drops in the fall and winter as reservoirs are refilled (Anon 2001a).
4. There have been unintended consequences of the flip-flop river management scheme. Specifically, salmonid parr are stranded (or isolated and ultimately killed by predators) in remaining side channels when flows are sharply reduced in the fall (Anon 2001a).

Highways, railroads, residential dikes and agricultural and urban development have also virtually disconnected the river from its floodplain (Anon 2001a). Yakima River reaches are now much narrower, faster and structurally simpler than they were historically. Therefore, most of the slow, shallow, structurally complex off-channel habitat required by chinook juveniles has been eliminated, as has much of the hyporrheic habitat that formerly "fertilized" the entire food chain (Anon 2001a).

The range of changing mortality factors affecting juvenile production within the Yakima Subbasin (plus the additional extra-basin mortality factors that must be faced during smolt migration and adult ocean residence periods) make it perhaps not surprising that a retrospective analysis of the type attempted here would fail to isolate a positive effect of fish screening on subbasin productivity. Paulsen and Fisher (in review) have suggested that there is likely too much general uncertainty associated with the life history patterns of anadromous salmon for us to expect a clear answer from retrospective correlative analyses, which is why a deliberate experimental management approach must be adopted to more clearly address the benefits of habitat restoration actions in Columbia Basin watersheds.

What could improve our retrospective analysis? (Lessons learned)

It is often the case that our greatest data needs are for "better historical data". This case study is no different. Were it feasible it would have been valuable to:

1. Find datasets with greater amount of spatial and temporal contrasts i.e., more tributaries or watersheds, longer time series of pre-screen data.
2. Obtain better geographically paired controls for treatment watersheds. For our analyses longterm smolts/spawner data were not available for the Wenatchee watershed (which represented a better geographic pairing with Yakima than was Warm Springs).
3. Obtain more accurate annual canal survival rate estimates at individual canals assessed. Our analysis relied on assumed extrapolations of screen survival from Chandler Canal relationships.
4. Obtain better estimators of actual downstream smolt passage survival through the hydro system. This information is now becoming available for the Yakima River through recent (1999 onwards) PIT tag smolt survival data.
5. Obtain complete water temperature datasets for use as a covariate. In our analyses available water temperature datasets were incomplete for the compared subbasins. We instead had to rely on more complete air temperature datasets for use as surrogates.
6. Obtain more smolt data from well monitored traps with careful estimates of trap efficiency. Lack of longterm datasets for juvenile productivity in Columbia River tributaries was a common problem limiting possible inter-tributary and inter-basin comparisons.

The datasets we developed can be used to undertake simulated sensitivity analyses. Such simulations are required to help determine the sensitivity of similar correlative approaches at actually detecting positive canal survival effects at a sub-basin scale. Sensitivity analyses will allow us to explore how easy/difficult it might be to pick up a positive effect of screening on chinook productivity if we had had greater options for study/control sites, longer datasets to work with, greater contrasts etc. (i.e., an assessment of the power and effect size of our analyses). We address these concepts more fully in Chapter 7. Within the limited time and budget of this project, we were only able to conduct a preliminary sensitivity analysis of the Yakima case study to answer a simple series of questions:

- How sensitive was our analysis to inclusion/exclusion of BY 82; the highest fish smolt/spawner year in the Yakima dataset (occurred prior to initiation of fish screen construction)?
- How sensitive was our analysis to sharper contrasts in the *Sc* index in pre vs. post screening years?
- How sensitive was our analysis to sharper contrasts in smolt/spawner numbers in pre vs. post screening years?
- How sensitive was our analysis to simulated increases in the pre-screening time series?

The tables 1 through 3 in Appendix 2.E examine these questions in a series of model runs of possible simulated combinations of varied *Sc* contrasts, smolt/spawner numbers, longer time series and inclusion/exclusion of the higher leverage BY82 data.

The results of our sensitivity analysis illustrated the difficulty of detecting a significant screening effect within the data series available for the Yakima. The limited pre-screen years showed higher average smolt/spawner numbers versus the later post screen years, even if the most productive pre-screen year (BY 82) is removed from the comparison. Hence simulations of time series based on the existing data set will not likely generate much change in the original interpretations of the *Sc* index. Only by simulating radical contrasts in screening survival rates pre-versus-post screening, or major contrasts in yearly ln(smolt/spawner) numbers was the sensitivity analysis able to produce a significant positive effect of fish screening.

2.9 Recommendations for future studies

Looking forward with the increased wisdom gleaned from the Yakima retrospective analyses we would recommend the following guidelines for future experimental management studies of restoration actions:

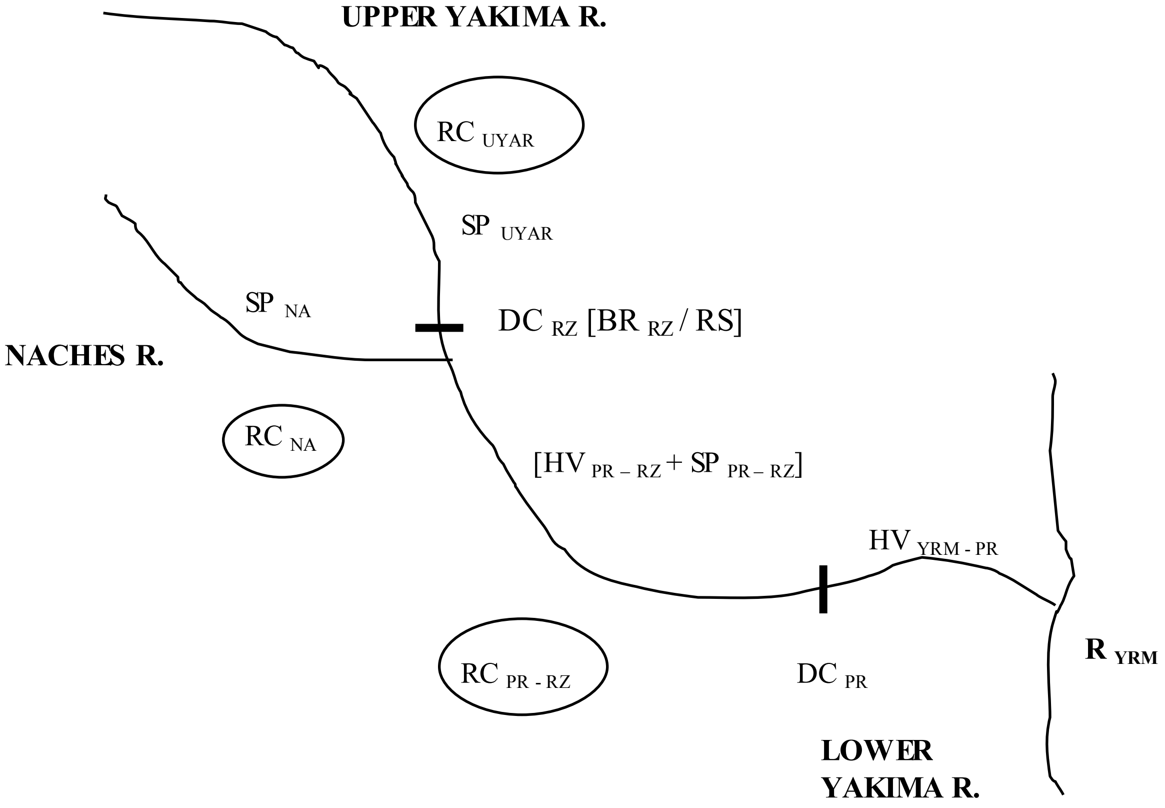
1. Develop solid, well-designed projects across multiple tributaries and reaches (e.g., thoughtful staircase designs with controls and strong spatial/temporal contrasts in treatments (Ward et al. 2002).
2. Assess project effectiveness as close to actions in space and time as possible (e.g., project scale tributary smolts/spawner indices), as well as across entire fish life cycles (e.g., R/S). The multiple fish response measures in the Yakima case study were valuable in assessing the persistence of survival benefits over the life cycle (or lack thereof).
3. Continue to develop a multi-project, multi-tributary, multi-watershed perspective; don't evaluate and fund project proposals independently.
4. Build on existing long term monitoring sites and use extensive surveys to find good treatment-control pairs. Extensive pre-treatment monitoring is critical to detecting post-treatment effects.
5. Design management experiments strategically, so that results can be fed back into both subbasin and regional scale decisions.
6. Since land use cannot be frozen in control tributaries or subbasins, continue to monitor key covariates that might confound the treatment effect of interest.

2.10 Acknowledgements

We acknowledge the generous provision of data and time by the following fisheries scientists and managers: Earl Weber, Bill Bosch, Tom Cooney, Bob Spateholts (spring chinook datasets for the Yakima, Wenatchee and Warm Springs systems), Steven Hare (OCI data), Mark Scheuerell and Nathan Mantua (CUI index), Charlie Paulsen (Yakima PIT Tag data). Carl Schwarz (Simon Fraser University) and Charlie Paulsen (Paulsen Environmental Ltd.) provided statistical advice and early feedback on the methods and results presented here.

Appendix 2.A – Yakima and Naches Run Reconstructions

Critical components of algorithms used by Yakama Nation Fisheries Program for determining spring chinook run reconstructions on the Yakima and Naches Rivers, Washington.



Yakima and Naches River Run Reconstruction algorithms (refer to above figure),

where:

YRM = Yakima River Mouth
PR = Prosser Dam
RZ = Roza Dam
UYAP = Upper Yakima River above Prosser Dam
UYAR = Upper Yakima River above Roza Dam
NA = Naches River

Variable Names:

R = returns
SP = spawners
R/S = returns/spawner

DC = dam count
RC = redd count
HV = harvest
RS = Roza subtractions, which could include harvest above Roza, hatchery removals, and/or wild broodstock removals
BR = broodstock removals at Roza Dam

YAKIMA RIVER

[1] Upper Yakima River Spawners:

Estimated escapement into the upper Yakima River above Roza Dam is the Roza Dam count less harvest or broodstock removals:

i) $SP_{UYAR} = DC_{RZ} – RS$

The exception to this is in 1991 (when there were no Roza Dam counts undertaken). In 1991, upper Yakima River escapement above Roza was estimated as the (Prosser Dam count - harvest above Prosser Dam - Roza subtractions) times the proportion of redds counted in the upper Yakima:

ii) $SP_{UYAR} = (DC_{PR} – HV_{PR\text{-}RZ} – RS) * (RC_{UYAR} / (RC_{UYAR} + RC_{NA}))$

The estimated escapement in the Upper Yakima River between Prosser and Roza Dams is calculated as the yearly fish per redds determined for the Upper Yakima above Roza dam, multiplied by the combined Redd Counts for the river stretch between Prosser and Roza Dams:

$SP_{PR\text{ - }RZ} = RC_{PR\text{ – }RZ} * \text{fish/redd}$

[2] Yakima River Mouth Returns:

Yakima River mouth returns are the summation of the Prosser Dam counts plus lower Yakima River harvest numbers. In years in which the Prosser Dam counts were considered unreliable (1982, 1983 and 1990) the Yakima River mouth returns are instead calculated as the estimated river escapements plus all known harvest and removals:

If

$DC_{PR} + HV_{PR – RZ} => SP_{PR – RZ} + SP_{UYAR} + SP_{NA} + HV_{RM – PR} + HV_{PR – RZ} + RS$

Then

$R_{YRM} = DC_{PR} + HV_{YRM\text{ - }PR}$

Else

$R_{YRM} = SP_{PR – RZ} + SP_{UYAR} + SP_{NA} + HV_{RM – PR} + HV_{PR – RZ} + RS$

[3] Upper Yakima River Returns:

Returns to the Upper Yakima River above Prosser Dam are calculated as (the proportion of estimated spawners in the Upper Yakima river above both Prosser and Rosa Dams in relation to the estimated spawner numbers in the Upper Yakima and Naches Rivers combined), multiplied by (the Yakima River mouth returns – Roza Dam broodstock removals), plus the Roza Dam broodstock removals. The calculation determines the proportions and total numbers of spawners that occur in the Yakima River above Prosser Dam, as opposed to within the Naches River system. The broodstock removal component of the equation corrects for the fact that all broodstock fish removed at Roza Dam would be Upper Yakima River spawners:

$$R_{UYAP} = ((SP_{UYAR} + SP_{PR-RZ}) / (SP_{UYAR} + SP_{PR-RZ} + SP_{NA}) * (R_{YRM} - BR_{RZ})) + BR_{RZ}$$

[4] Upper Yakima River Returns/Spawners:

The yearly returns/spawner estimates for the Upper Yakima River above Prosser Dam are based on back-calculated return numbers for fish aged 4 through 5. From 1982 to 1985 these age fractions were fixed due to lack of data. From 1986 to 1996 age proportions of returning spawners were determined by fish sampling on Yakima River spawning grounds:

$$R/S_{UYAP} = (R_{UYAP\ (age\ t+4)} + R_{UYAP\ (age\ t+5)}) / SP_{UYAP,\ t}$$

From 1997 onwards age proportions of returning Upper Yakima spawners were determined by direct sampling at Roza Dam.

NACHES RIVER

[5] Naches River Spawners:

Naches River escapement is estimated as the Prosser Dam count minus the harvest above Prosser Dam and the Roza Dam counts, except in 1982, 1983 and 1990 where the Prosser Dam counts were considered unreliable. In those years Naches escapement is estimated as the (number of estimated Upper Yakima River spawners above Roza Dam divided by the total redds counted in the Upper Yakima above Roza Dam) multiplied by the Naches River redd counts:

If

$$DC_{PR} - HV_{PR-RZ} - SP_{PR-RZ} => DC_{RZ}$$

Then

$$SP_{NA} = DC_{PR} - HV_{PR-RZ} - SP_{PR-RZ} - DC_{RZ}$$

Else

$$SP_{NA} = (SP_{UYAR} / RC_{UYAR}) * RC_{NA}$$

[6] Naches River Returns:

Naches River returns are calculated as the returns estimated for the Yakima River mouth minus the returns estimated for the Upper Yakima River above Prosser Dam:

$$R_{NA} = R_{YRM} - R_{UYAP}$$

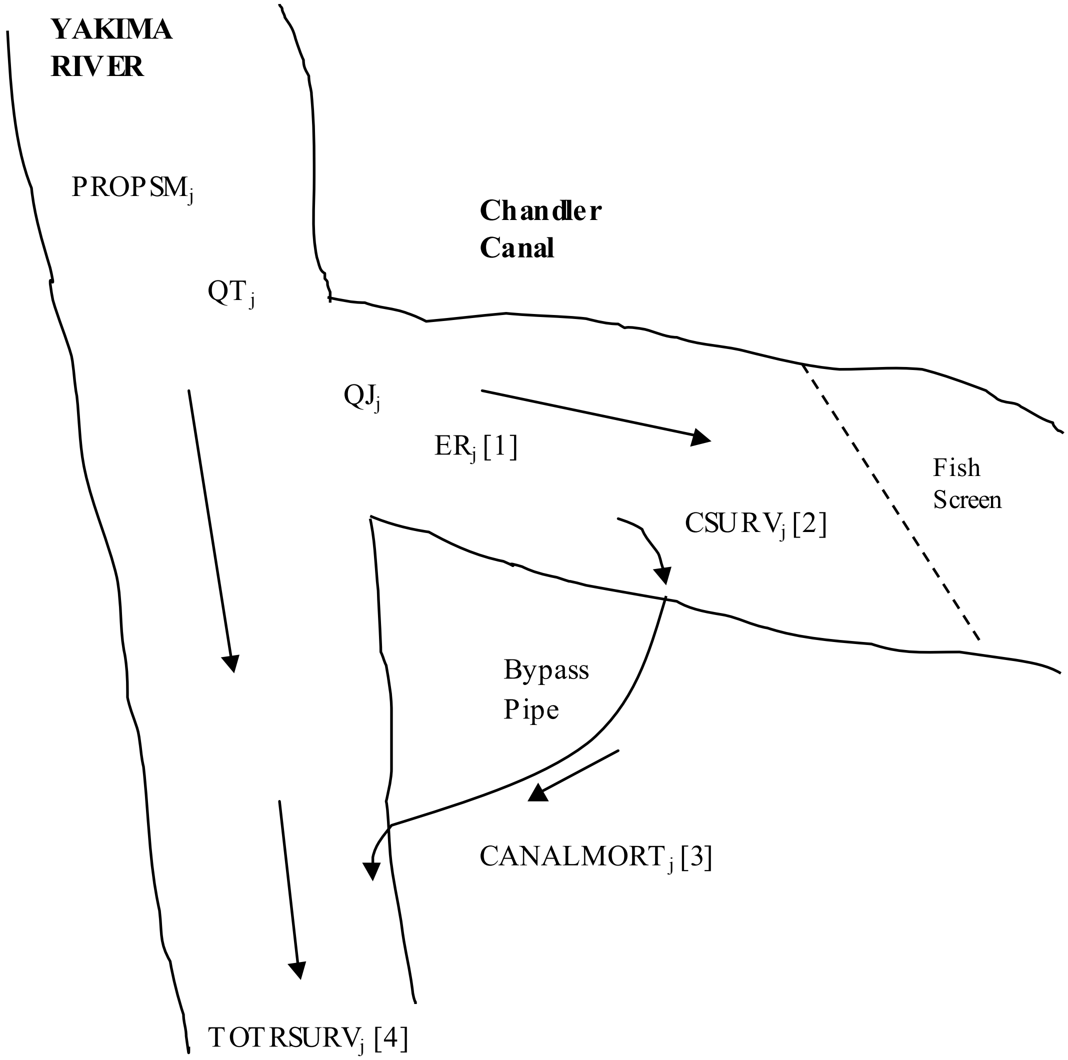
[7] Naches River Returns/Spawners:

The yearly returns/spawner estimates for the Naches River are based on back-calculated return numbers for fish aged 4 through 6. Age proportions of returning spawners are determined by fish sampling on Naches River spawning grounds.

$$R/S_{NA} = (R_{NA\ (age\ t+4)} + R_{NA\ (age\ t+5)} + R_{NA\ (age\ t+6)}) / SP_{NA,\ t}$$

Appendix 2.B – Fish Survival Rates at Chandler Canal

Critical components of algorithms used to determine yearly fish run survival rates at the **Chandler Canal** diversion on the Yakima River, WA. The figure is not to scale and is intended only as a rough approximation of the configuration at the Chandler Canal. Arrows represent water flow and associated fish movement, numbers refer to equations in text.



Survival rate variables and algorithms for Chandler, Sunnyside, Wapato and Roza canals

Variables:

$PROPS_j$ = proportion of theYakima River's spring chinook smolt run that passes Chander Canal on day j (determined from daily Prosser Dam fish counts for 1982 to 1998, tabulated in Neeley 1998).
QT_j = total daily river flow (cfs)
QJ_j = daily canal flow (cfs)

Algorithms:

CSURVj = daily canal survival rate of fish entrained in Chandler (reflective of a mix of screen impingement, predation and temperature induced mortalities, Neeley 1998), where:

$$CSURV_j = 1 / (1 + \exp[-b(CSURV,0) - b(CSURV,1), x_j]) \qquad [1]$$

where b(CSURV,0) and b(CSURV,1) are empirically derived coefficients determined each year at Chandler Canal and, x_j = is 0 before May 20 and x_j = 1,2,3,… for May 20, May 21, May 22, …. etc. (this correction is designed to account for the progressively deteriorating water conditions, and associated increased mortality, post May 20th of each calendar year). Canal survival rate becomes 1 if the canal is closed after the irrigation season and mainstem flow is no longer diverted into the canal.

$$ERj = 1 / 1 + \exp[-b(ER,0) - b(ER,1)CDj - b(ER,2)CDj3] \qquad [2]$$

where ER_j is the proportion of daily fish passage entrained within the canal on day j,
and $CD_j = QJ_j / QT_j$ (the proportion of river flow diverted to canal on day j), Neeley 1998:

before 1987 (year of new fish screen installation at Chandler Canal):
b(ER,0) = -4.1588
b(ER,1) = 11.8804
b(er,1) = 0

in 1987 and following years:
b(ER,0) = -5.1131
b(ER,1) = 18.0524
b(ER,2) = -12.1010

$$CANALRMORTj = ERj * (1 - CSURVj) * PROPSMj \qquad [3]$$

where $CANALMORT_j$ is the proportion of the total yearly Spring Chinook run that is killed in Chandler canal on day j

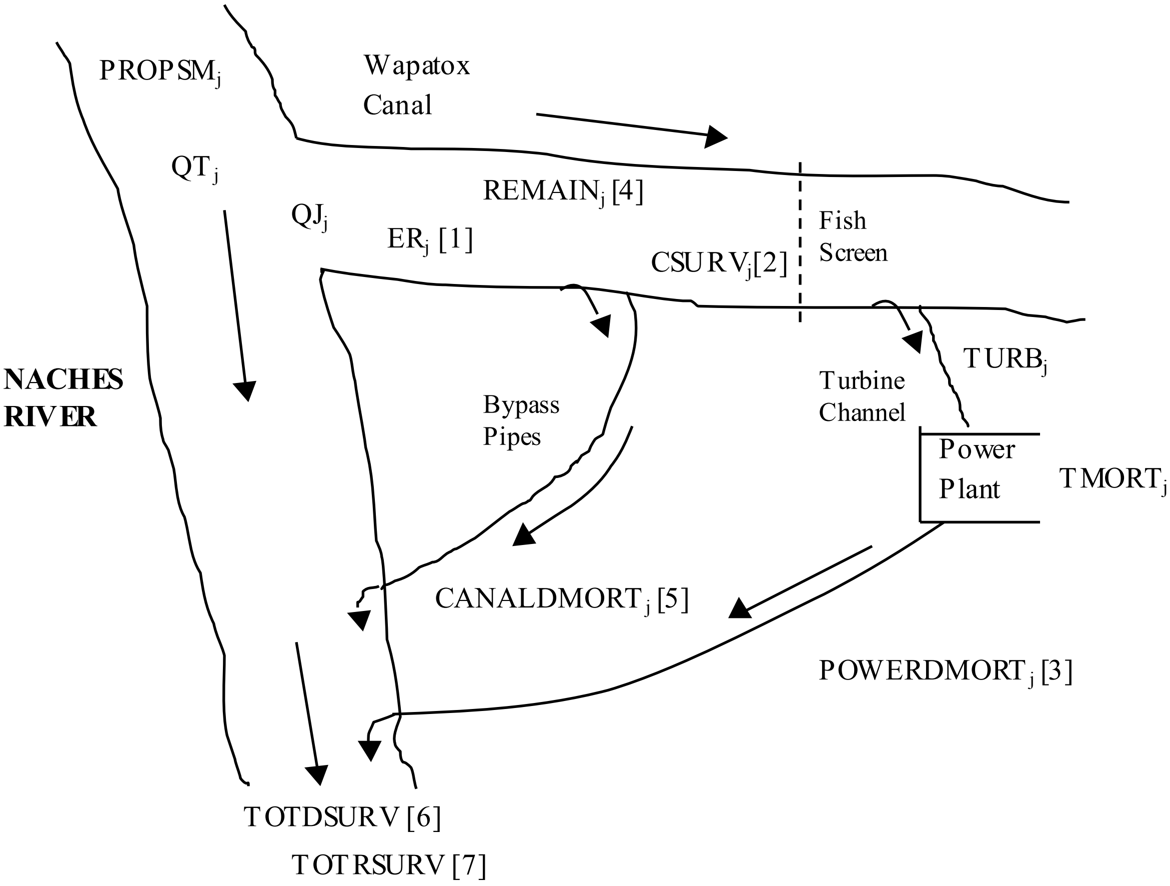
$$TOTRSURVj = PROPSMj - CANALMORTj \qquad [4]$$

where $TOTRSURV_j$ is the proportion of the total yearly Spring Chinook run that survives by and through Chandler Canal to continue migration down the Yakima River on day j

Algorithms used to develop survival rate indices at Chandler Canal were similarly applied at other Upper Yakima River Phase 1 fish screens (i.e., Sunnyside, Wapato and Roza canal diverisions).

Appendix 2.C – Fish Survival Rates at Wapatox Canal

Critical components of algorithms used to determine daily and yearly fish survival rates at the **Wapatox Canal** diversion on the Naches River, Washington. The figure is not to scale and is intended only as a rough approximation of the configuration at the Wapatox Canal. Arrows represent water flow and associated fish movement, numbers refer to equations in text.



Wapatox Canal survival rate variables and algorithms

Variables:

QT_j = total daily river flow (cfs)

QJ_j = daily canal flow (cfs)

$TURB_j$ = daily diversion rate of canal entrained fish into Wapatox power turbine channel (fish that are trapped behind fish screens and are drawn through turbines), set at 0.36 before Phase II screens installed in 1993 (Yakima River Subbasin Salmon and Steelhead Production Plan 1990) and 0 afterwards (assumption)

$TMORT_j$ = daily mortality rate for chinook smolts passing through Wapatox turbines, set at 0.88 (Yakima River Subbasin Salmon and Steelhead Production Plan 1990

$SURVRATE_j$ = daily canal survival rate of fish entrained in Wapatox canal but not diverted into power turbine channel (reflective of a mix of screen impingement, predation and temperature induced mortalities)

Algorthims:

ERj is as defined as above for Chandler Canal (equation 1), except that 1993 is used for year of screen installation.

$CSURV_j$ is as defined as above for Chandler Canal (equation 2)

$$POWERDMORT_j = ER_j * TURB_j * TMORT_j \qquad [3]$$

where $POWERDMORT_j$ is the proportion of the total daily fish population killed by turbines following diversion through the Wapatox power generation plant.

$$REMAINj = ERj - (ERj * TURBj) \qquad [4]$$

where $REMAIN_j$ is the proportion of the total daily fish passage that is not diverted to the turbines but remains entrained in the canal and could escape via the canal bypass pipes

$$CANALDMORTj = REMAINj * (1 - CSURVj) \qquad [5]$$

where $CANALDMORT_j$ = the proportion of the total daily fish passage that is killed within the main Wapatox canal or bypass pipes

$$TOTDSURVj = 1 - (POWERDMORTj + CANALDMORTj) \qquad [6]$$

where $TOTDSURV_j$ is the proportion of the total daily river fish passage that survives by and through Wapatox Canal to continue migration down the Naches River on day j

$$TOTRSURVj = PROPSMj * (1 - POWERDMORTj - CANALDMORTj) \qquad [7]$$

where $TOTRSURV_j$ is the proportion of the total yearly Spring Chinook run that survives by and through Wapatox Canal to continue migration down the Naches River on day j.

Appendix 2.D – Data Inventory – Yakima and Warm Springs

Item	File Name	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1	Other notes, issues or questions 2
1	YAKSAR.xls	Earl Weber		SARs from transported spring chinook and downriver stocks. (Time series start at different points for different rivers).	Spring chinook	Yakima, Snake River, Warm Springs	1983	1995			
2	Yakama_Run-Recon.xls	Earl Weber	Primary data were collected and processed by the Yakama Nation's Fisheries Program.	Annual estimates of the number of spawning adults and the numbers caught by the Tribe in the Yakama River. Fish were also sampled to determine their ages. Data for two stocks, the upper Yakama stock and the Naches/American River stock, were processed separately. The end result of initial processing was annual, age specific estimates of spawners for brood years 1982 through 2001, to the mouth of the Yakama River for the two stocks. Regional fisheries assessment models typically assume a moderate level of prespawning mortality (10%) thought to occur between the mouth (of the Yakama in this case) and the spawning grounds. Spawning escapements are presented both with and without assumed prespawning mortality for the sake of flexibility.	Spring chinook	2 stocks: Upper Yakama and Naches/American River stock	1982	1997 (returns) 2001 (spawners)	Data for 1998 should be available, as well as most of 1999 (except for 5 yr olds)	Estimating the number of spawning adults that arrived at the mouth of the Columbia River required two additional pieces of information: **mainstem harvest rates and conversion rates**. Harvest rates in zones one through six are estimated annually by the Pacific Salmon Commission's Technical Advisory Committee (TAC). Conversion Rates (upstream adult survival through the dams) was calculated by Oregon Department of Fish and Wildlife (E. Tinus, pers. comm.)	Results appear in a spreadsheet entitled "Yakama_run_recon.xls". The two stocks appear in separate tabs. The source of the Yakama fisheries data is a spreadsheet entitled: "SpCkDataBase2.xls". (item 11) Harvest and conversion rates came from a spreadsheet entitled: "REVIEW DRAFT EDTsck2001~mainstem6_7_2002.xls"

Item	File Name	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1	Other notes, issues or questions 2
3	en1204_YakimaCaseHist3.doc		US Fish and Wildlife Service Columbia River Fisheries Program Office 9317 NE Highway 99, Suite I Vancouver, Washington 98665	Annual summary of bull trout spawning surveys in the Yakima core area, 1984 - 2001 (see Table 1). Yakima Basin Case History for Bull Trout. A case history for the Yakima River has been developed to provide some background and context for exploring bull trout monitoring and evaluation issues. The document provides information on the geography, bull trout biology, historic and current distribution, and reasons for decline.	Bull Trout	Ahtanum Creek, Naches River, Rimrock Lake, Bumping Lake, North Fork Teanaway River, Cle Elum Lake, Kachess Lake, and Keechelus Lake.	1984	2001		Eight bull trout populations were identified in the Yakima River basin (USFWS 1998). These populations included; Ahtanum Creek, Naches River, Rimrock Lake, Bumping Lake, North Fork Teanaway River, Cle Elum Lake, Kachess Lake, and Keechelus Lake. At the time of listing (June 1998), only the Rimrock Lake population was considered stable and increasing.	
4	en1204_USFWS PPT Yakima Bull Trout.ppt		Eric Anderson	Yakima Basin Bull Trout: Case History (presentation)	Bull Trout						
5	Schwartzberg-Yakima-Wenatchee-redd ct.tif	Dale McCullough		redd count information and brief description of redd count survey methodology	Spring chinook, fall chinook p. 13 (but for fewer sites)	Yakima mainstem, Cle Elum, Naches, Bumping, American	1960	1984	Data need to be put into spreadsheet. Counts for specific index sites/reaches often very sporadic.	Need expansion factors	
6	Yakima-stock summary report.tif	Dale McCullough		A spring chinook salmon stock summary report. Total abundance estimates (escapement + harvest). Some tidbits on age composition. Provides tidbits on changes in estimation methods (e.g., expansion factors for redd counts). **Egg-to-smolt and smolt-to-adult survival estimates for 7 brood years (1981 to 1987). Hatchery release information (p.21).**	spring chinook, fall chinook, coho, summer steelhead	American, Naches, Upper Yakima	1957	1990	Data need to be put into spreadsheet.		

Item	File Name	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1	Other notes, issues or questions 2
7	Redds1980toDate.xls	Joel Hubble		Spring chinook redd counts	spring chinook	**Upper Yakima** (Keechelus Dam to Easton Dam, 7.5 mi.* Easton Dam to Game Ramp, 6.4 mi. Game Ramp to Freeway Br., 4.6 mi. Hatchery Slough Freeway Br. To S. Cle Elum Br., 7.9 mi. S. Cle Elum Br. to Teanaway River, 7.0 mi Teanaway to Thorp Br., 10.7 mi. Thorp Br. To KOA, 9.5 mi. KOA to Roza Dam, 24.9 mi. Roza Dam to Selah Br., 4.9 mi.** Cle Elum River Teanaway River Manastash Cr. Yakima below Naches) **and Naches Rivers**	1980	2002		Already in spreadsheet format	
8	Prosser & ROZA SPCK DAILY COUNTS ALL YEARS.xls	Joel Hubble		Daily roza dam (fish trap) passage counts with hatchery (marked)/wild (unmarked) estimates for 2000+	spring chinook	Roza Dam (Yakima mainstem, central basin)	1992	2002	Definition of: "WASCK HACSK WJSCK HJSCK"		
9	IntColstatusrevdata2.xls	Chris Toole (anonymously)	Tom Cooney	historical returns, hatchery fraction and age structure for salmon in the Upper Columbia River systems	spring chinook, fall chinook, steelhead	Middle Columbia, Upper Columbia (including Wenatchee), Snake	varies (some as far back as 1958)	2001			
10	ucsp&sthdfile.xls	Tom Cooney		historical natural estimates of spawners, hatchery fraction, and age structure for salmon in the Upper Columbia	spring chinook, steelhead	Wenatchee, Methow, Entiat,above Wells	chinook (1960, steelhead (1976)	2001			
11	SpCkDataBase.xls	Bill Bosch		Yakima River run reconstructions	spring chinook	Yakima River	1982	2002			

Item	File Name	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1	Other notes, issues or questions 2
12	wssspch_sar.xls	Earl Weber		Warm Springs redd counts and outmigration estimates	spring chinook, fall chinook	Warm Springs	1969	2002	SARS estimates only between 1977 and 1995		
13	1-Humprey Trap Modeling_ew.xls	Bob Spateholts		Warm Springs redd counts and outmigration estimates	Spring chinook, Fall chinook	Warm Springs	1969	2002	Warm Springs River Spring Chinook Redd Counts and Outmigration Estimates for Wild Chinook by Brood Year 1975-2000		
14	cana_survival_prosser	Joel Hubble		Daily counts of smolt numbers passing Prosser Dam and associated entrainment and survival rates for smolts at Chandler Canal	spring chinook, steelhead, coho	Yakima River	1983	1998			
15	Rosa survs only v11	Charlie Paulsen	Joel Hubble	Survival rates for downstream migration of PIT tagged chinook smolts	chinook	Yakima River	1999	2003	limited time series of information, PITT tag detectors were not in place prior to this date		

Appendix 2.D – Data Inventory – Wenatchee

Item	File Name	Network Location	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1
1	Tumwater Dam Adult Salmon Fish Counts	hard-copy only - in "Wenatchee folder" in Clint's filing cabinet	Chuck Peven		Tumwater Dam counts 1935-37, 1954-1959, 1964-67, 1988-1991	Chinook, steelhead, blueback	Tumwater dam	1935	1991		Rough paper copy data sheets, some hand-written
2	QAR steelhead smolt production potential_methods.wpd ;"GAFM" Parr production estimates	hard-copyin "Wenatchee folder" in Clint's filing cabinet + "N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\QAR steelhead smolt production potential_methods.wpd"		Tom Cooney	Memo discussing estimates of steelhead smolt production potentials for mid-Columbia tributaries (based on spreadsheet models and conversations with Larry Brown). Some interesting steelhead age estimates for Rock Island Dam and estimates of parr-to-smolt (overwinter) survival rates.	Steelhead	Methow/Wenatchee, Entiat	n/a	n/a	Do we want to pursue the GAFM model(s)?	
3	ucsthd1.xls	"N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\"	Tracy Hillman		Mid Columbia Steelhead Spreadsheet: steelhead SARs. Includes brood table information, escapement, hatchery/wild information and stock-recruitment assessment information (i.e., Ricker/B-H model fits).	Steelhead	?	1981	1996		
4	Wenatchee spring chinook run reconstruction_wenss.xls	"N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\Wenatchee River\"	Tom Cooney		Wenatchee spring/summer chinook run reconstruction.	Spring/ Summer Chinook	Wenatchee River	1960	1998		This spreadsheet is reasonably well documented (relative to ucsthd1.xls)
5	Historical Redd Counts Wenatchee_APPDX2_02.xls	"N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\Wenatchee River\"	Chuck Peven		Historical tributary specific spawner and redd counts	Spring chinook	Various tributaries: Nason, little Wenatchee, White River, Chiwawa, Icicle	1954	2002	Changes in agencies and survey methods over time. What years constitute time frames when survey methods were generally the same?	Reformat (so years are rows, not columns, and locations are columns)
6	Description of Spawning Ground Surveys_SPWNSV01.doc	"N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\Wenatchee River\"	Chuck Peven		Spring and Summer Chinook Spawning Ground Surveys on the Wenatchee River Basin, 2001. Describes redd survey methods used in 2001 for several tributaries.	Spring/Summer chinook	Several tributaries	2001	2001		

Item	File Name	Network Location	Provided by 1	Provided by 2	Description	Primary Species	Locations	Start Year	End Year	Questions/Issues	Other notes, issues or questions 1
7	Methow natural spring chinook run reconstruction_metss.xls	N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\Methow River\	Chuck Peven		Methow spring/summer chinook run reconstruction.	Spring/Summer Chinook					Some of the graph titles and headings in the spreadsheet say Wenatchee, but shouldn't these be "Methow"?? >> Cohort Analysis worksheet is for Methow population.
8	Chiwawa Data.xls	N:\en1263\Databases\DataInventory\Wenatchee & Mid Columbia\Chiwawa stuff from Tracy Hillman	Tracy Hillman		Numbers of redds, eggs, and age-0 chinook salmon, and percent egg-parr survival in the Chiwawa River Basin, 1991-2002. Numbers of eggs were calculated as the number of redds times 4600 eggs per female. + Estimated numbers of juvenile (age-0) chinook salmon in the Chiwawa River Basin. + Some information on proportion of chinook in different habitat types (pools, riffle, mid-channel..)	Mostly chinook/ some steelhead juvenile abundance data	Chiwawa basin	1991	2002	Need to ascertain sampling methodology. gSee item 9.	
9	Abundance and Total Numbers of Chinook salmon and trout in the Chiwawa River Basin, Washington, 2002	hard-copy only - in "Wenatchee folder" in Clint's filing cabinet	Tracy Hillman	M.D. Miller							This is the report that accompanies item 8. Part of a 10 year study of the impact of hatchery supplementation on production of juvenile chinook in the Chiwawa Basin. There's quite a bit of data in this report starting on p.20.
10	Schwartzberg-Yakima-Wenatchee-redd ct.tif	N:\en1263\Databases\DataInventory\Yakima Data	Dale McCullough		redd count information and brief description of redd count survey methodology	Spring chinook (p.16), summer chinook (p.19 but fewer sites)	Wenatchee River, Icicle River, Chiwawa, White, Little Wenatchee, Nason	1961	1984	Data need to be put into spreadsheet	

Appendix 2.E – Sensitivity Analyses

Table 2E.1. Smolt/spawner model sensitivity analysis (Yakima treatment – Warm Springs control). Environmental covariates are unchanged, but sensitivity is evaluated for 1) varying smolt/spawner numbers in pre and post screening years; and 2) inclusion/exclusion of BY82 (highest fish productivity year). Base pre-screening years for simulated smolt/spawner adjustments are represented either by 1982-1984 (first fish screens constructed in 1985) or by 1982-1992 (last fish screen constructed in 1993). Model estimates are based on the full fitted model, *Sc* coefficients (with 95% confidence intervals) are based on bootstrapped estimates (2500 iterations). Significant positive values of the *Sc* coefficient are bolded.

N	Database Adjustment	Smolt/spawner Adjustment	Regression p-value	Regression R^2	*Sc* p-value	Bootstrapped *Sc* coefficient (95% CI)
Base Data						
37	none	base	0.05	0.41	0.29	-1.42 (±0.26)
35	BY82 deleted	base	0.11	0.36	0.92	0.37 (±0.33)
Pre-screening BY 1982-1984						
37	none	0.50*base (BY 82-84)	0.09	0.36	0.97	0.57 (±0.24)
37	none	0.25*base) (BY 82-84)	0.10	0.35	0.31	2.54 (±0.25)
37	none	0.125*base (BY 82-84)	0.06	0.39	**0.05**	**4.42 (±0.30)**
Pre-screening BY 1983-84						
35	BY82 deleted	0.50*base (BY 83-84)	0.10	0.37	0.36	2.50 (±0.29)
35	BY82 deleted	0.25*base (BY 83-84)	0.06	0.40	0.09	4.73 (±0.25)
35	BY82 deleted	0.125*base (BY 83-84)	0.03	0.45	**0.02**	**6.91 (±0.30)**
Prescreening BY 1982-1992						
37	none	0.50*base (BY 82-92)	0.07	0.38	0.92	0.59 (±0.34)
37	none	0.25*base (BY 82-92)	0.03	0.43	0.48	2.52 (±0.41)
37	none	0.125*base (BY 82-92)	0.01	0.50	0.19	4.61 (±0.53)
Prescreening BY 1983-1992						
35	BY82 deleted	0.50*base (BY 83-92)	0.07	0.40	0.37	2.94 (±0.43)
35	BY82 deleted	0.25*base (BY 83-92)	0.02	0.47	0.13	5.34 (±0.53)
35	BY82 deleted	0.125*base (BY 83-92)	0.01	0.55	**0.05**	**8.09 (±0.64)**

Average smolts/spawner estimated for Yakima River stocks:

1982-84 = 173
1983-84 = 117
1985-2000 = 66
1982-1992 = 75
1993-2000 = 94

Table 2E.2. Smolt/spawner model sensitivity analysis (Yakima treatment – Warm Springs control) Environmental covariates are unchanged, but sensitivity is evaluated for: 1) varying smolt/spawner numbers in pre and post screening years, 2) simulated sharpening of screen effect contrasts, and 3) inclusion/exclusion of BY82 (highest fish productivity year). Base pre-screening years for simulated smolt/spawner adjustments are represented either by 1982-1984 (first fish screens constructed in 1985) or by 1982-1992 (last fish screen constructed in 1993). Model estimates are based on the full fitted model, *Sc* coefficients (with 95% confidence intervals) are based on bootstrapped estimates (2500 iterations). Significant positive values of the *Sc* coefficient are bolded

N	Database Adjustment	Smolts/spawner Adjustment	*Sc* adjustment	Regression p-value	Regression. R^2	*Sc* p-value	Bootstrapped *Sc* coefficient (95% CI)
Base Data							
37	none	base	none	0.05	0.41	0.29	-1.42 (±0.26)
35	BY82 deleted	base	none	0.11	0.36	0.92	0.37 (±0.33)
Base Data, Simulated Smolt/Spawner Adjustments (pre vs. post screen), Screen Effect Sharpened							
Pre-screening BY 82-84							
37	none	base	BY82-84 = 0 BY85-2000 = 1	0.03	0.42	0.13	-0.74 (±0.05)
37	none	0.5*base (BY 82-84)	BY82-84 = 0 BY85-2000 = 1	0.09	0.36	0.79	-0.10 (+0.05)
37	none	0.25*base (BY 82-84)	BY82-84 = 0 BY85-2000 = 1	0.01	0.35	0.32	0.59 (±0.05)
37	none	0.125*base (BY 82-84)	BY82-84 = 0 BY85-2000 = 1	0.04	0.4	**0.03**	**1.26 (+0.05)**
Pre-screening BY 82-92							
37	none	base	BY82-92 = 0 BY93-2000 = 1	0.06	0.39	0.50	0.14 (±0.06)
37	none	0.5*base (BY 82-92)	BY82-92 = 0 BY93-2000 = 1	0.01	0.47	**0.04**	**0.83 (±0.07)**
BY82 Deleted, Simulated Smolt/Spawner Adjustments (pre vs. post screen), Screen Effect Sharpened							
Pre-screening BY 83-84							
35	BY82 deleted	None	BY83-84 = 0 BY85-2000 = 1	0.06	0.37	0.37	-0.46 (±0.04)
35	BY82 deleted	0.5*base (BY 83-84)	BY83-84 = 0 BY85-2000 = 1	0.13	0.35	0.84	0.16 (±0.04)
35	BY82 deleted	0.25*base (BY 83-84)	BY83-84 = 0 BY85-2000 = 1	0.11	0.37	0.22	0.77 (±0.05)
35	BY82 deleted	0.125*base (BY 83-84)	BY83-84 = 0 BY85-2000 = 1	0.05	0.42	**0.03**	**1.37 (±0.07)**
Pre-screening BY 83-92							
35	BY82 deleted	None	BY83-92 = 0 BY93-2000 = 1	0.06	0.40	0.20	0.50 (+0.05)
35	BY82 deleted	0.5*base (BY 83-92)	BY83-92 = 0 BY93-2000 = 1	0.01	0.51	**0.01**	**1.18 (±0.05)**

Table 2.E3. Smolt/spawner model sensitivity analysis (Yakima treatment – Warm Springs control). Environmental covariates unchanged, but sensitivity to: 1) simulating an increase in the pre-screening time series to 6, 9, or 12 years (existing data) or 4, 8 or 12 years (BY82 deleted), 2) inclusion/exclusion of BY82 (highest fish productivity year), and 3) varying smolt/spawner numbers in pre and post screening years. Base pre-screening years for simulated smolt/spawner adjustments are represented here only by 1982-1984 (3 years of data that exist prior to first fish screen construction in 1985). Simulated increases in the time series is based on multiple repeats of the limited sequence of prescreen years. Model estimates are based on the full fitted model, Sc coefficients (with 95% Confidence intervals) are based on bootstrapped estimates (2500 iterations). Significant positive values of the *Sc* coefficient are bolded.

N	Database Adjustment	Smolt/spawner Adjustment	Pre-screening time series	Regression p-value	Regression R^2	*Sc* p-value	Bootstrapped *Sc* coefficient (95% CI)
37	none	base	base (3 yrs)	0.05	0.41	0.29	-1.42 (±0.26)
35	BY82 deleted	base	base (2 yrs)	0.11	0.36	0.92	0.37 (±0.33)
Base Data, Pre-screen Time Series Increased							
43	none	base	6 yrs	<0.01	0.44	0.09	-2.29 (±0.13)
49	none	base	9 yrs	<0.001	0.49	0.03	-2.47 (±0.10)
55	none	base	12 yrs	<0.001	0.54	0.01	-2.54 (±0.08)
BY82 Deleted, Pre-screen Time Series Increased							
39	BY82 deleted	base	4 yrs	0.06	0.37	0.80	-0.75 (±0.22)
47	BY82 deleted	base	8 yrs	<0.01	0.39	0.63	-1.29 (±0.18)
55	BY82 deleted	base	12 yrs	<0.001	0.42	0.36	-1.52 (±0.17)
2 Fold Difference in Smolt/Spawners (Pre vs. Post Screening), Pre-screen Time Series Increased							
43	none	0.5*base (BY 82-84)	6 yrs	0.04	0.36	0.74	-0.14 (±0.17)
49	none	0.5*base (BY 82-84)	9 yrs	0.01	0.37	0.59	-0.45 (±0.16)
55	none	0.5*base (BY 82-84)	12 yrs	<0.01	0.38	0.47	-0.54 (±0.13)
39	BY82 deleted	0.5*base (BY 83-84)	4 yrs	0.13	0.32	0.65	1.12 (±0.27)
47	BY82 deleted	0.5*base (BY 83-84)	8 yrs	0.07	0.30	0.80	0.39 (±0.20)
55	BY82 deleted	0.5*base (BY 83-84)	12 yrs	0.03	0.29	0.87	0.21 (+0.18)
4 Fold Difference in Smolt/Spawners (Pre vs. Post Screening), Pre-screen Time Series Increased							
43	none	0.25*base (BY 82-84)	6 yrs	0.06	0.33	0.28	1.88 (±0.17)
49	none	0.25*base (BY 82-84)	9 yrs	0.03	0.33	0.26	1.30 (±0.11)
55	none	0.25*base (BY 82-84)	12 yrs	<0.01	0.40	0.24	1.23 (±0.09)
43	none	0.125*base(BY82-84)	6 yrs	0.02	0.39	**0.02**	**3.73 (±0.18)**
39	BY82 deleted	0.25*base (BY 83-84)	4 yrs	0.12	0.32	0.64	1.05 (±0.28)
47	BY82 deleted	0.25*base (BY 83-84)	8 yrs	<0.01	0.41	**0.02**	**4.47 (±0.16)**

It should be noted that these tables represent only the initial template for a full sensitivity analysis on this data. Further work is required to explore how power/precision might change by varying particular design features such as:

1. Increasing the effect size (e.g., given the observed variation prior to the onset of some habitat action, how large would an effect have to be to achieve a specified level of statistical power?).
2. Changing the pattern of Before and After years of data (e.g., 10/10, 5/10, 10/5, etc.). An advantage of monitoring a suite of treatment-control pairs is that we can then estimate the common year effects, which can increase precision and statistical power.

3. Relationship of an Index of Egg-to-Parr Survival Rates to the Number of Habitat Restoration Actions in Watersheds of the Salmon River Sub-basin

(Ian J. Parnell)

3.1 Abstract

The many habitat restoration projects implemented in the Salmon River sub-basin since the early 1980s provide few examples of project effectiveness in terms of increased salmon survival rates. This is due to lack of coordinated implementation of projects, controls, and monitoring designs that fail to account for the high variability and confounding inherent in biological data. Multi-watershed retrospective models that explicitly account for the spatial and temporal pattern of projects and include project-independent data provide an opportunity to account for these shortcomings. We used historical data to develop a chinook egg-to-parr survival rate index for several tributaries in the Salmon River subbasin with contrast in the pattern of habitat actions and tested the hypothesis that higher egg-to-parr survival rates are associated with more habitat actions. We used information-theoretic methods to rank a set of 52 log-linear multi-stock regression models that accounted for density dependence, common brood year effects, fecundity, seasonal flow, and habitat actions. The top four models included the habitat index, had similar coefficients (0.22–0.29), and accounted for 82% of the relative probability. Our results suggest that more habitat actions are associated with higher egg-to-parr survival rates, but do not provide insight about the relative effectiveness of particular classes of habitat actions.

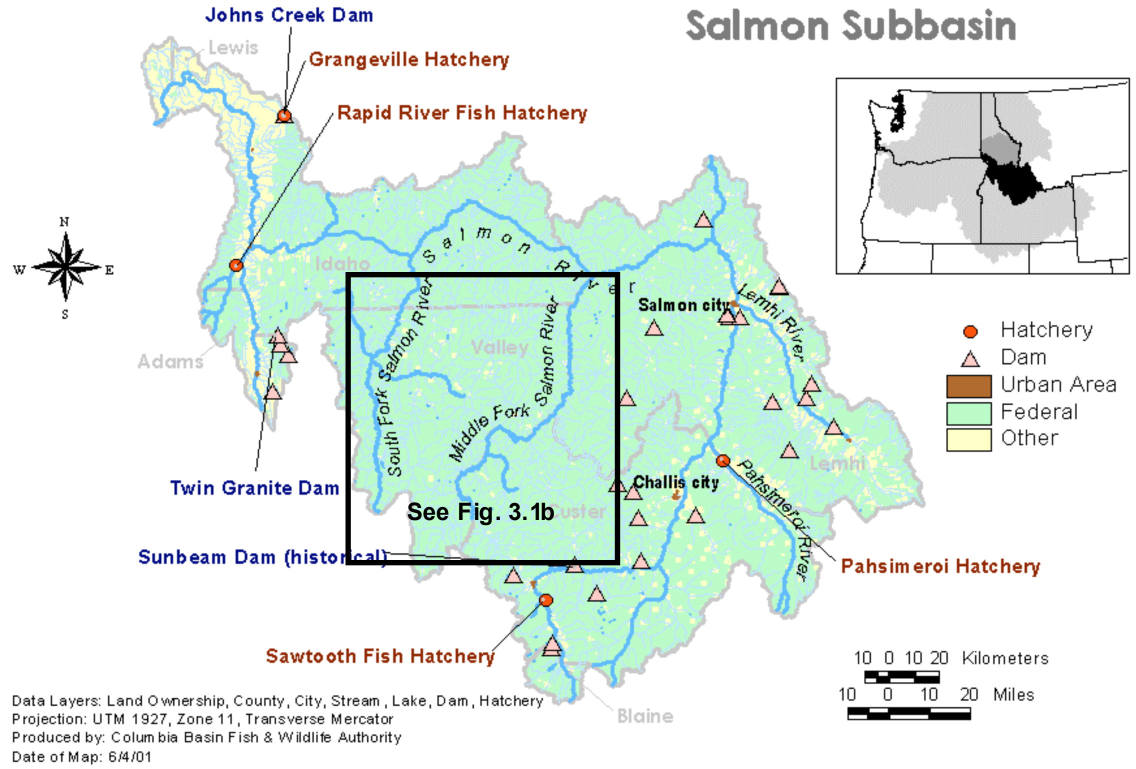
3.2 Introduction

Survival rates for the spring-summer chinook populations of the Snake River basin plummeted after the early 1970s (Schaller et al. 1999), with a consequent decline in adult abundance. These declines followed the creation of four lower Snake River dams, and were concurrent with increased barging of fish, increased hatchery production and poorer ocean conditions (Marmorek and Peters 2002). While the steepest declines in recent history occurred after 1975, the overall decline began much earlier under the impact of a variety of human activities, including the degradation and destruction of spawning and rearing habitat (NAP 1996). After the passage of the Northwest Power Act in 1980, Bonneville Power Administration (BPA) began funding habitat restoration projects to help offset the declines in salmon survival rates resulting from the construction and operation of the dams under the Northwest Power Planing Council's (NWPPC) Columbia River Basin Fish and Wildlife Program (Lee 1993). Since then, at least 164 habitat restoration/maintenance projects have been implemented in the Salmon River subbasin alone (T. Fisher, unpublished data).

The implicit hypothesis behind habitat restoration is that better quality spawning and rearing habitat is better for salmon. However, despite abundant evidence that habitat restoration actions can improve the habitat components that managers believe are important for fish (e.g., Platts et al. 1989) there is only sparse quantitative evidence showing that these actions also increase survival rates (e.g., Roni et al. 2002). Two reasons why this evidence is lacking are that historically most habitat projects were either implemented without monitoring programs or with poorly designed monitoring programs. Design weaknesses include equivocal indices of survival (e.g., density), inadequate accounting of high natural variability in indices of survival rate (e.g. pre-treatment monitoring period too short), lack of recognition of confounding factors (e.g., low seeding levels, redd location, multiple concurrent actions), poor logical construction (no controls, no before data), or not considering the time lags between project implementation and effectiveness (e.g., monitoring too short after implementation).

The NOAA Fisheries 2000 Federal Columbia River Power System Biological Opinion requires the Action Agencies (BPA, Bureau of Reclamation and Corps of Engineers) to demonstrate that the habitat restoration actions they fund meet their obligations towards the recovery of Columbia River salmon populations (BiOp 2000). To this end, a number of pilot studies have been designed to rigorously evaluate the effectiveness of particular habitat restoration actions (Jordan et al. 2003). However, much may also be learned through retrospective evaluation of historical data. We treated historical habitat projects as a poorly designed large-scale multi-watershed management experiment and used existing data sets to test hypotheses about whether historic habitat actions have increased chinook salmon survival rates (ESSA 2002). We seek to apply what we learn in the design of prospective actions.

Earlier research failed to find significant changes in freshwater survival rates (Petrosky et al. 2001). However this research used an aggregate spawner-to-smolt index of survival for the Snake River basin based on dam counts of spawners and adults, which may not be sensitive to tributary-scale effects. In this analysis we use retrospective data to test the tributary-scale hypothesis that historical habitat actions have increased spring-summer chinook egg-to-parr survival rates in the Salmon River subbasin (Figure 3.1a).


Salmon Subbasin

Data Layers: Land Ownership, County, City, Stream, Lake, Dam, Hatchery
Projection: UTM 1927, Zone 11, Transverse Mercator
Produced by: Columbia Basin Fish & Wildlife Authority
Date of Map: 6/4/01

Figure 3.1a. Salmon subbasin (Source: Huntington 2001). Box shows the geographic area included in this analaysis, see Figure 3.1b for more detail on tributaries.

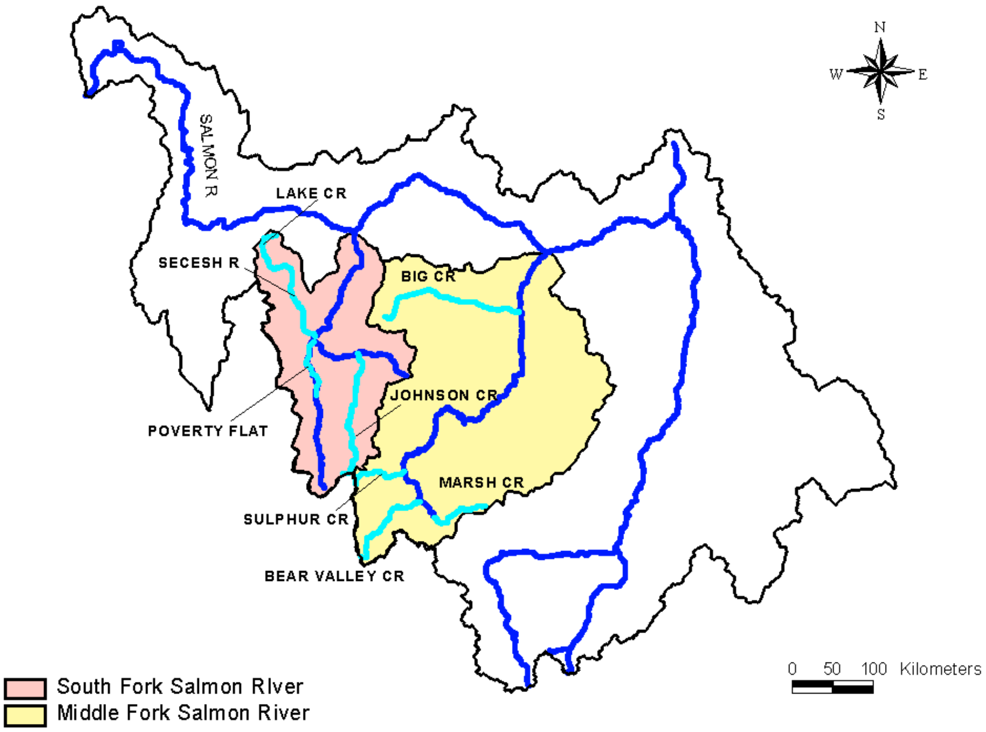


Figure 3.1b. Tributaries of the South Fork and Middle Fork Salmon River watersheds used in this analyses.

3.2.1 Study area

We used data for eight streams in the South and Middle Forks of the Salmon River subbasin that correspond to the spawner-recruit run reconstruction stocks that have been used in other analyses (Beamesderfer et al. 1997, Schaller et al. 1999) (Figure 3.1b). The streams represent different levels of management impact, habitat condition and habitat restoration and thus provide a range of contrasts in both the timing of actions and level of impact prior to actions taking place. Using multiple watersheds also allows us to explore statistical methods for removing common sources of variation and increase our chances of detecting the effects of habitat actions.

The South Fork Salmon River (SFSR) watershed has been heavily managed with both land-use impacts and hatchery influences on summer chinook stocks (Beamesderfer et al. 1997). Some spawning and rearing sites were heavily impacted by sedimentation from logging-induced slope failures in the mid 1960s (e.g., Seyedbageri et al. 1987, Platts et al. 1989, Megahan et al. 1990). Management actions since that time include a logging moratorium and the development of best management plans for logging. We used parr density, redd density and habitat data for Poverty Flat (mainstem SFSR), Johnson Creek (a tributary to the East Fork, South Fork Salmon River), Secesh River (a tributary of the SFSR) and Lake Creek (a tributary of the Secesh River).

The Middle Fork Salmon River (MFSR) is considered to be primarily wilderness (Beamesderfer et al. 1997). Its tributaries provide spawning and rearing habitat for the last remaining runs of wild spring chinook salmon in Idaho. Much of this habitat is in pristine condition and there are no hatchery impacts. There have been localized impacts in some tributaries, such as placer mining and grazing related impacts in the Bear Valley Creek watershed with subsequent habitat restoration actions by the Shoshone Bannock Tribes (SBT) and US Forest Service (USFS). We used parr density, redd density and habitat data for Big Creek, Bear Valley/Elk Creek, Sulphur Creek and Marsh Creek.

3.3 Methods

We developed an index of egg-to-parr survival rate for the eight streams along with a suite of independent variables chosen to account for factors that may drive common patterns of variation in egg-to-parr survival rates, or which may mask or be confounded with the effects of habitat actions. We then constructed a set of log-linear regression models using different combinations of the independent variables.

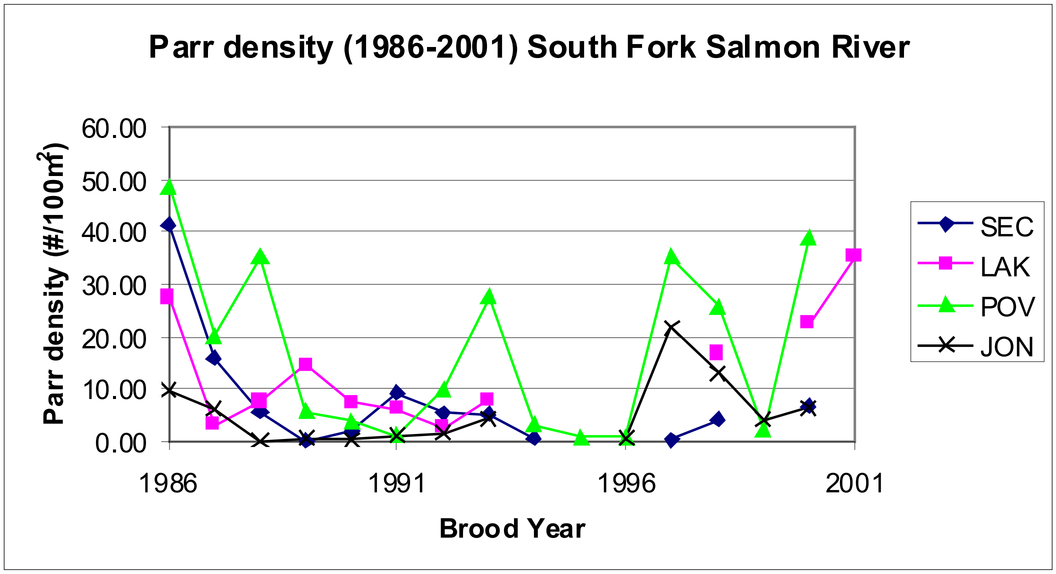
3.3.1 Indices

Dependent Variable

Index of egg-to-parr survival rate

Through consultation with regional habitat and fisheries managers and scientists, and our own review of the available data, we determined that the biological data sets with the most complete spatial and temporal coverage relevant to the development of indices chinook egg-to-parr survival rates were the Idaho Department of Fish and Game's (IDFG) General Parr Monitoring parr density database (Hall-Griswold and Petrosky 1996) and index redd count database (Hassemer 1993).

<u>General Parr Monitoring Data (1985-2002):</u> Each year, IDFG crews conduct summer parr snorkel counts on a limited number of sites within a set of core index streams (Hall-Griswold and Petrosky 1996). More sites and streams may be sampled in a given year if funding is available. Each site is classified by Rosgen channel type (Rosgen 1985) with the preferred rearing habitat of juvenile chinook being low gradient sinuous C channel habitat. For each stream we calculated the average 0+ chinook parr density (#parr/100m^2) over all C channel sites as close as possible to the index redd count reaches (Figure 3.2 and Appendix A). Summer parr counts are affected by variation in fry emigration rates, which may bias the survival rate index. For this analysis we could not estimate emigration rates directly, however, we did include indices that may influence fry emigration such as flow and redd density (see Independent Variables). If emigration is negatively correlated with rearing habitat quality, then emigration rates will be confounded with improvements in habitat due to habitat actions.



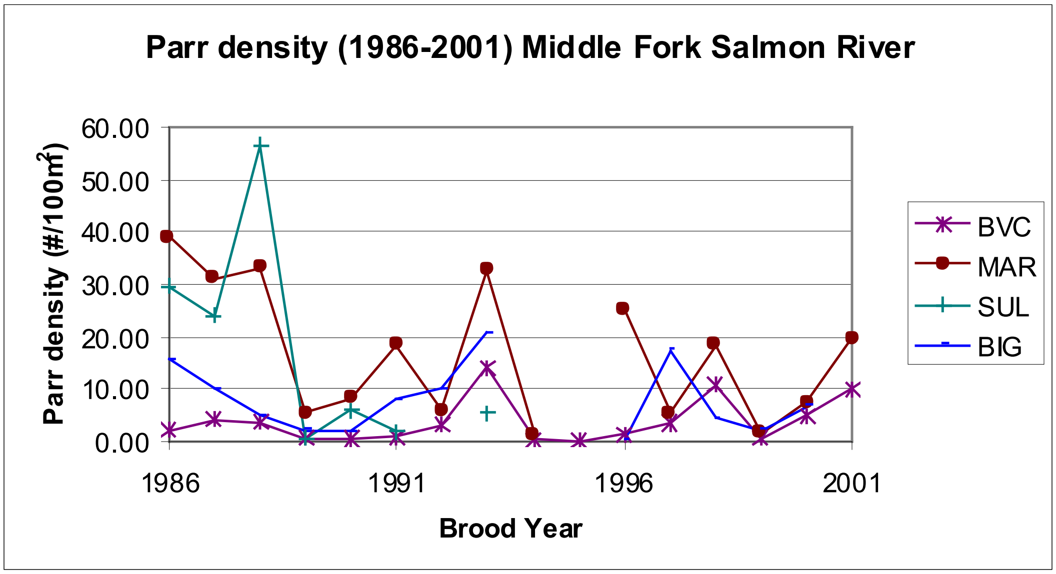
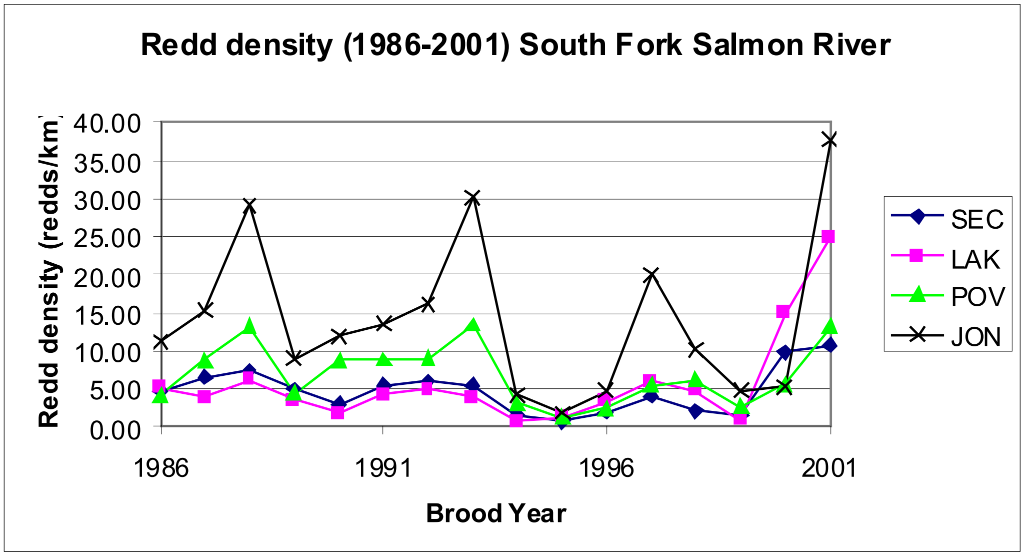


Figure 3.2. Time series of average parr densities (# parr/100m^2) for tributaries of the South Fork and Middle Fork Salmon River from brood year 1986 to 2001. South Fork: SEC = Secesh River; LAK = Lake Creek; POV = Poverty Flat; main stem SFSR; JON = Johnson Creek. Middle Fork: BVC = Bear Valley/Elk Creek; MAR = Marsh Creek; SUL = Sulphur Creek; BIG = Big Creek.

Redd Count Data (1957–2002): IDFG has completed index redd counts annually since at least 1957. These counts are conducted by reach on a large number of Idaho streams, and provide a primary component of the IDFG spring-summer chinook S-R run reconstruction data (Beamesderfer et al. 1997). We used total redd densities (#redds/km) as an index of female spawner abundance (one female per redd) and therefore also as an index of total egg deposition (Figure 3.3 and Appendix 3.B).



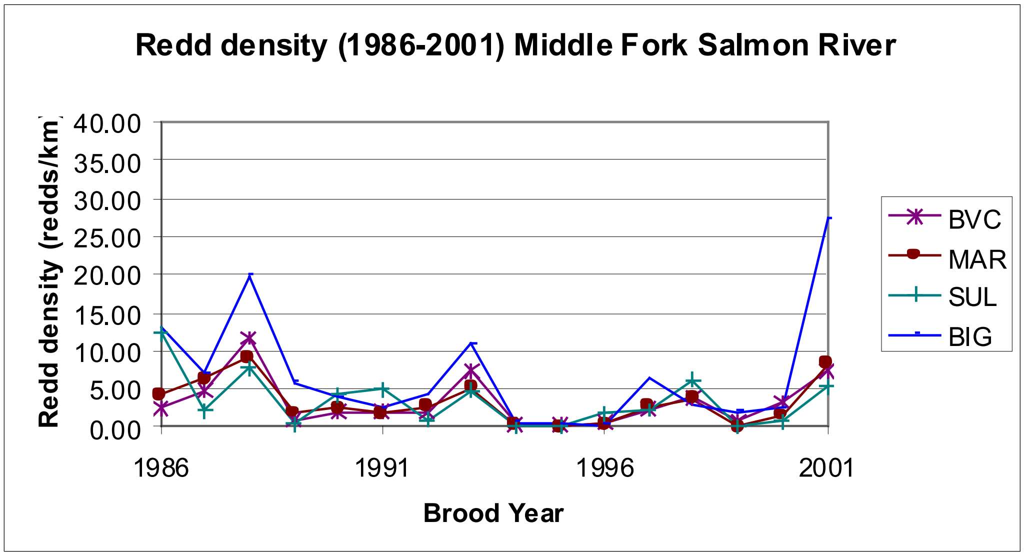


Figure 3.3. Time series of redd densities (redds/Km) for tributaries of the South Fork and Middle Fork Salmon River from brood year 1986 to 2001. South Fork: SEC = Secesh River; LAK = Lake Creek; POV = Poverty Flat; main stem SFSR; JON = Johnson Creek. Middle Fork: BVC = Bear Valley/Elk Creek; MAR = Marsh Creek; SUL = Sulphur Creek; BIG = Big Creek.

From the parr and redd density data we constructed our annual index of the egg-to-parr survival rate as the natural log of brood year parr density (P) to brood year redd density (R), Ln[P_t/R_{t-1}] (Figure 3.4 and Appendix 3.C) to better meet standard regression assumptions about normality (e.g., Peterman 1981, Bradford 1995). We used data for brood years 1986 to 2001 for which the data were most complete across streams (Table 3.1). We also used several ancillary data sets to supplement or cross-check assumptions about the relationship of GPM parr density and Index redd indices to other data sets with parr and redd counts (Appendix 3.D).

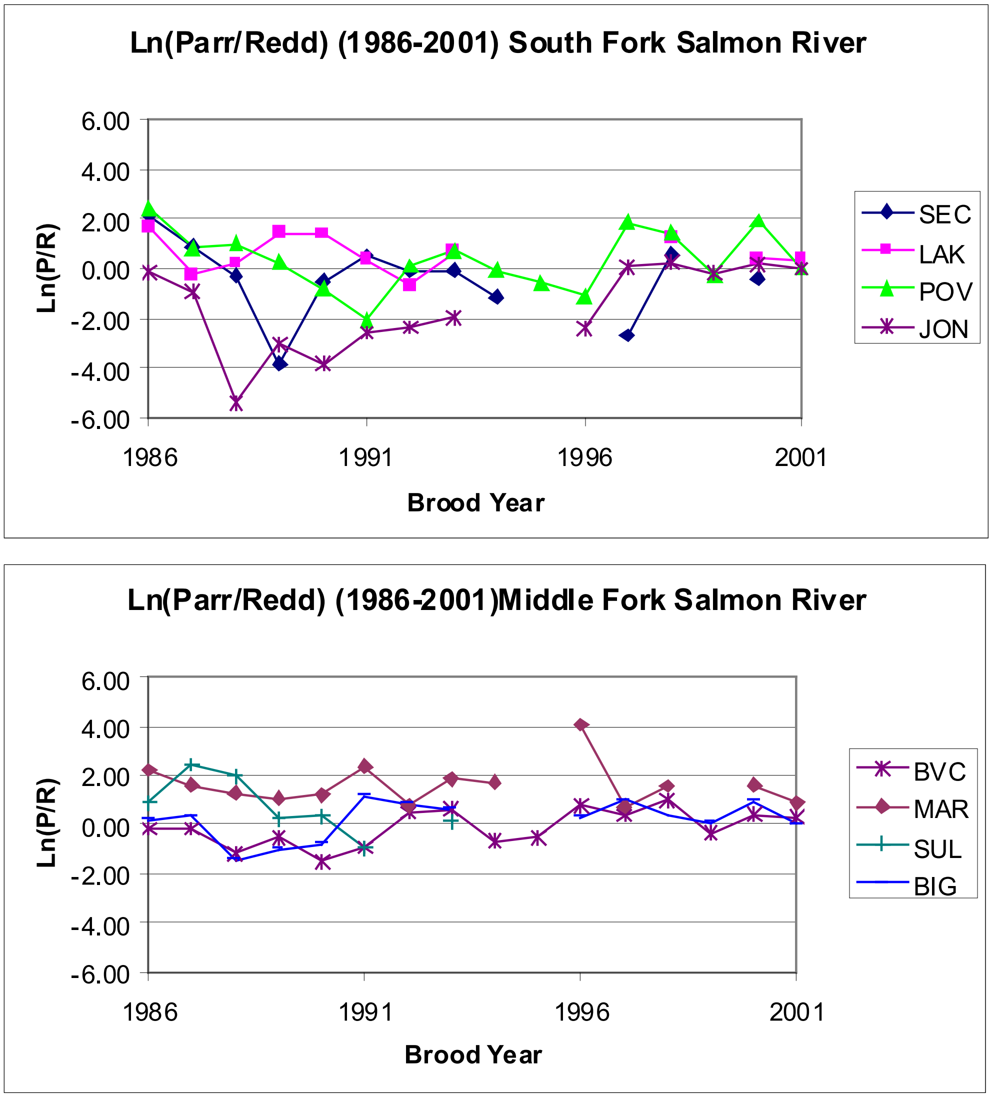


Figure 3.4. Time series of the unadjusted survival rate index (Ln(parr density/redd density) for tributaries of the South Fork and Middle Fork Salmon River from brood year 1986 to 2001. South Fork: SEC = Secesh River; LAK = Lake Creek; POV = Poverty Flat; main stem SFSR; JON = Johnson Creek. Middle Fork: BVC = Bear Valley/Elk Creek; MAR = Marsh Creek; SUL = Sulphur Creek; BIG = Big Creek.

Table 3.1. Raw survival rate index (Ln(parr density/redd density)) by tributary for 1986-2001. South Fork: SEC = Secesh River; LAK = Lake Creek; POV = Poverty Flat; main stem SFSR; JON = Johnson Creek. Middle Fork: BVC = Bear Valley/Elk Creek; MAR = Marsh Creek; SUL = Sulphur Creek; BIG = Big Creek.

BY	SEC	LAK	POV	JON	BIG	BVC	MAR	SUL
1986	2.14	1.67	2.43	-0.15	0.18	-0.17	2.21	0.88
1987	0.89	-0.24	0.82	-0.93	0.34	-0.18	1.59	2.45
1988	-0.27	0.20	0.98	-5.41	-1.42	-1.16	1.29	1.99
1989	-3.85	1.42	0.24	-3.04	-1.01	-0.51	1.06	0.22
1990	-0.52	1.40	-0.82	-3.82	-0.78	-1.52	1.21	0.35
1991	0.52	0.36	-2.07	-2.58	1.14	-0.93	2.38	-0.94
1992	-0.12	-0.66	0.11	-2.37	0.85	0.50	0.77	
1993	-0.09	0.67	0.71	-1.96	0.64	0.64	1.86	0.12
1994	-1.15		-0.07			-0.67	1.74	
1995			-0.59			-0.54		
1996			-1.10	-2.40	0.29	0.76	4.08	
1997	-2.69		1.84	0.08	0.99	0.38	0.72	
1998	0.58	1.24	1.41	0.23	0.38	0.99	1.57	
1999			-0.24	-0.18	0.07	-0.36		
2000	-0.39	0.40	1.92	0.19	0.95	0.42	1.59	
2001		0.34 .	.	.		0.30	0.86	

We assumed the parr counted in the GPM surveys arose only from the redds counted in the index redd surveys. The survival rate index will be upwardly biased if fry migrate from areas in the stream not included in the redd counts. This might occur if the index counts miss a substantial portion of spawning habitat and if redd distribution fluctuates with spawner abundance (e.g., Thurow 2000).

Independent Variables

The raw survival rate index could be considered an index of annual productivity (e.g., Shaller et al. 1999, Petrosky et al. 2001). This is because the annual survival rate may be confounded with several factors, such as density dependence effects, flow effects, and the effects of conditions outside of the systems that cause the average fecundity of females to fluctuate (e.g., age-at-return, size of spawners). These effects could mask habitat effects, so we tried to account for them by including them as covariates in our models.

Index of Density Dependence

A standard assumption in fisheries research is that juvenile survival rates may be negatively correlated with increasing juvenile abundance due to density dependent interactions such as intra-specific competition (e.g., Hilborn and Walters 1992). Increases in survival due to reduced juvenile abundance will be confounded with habitat effects. For example, if juvenile abundance declines over the same period that habitat projects are being implemented (e.g., due to lower adult returns) and this is not accounted for, increased survival rates would be attributed solely to the effects of habitat restoration. Therefore, to account for density dependent effects, we included redd density as an index of density dependence in our regression models.

A decline in redd density over time in the index reaches could mean either that spawner abundance has declined, or that there has been a shift in the core spawning areas. With respect to the latter, redd density may be confounded with changes in habitat conditions for locations not included in the redd count.

Indices of Hydrological Conditions

Variation in stream flow may affect the intensity of the interaction between egg-to-parr survival rates and other important physical and biological components (e.g., Bell et al. 2001), or bias the data used to prepare survival indices. For example, flow may buffer winter and summer water temperatures, control access to high quality off-channel rearing habitat, influence the risk of scour to redds, or vary the intensity of sedimentation. Additionally, it may bias annual survival rate estimates by leading to under counts of redds, or emigration of fry prior to summer parr counts. To account for flow effects we developed flow indices using data from the United States Geological Survey gauging stations closest to the streams used in this analysis (Table.3.2, Appendix 3.E). We assumed that the large-scale pattern of average seasonal flow for these gauges would reflect that for the streams in our analysis, although the magnitudes and finer-scale patterns would be different. We developed brood year specific indices for 'fall', 'winter' and 'freshet' periods, since flow may be an important factor for juvenile survival and/or abundance in each of these seasons (Figure 3.5).

The brood year 'fall' flow index is the average of the mean monthly September to October flows. We assumed that fall flows affected egg-to-fry survival rates by controlling sediment deposition and the risk of scour or desiccation to redds. One can hypothesize an inverse relationship between fall flows and survival rate where lower flows increase sediment deposition and decrease survival and higher flows increase scour and decrease survival, and survival is highest over some medium range of flows.

The brood year 'winter' flow index is the average of the mean monthly November to March flows. We assumed that low average winter flows increase the risk of the formation of anchor ice, which lowers egg-to-parr survival rates by freezing redds or making overwintering habitat (e.g., inter-cobble spaces) unavailable.

The brood year 'freshet' flow index is the average of the mean monthly May to July flows in the year following spawning. We assumed that freshet flows affect the emigration of juveniles from the systems (flushing) as well as the level of sedimentation in the spawning areas for that calendar year. They may also influence parr abundance estimates that do not account for off-channel habitat where juveniles may take refuge during high freshet flows.

Table 3.2. Gauges used to prepare flow indices (Source: United State Geological Survey website)

Stream used for	Gauge	Data	Comments
South Fork Salmon River Secesh River Lake Creek	USGS 13310700 SF SALMON RIVER NR KRASSEL RANGER STATION ID	1966-1982 1985-1986 1989-2002	
Johnson Creek	USGS 13313000 JOHNSON CREEK AT YELLOW PINE ID	1929-2002	The longest continuous time-series. It spans the period of the other series.
Bear Valley/Elk Creeks Marsh Creek Sulphur Creek Big Creek	USGS 13309220 MF SALMON RIVER AT MF LODGE NR YELLOW PINE ID	1973-1981 1999-2002	

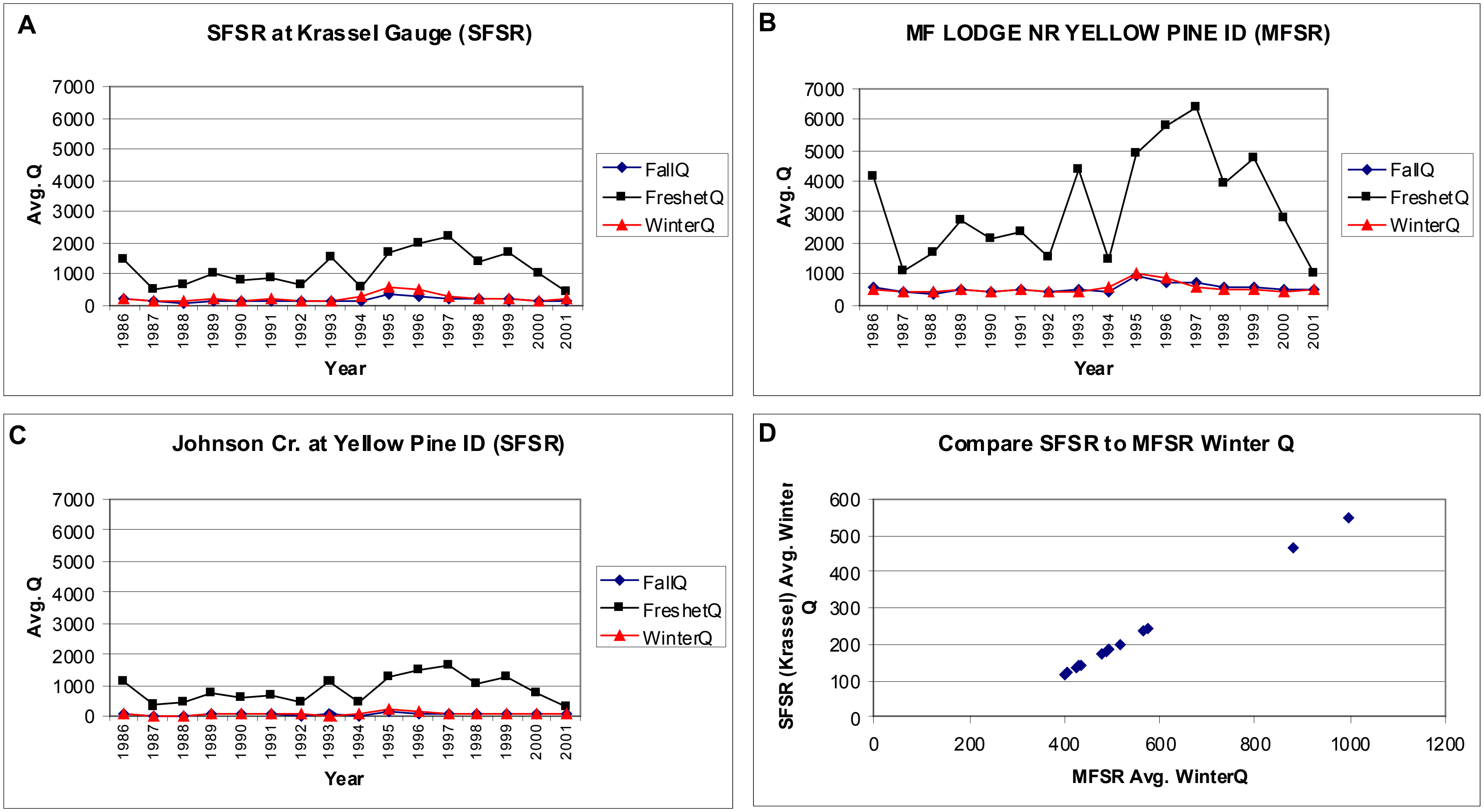


Figure 3.5. Flow indices used for this analysis. Panels A, B and C show the flow indices for Krassel, Middle Fork and Johnson Creek gauges respectively. Panel D shows an example XY plot of the Winter flow index (WINTERQ) for the Krassel vs. the Middle Fork gauge. (Source: US Geological Service data, http://waterdata.usgs.gov).

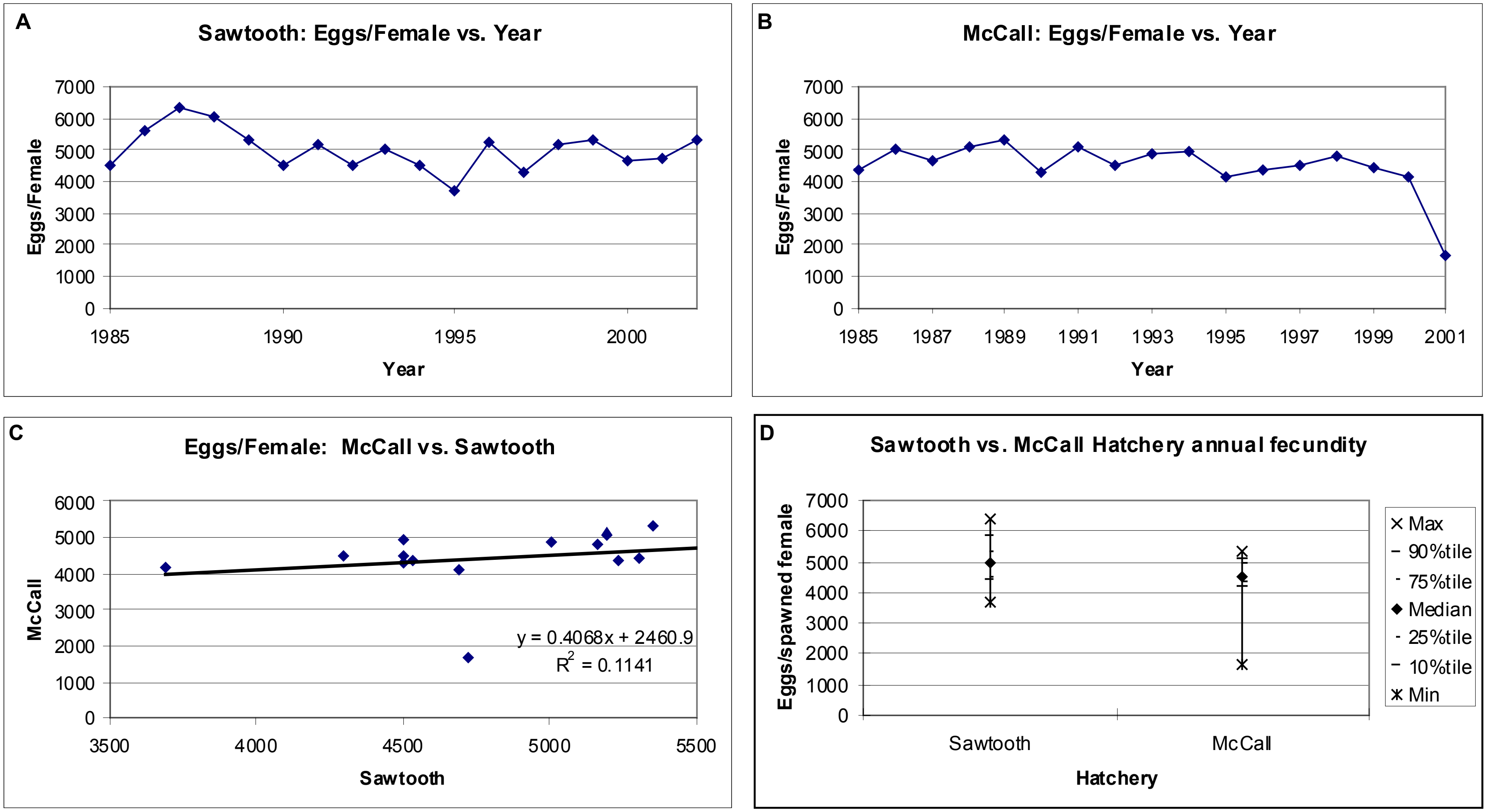


Figure 3.6. Hatchery fecundity (eggs/spawned female) for Sawtooth and McCall Hatcheries for brood years 1985 to 2001. Sawtooth hatchery collects predominantly Age 5 fish, like Middle Fork Salmon river; McCall hatchery collect predominantly Age 4 fish from the South Fork Salmon River. Panels A and B show the time series of hatchery fecundities. Panel C shows the relationship in fecundities between the two hatcheries. Panel D shows the distribution in fecundity for each hatchery as the maximum and minimum values, plus the 10th, 25th, 50th, 75th, and 90th percentiles; points are in the order shown on the legend. Note that 2001 value for McCall hatchery is probably an error, but this could not be confirmed at the time of this report. The Sawtooth datum for 1986was also incorrect but was corrected using the data from the original hatchery report obtained from the Streamnet library. (Data source: www.streamnet.org).

Index of Fecundity

The egg-to-parr survival rate is a function of not only the number of females, but also their fecundity, which may vary from year to year. Because the denominator of our survival rate index represents numbers of females only, a negative trend in fecundity could mask increasing egg-to-parr survival rates resulting from improved habitat conditions. To account for this possibility, we downloaded spring and summer chinook fecundity data (eggs/spawned female) for the Sawtooth and McCall hatcheries from Streamnet (www.streamnet.org) (Figure 3.6 and Appendix 3.F). The Sawtooth hatchery collects adult spring chinook at the Sawtooth weir in the upper salmon river. We used these fecundities to represent the fecundity of the MFSR wild spring chinook stocks, since the Sawtooth fish are similar in size and age of return (primarily age 5) to those of MFSR (e.g., Table 14 of Petrosky and Holubetz 1988). The McCall hatchery collects adult summer chinook (primarily age 4) at a weir within the South Fork Salmon River (upstream from Poverty Flat), so we used McCall fecundity to represent the fecundity of the SFSR summer chinook stocks (Poverty Flat, Johnson Creek, Secesh River, Lake Creek).

Mean fecundity over the time series was lower for SFSR than MFSR as would be expected based on their different mean age of return for the stocks in these two subbasins, but this difference was not significant (Appendix 3.F). Additionally, there was only a weak relationship between mean annual fecundity and proportion at age of return for the two hatcheries. This may be due to bias in the selection of fish at the hatcheries if, for example, hatchery staff select only the largest females for brood stock. There was a weak positive correlation in mean fecundity among the two hatcheries, suggesting that common factors affect fecundity for SFSR and MFSR stocks.

Index of spawner condition

Based on the weak relationship of fecundity with age-at-return, which suggests bias in hatchery fecundity estimates, and noting the weak positive relationship between mean fecundity for each hatchery, we hypothesized that mean fecundity may also be a function of conditions independent of age structure. For example, ocean or passage conditions might deplete the energy reserves available for egg production without necessarily affecting age-structure. To account for this we included an index of conditions experienced by the spawners that produced the parr in a particular brood year outside of the natal stream. This was the common brood year effect from the top weighted model in our Sp-Sp analysis (“BY index”) (Figure 3.7 and Appendix 3.G). We lagged the BY Index to match the conditions experienced by Age 4 (SFSR) or Age 5 (MFSR) fish that contributed to each year’s average fecundity. For the BY index, this was just the Brood year for the fish producing the brood year parr.

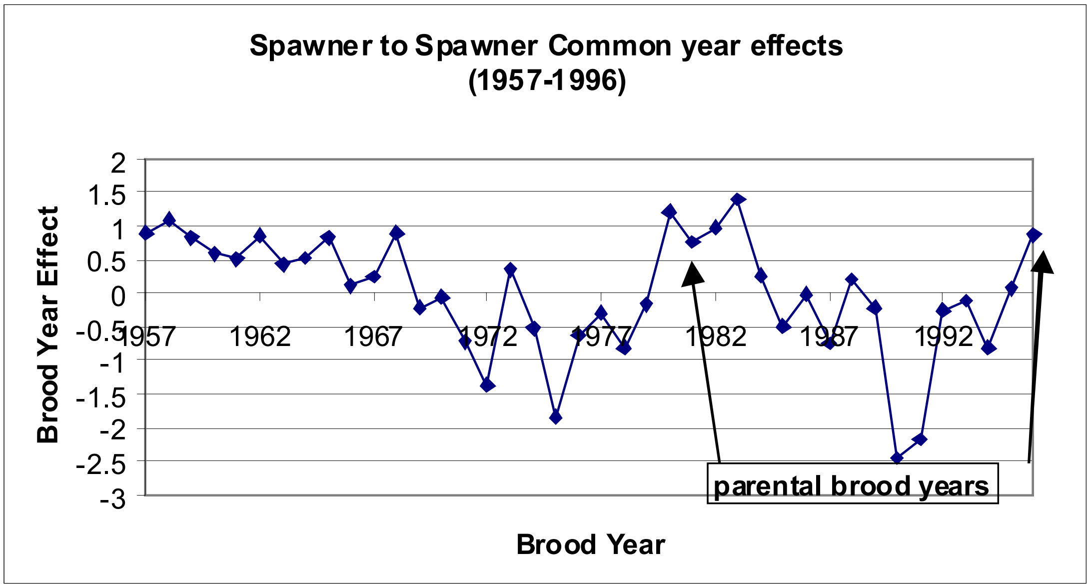
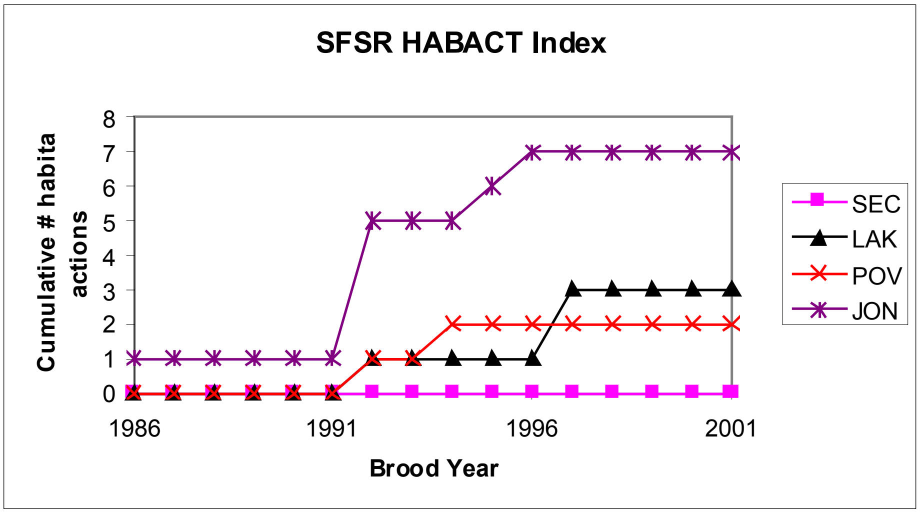


Figure 3.7. Parental (Spawner to Spawner) common brood year effects used as an index of adult condition in this analysis. The values from 1981 to 1996 are the values for the parental brood years of the spawners that produced the parr used in this analysis (parr brood years 1986-2001) assuming an average Age 5 return.

Index of habitat restoration actions

Through our workshops and data inventory period we reviewed a number of sources of habitat project information to try and develop suitable indices of habitat restoration actions (Table 3.3). We had hoped to use the habitat project information to develop several time-series of habitat indices. However, these data have rarely been collected. These limitations forced us to use a less informative habitat index: the cumulative number of habitat projects within a stream expected to positively impact egg-to-parr survival rates (T. Fisher, Fisher Fisheries, unpublished data, see also Chapter 4) (Figure 3.8). These data were originally classified by PIT tag location, which is at a finer spatial scale for some streams than we use for the parr density data, so we summed projects over streams where this occurred. We did this for the Marsh Creek complex (sum of Knapp Creek and Marsh Creek data, which was zero for Knapp Creek anyway) and for Bear Valley and Elk Creeks.



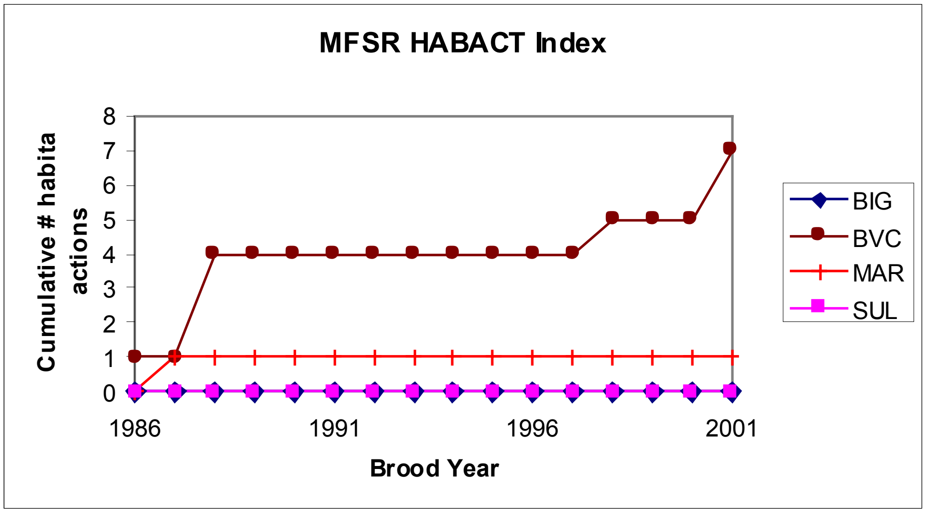


Figure 3.8. Cumulative number of habitat actions over time (HABACT index) for tributaries of the South Fork (SFSR) and Middle Fork (MFSR) for the period 1986 to 2001. South Fork: SEC = Secesh River; LAK = Lake Creek; POV = Poverty Flat; main stem SFSR; JON = Johnson Creek. Middle Fork: BVC = Bear Valley/Elk Creek; MAR = Marsh Creek; SUL = Sulphur Creek; BIG = Big Creek. (Source: T. Fisher, Fisher Fisheries, Ltd., unpublished data).

We also assigned habitat categories of two types. For one we subjectively assigned ratings of ‘high’, ‘low’, or ‘medium’ impact to streams based on our understanding from the literature we reviewed and discussions with habitat experts in our workshops. For the other, we set a switch to be ‘OFF’ in years there were no habitat actions, and ‘ON’ for every after the first action. Table 3.4 summarizes the full set of indices.

Table 3.3. Sources of information on habitat actions.

Source	Content
NPPC Subbasin Summaries	Tables in appendices listing projects.
BPA Project database	USFS proposal for work in Bear Valley Creek – lists expected benefits in terms of smolts.
	IDFG reports
	Shoshone-Bannock Tribe reports
	OEA reports for upper Salmon River and Middle Fork Salmon River.
NOAA Fisheries	Compilation of project information which draws on some of same sources.
Screening Project Database	
Miscellaneous reports and papers	Platts et al. 1989, Megahan et al. 1990. Timing and type of management actions to control sedimentation in the South Fork Salmon River.
	American Fisheries Society pamphlet on Bear Valley Creek, which describes changes to grazing allotments to protect riparian vegetation and banks.
2 Workshops	Anecdotal information provided by regional habitat and fisheries managers and scientists.

Table 3.4. Covariates and factors included in the models. '$' indicates a categorical variable.

Type	Variable	Definition	Source
Categorical	FORK$	Subbasin, 2 levels (i.e. SFSR, MFSR)	n/a
	STOCK$	Stock, 8 levels.	n/a
	BY$	Common brood year effect, 15 levels	n/a
	SEDCAT1$	Sediment category, 3 levels (high, medium, and low sediment impact)	Subjectively assigned based on literature comments about impacts to each stream.
	HABSTAT$	Habitat action status, 2 levels ("On" if projects present or "OFF" if projects absent).	Assigned based on data provided by T. Fisher, Fisher Fisheries (Figure 3.8).
Biological	ALLREDD	Redd density (#/km) for IDFG redd index counts over the reaches associated with S-R run reconstruction data set.	IDFG redd count data from Evan Brown, IDFG
	IDFG_PARR_D	IDFG C Channel parr densities for sites within or close to index redd count reaches	IDFG GPM parr density data from Judy Hall-Griswold, IDFG
	BYAGE4	Common brood year effects for 4 year old spawners.	Estimated from top Sp-Sp model
	BYAGE5	Common brood year effects for 5 year old spawners.	Estimated from top Sp-Sp model
	FECUNDITY	Eggs/spawned female	Derived from McCall and Sawtooth hatchery data available on Streamnet.org.
Hydrological	FALLQ	Average fall flow (Sep-Dec)	Derived from data available off the USGS website.
	FRESHETQ	Average freshet flow (May-Jul)	
	WINTERQ	Average winter flow (Nov-Mar)	
Habitat	HABACT	Cumulative number of habitat actions over time by stream.	Tim Fisher, Fisher Fisheries
	SEDCAT2	Qualitative rating of "High" or "Medium" or "Low" sediment impacts.	Subjectively assigned based on literature comments about impacts to each stream.

3.4 Models

We constructed a set of log-linear models, each with the same survival index as the dependent variable, but with different combinations of the independent variables shown in Table 3.4 and different assumptions about how the independent variables affected the stocks (e.g., stock-specific or common habitat effects). Our base model was the natural log-transformed Ricker production model (Ricker 1975), which accounted for density-dependent effects of redds density on the survival rate index (Eq 1):

$$\mathrm{Ln}(P/R)_{i,t} = a_i + b_i \times R_{i,t} + \varepsilon_{i,t} \qquad \text{(Eq. 1)}$$

where i is stock, t is brood year, a_i is stock specific density-independent natural productivity at low spawner abundance, b_i is the stock-specific density-dependent term (related to carrying capacity), P is parr abundance, R is redd density, and ε is a mixture of log-normally distributed random process and measurement error.

To account for factors that may influence egg-to-parr survival rates independently of habitat actions, or that may account for potential sources of bias, we considered variations on a base model of the general form shown in Eq. 2

$$\mathrm{Ln}(P/R)_{i,t} = a_i + b_i \times R_{i,t} + H_{i,t} + Y_t + \varepsilon_{i,t} \qquad \text{(Eq. 2)}$$

where "H" represents either a habitat covariate (i.e. the 'HABACT' or 'SEDCAT' covariates), or factor (i.e. the 'SEDCAT1$' or 'HABSTAT$' factors; Table 3.4) and "Y" represents common brood year effects. By accounting for common sources of variation we hoped to increase our power to detect stream-specific habitat effects. Similar models have been applied to spawner-recruit and parr-to-smolt survival data (e.g., Deriso et al. 2001, Paulsen and Fisher 2003), but to our knowledge this is the first time they have been applied to egg-to-parr survival data. We implemented the common year effect in two ways: (1) by estimating it from the data (BY_t in Eq. 4a, the parr brood year effect); or (2) by including biological (B) and/or physical (P) indices as covariates (Eq. 4b):

$$\mathrm{Ln}(P/R)_{i,t} = a_i + b_i \times R_{i,t} + H_{i,t} + BY_t + \varepsilon_{i,t} \qquad \text{(Eq. 4a)}$$

$$\mathrm{Ln}(P/R)_{i,t} = a_i + b_i \times R_{i,t} + B_{i,t} + P_{i,t} + H_{i,t} + \varepsilon_{i,t} \qquad \text{(Eq. 4b)}$$

We examined a set of 52 models that included models with and without a habitat index. We did this because we wanted to address other questions independently of habitat actions, such as the relative importance of common year effects, and different forms of the base production model (e.g., common a and b, common a different b's, etc). Support for the main hypothesis tested in this analysis would be a model that ranked highly based on the selection criterion, that included the habitat index with a habitat coefficient that was positive and statistically significant. We implemented the models in SYSTAT® V9 using the GLM and REGRESS modules.

Model Selection:

We took an information theoretic approach to model selection using a form of the Akaike Information Criterion (AIC), the AICc (Burnham and Anderson 1988), practical applications of which are well documented in the literature (Thompson and Lee 1999, Thompson and Lee 2002, and Paulsen and Fisher 2003).

In brief, the AIC penalizes improvements in model fit that arise from increasing the number of estimated model parameters. Although AIC it is commonly calculated from model likelihood estimates, we used the error sum-of-square from our regression fits, which is appropriate under standard least squares assumptions (Burnham and Anderson 1998). The AICc is an adjustment for small sample sizes. As sample size (n) increases relative to the number of model parameters that are estimated (k), the AICc value will approach the AIC value. It is recommended that AICc be used when n/k < 40 (Burnham and Anderson 1998). The AICc score of each model is converted to a relative probability of that model within the set of models evaluated. This probability, or AIC weight (ΔAICc), is calculated relative to the lowest AIC score.

We calculated each model's AICc score and then ranked them by their ΔAICc value. We further evaluated models with ΔAICc ≥ 5% (i.e. ≥ 5% relative probability) that included the habitat index by assessing the importance of the model terms based on their standard ANOVA results, the sign and statistical significance of the habitat coefficient, and influence diagnostics. We used statistical significance only as a guide to the relative importance of model terms and coefficients using $p<0.05$ as our level of statistical significance.

Influence diagnostics are important because individual data points are of interest beyond how they may affect the statistical results (e.g., Hinrichsen 2001). They can also help us understand more about possible interactions between habitat effects and egg-to-parr survival rates not accounted for in our models. For example, by examining influence plots we may be able to determine if there was something special about a particular year and location by going back to the raw data. We used composite plots of studentized residuals (externalized), leverage and Cook's distance to explore the influence of data points.

These diagnostics are useful for examining results with respect to regression assumptions (SYSTAT 1995). For the assumption that errors have constant variance plots of studentized residuals vs. predicted values can help identify outliers in the independent variable space. Plots of Cook's distance against the estimated values are useful for assessing the assumption that the same linear model describes all members of the population. Cook's distance measures the influence of each sample observation on the coefficient estimates. Observations that are far from the average of all the independent variable values or that have large residuals tend to have a large Cook's distance value (D). Finding a large Cook's D value for an observation means that the coefficient estimates would change substantially if we deleted that observation. Leverage is also useful for identifying outliers in the independent variable space.

In addition to influential data points, lack of independence over time, or serial correlation, in the survival rate indices may bias parameter estimates and violate regression assumptions (Hilborn and Walters 1992, Draper and Smith 1998). To address this possibility we bootstrapped (Efron and Tibshirani 1993) the parameter estimates for the top ranked models by sampling with replacement from the original data and fitting each model 2500 times. We assessed the bootstrapped distribution of the habitat coefficient for its skew, overlap with zero and difference from the least square coefficient estimate.

3.5 Results

Prior to running the regression models we performed individual pair-wise correlations to provide a general overview of patterns in the data. In a simple pair-wise correlation, the HABACT index had a weak negative (non-significant) correlation with the raw survival rate index (Ln(P/R)); at this level of analysis there is no obvious positive effect of habitat action on egg-to-parr survival rates (Table 3.5). The redd density index was positively and significantly correlated with the HABACT index, suggesting that redd densities may have increased more over the 1986-2001 period in streams with more habitat actions. The negative correlation between the raw survival rate index and the redd density index suggests that density dependence is important to account for and also that it may be confounded with the habitat effect. This could occur where improved spawning and rearing habitat leads to more reds and subsequent lower raw survival rates due to density dependent effect. The raw survival index is positively and significantly correlated with each of the flow indices, but we cannot say which index actually accounts for this effect as the flow indices are highly correlated with one another. However, it does appear that higher flow years produce a higher survival rate index (consistent with analyses for the Yakima sub-basin, Chapter 2). The survival rate index has the highest positive and significant correlation with the parr density index.

Table 3.5. Pair-wise pearson correlations between continuous independent variables and the survival rate and habitat indices. Correlations with Bonferroni probabilities <0.05 are marked by (*); bolded correlations have unadjusted p<0.05.

Independent variable	Ln(P/R)	H
HABACT	-0.149	
Fall flow	**0.329***	-0.115
Winter flow	**0.309**	-0.137
Freshet flow	**0.281**	-0.068
Fecundity	0.021	**-0.21**
Redd density (R)	**-0.393**	**0.211**
Parr density (P)	**0.636**	-0.146
Age 4 spawner brood year effect	0.161	-0.114
Age 5 spawner brood year effect	0.07	-0.135

Of the 52 models we ran (Table 3.6), only the top five had ΔAICc ≥ 5% (i.e. >= 5% relative probability), and together they accounted for 88% of the total ΔAICc (Table 3.7). Of these, the top four included the habitat index (H) and together accounted for 82% of the total ΔAICc. Each of these models had separate Ricker a's and a common Ricker b and a common response to the number of habitat actions across stocks (i.e. same slope, no interaction).

Table 3.6. The full set of models run for this analyses. See Table 3.4 for a description of the model components.

#	Model
1	Ln(Parr/Redd) = CONSTANT + ALLREDD
2	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD
3	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD
4	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + FECUNDITY + FORK$*FECUNDITY
5	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + FECUNDITY + FORK$*FECUNDITY + BY$
6	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$
7	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FALLQ
8	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + WINTERQ
9	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FRESHETQ
10	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + HABACT + STOCK$*HABACT
11	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + HABACT + STOCK$*HABACT
12	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + BY$*HABACT
13	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FALLQ + STOCK$*FALLQ
14	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + WINTERQ + STOCK$*WINTERQ
15	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FRESHETQ + STOCK$*FRESHETQ
16	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + HABACT + STOCK$*HABACT + FALLQ + STOCK$*FALLQ
17	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + HABACT + STOCK$*HABACT + WINTERQ + STOCK$*WINTERQ
18	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + HABACT + STOCK$*HABACT + FRESHETQ + STOCK$*FRESHETQ
19	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + BY$*SEDCAT2
20	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + BY$*SEDCAT1$
21	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + HABACT + STOCK$*HABACT + FRESHETQ
22	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + HABSTAT$ + BY$*HABSTAT$
23	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + HABSTAT$
24	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + HABACT
25	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + BY$ + HABACT + BY$*HABACT
26	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FRESHETQ + HABACT
27	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FRESHETQ + HABACT + FRESHETQ*HABACT
28	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + FRESHETQ + FEDCUNDITY + HABACT
29	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$
30	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$
31	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$ + FALLQ
32	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$ + FRESHETQ
33	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$ + WINTERQ
34	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$ + BYAGE5
35	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT1$ + BYAGE4
36	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT2 + HABACT
37	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT2 + BY$*SEDCAT2
38	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + SEDCAT2
39	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT
40	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + BY$*HABACT
41	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + BYAGE5
42	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + STOCK$*BYAGE5
43	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + BYAGE4
44	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + FALLQ
45	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + WINTERQ
46	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + BY$*WINTERQ
47	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + WINTERQ + BY$*WINTERQ
48	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + FRESHETQ
49	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + WINTERQ
50	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + BYAGE5
51	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + WINTERQ + HABACT*WINTERQ
52	Ln(Parr/Redd) = CONSTANT + STOCK$ + ALLREDD + STOCK$*ALLREDD + BY$ + HABACT + STOCK$*HABACT

Table 3.7: Summary of model results. # = model number shown in Table 3.6. Rank = rank of model based on AICc weight, RSS = residual sum of squares, n = sample size, k = number of estimated parameters. AICc = Akaike's Information Criterion adjusted for small samples sizes (n/k <40). ΔAICc = AICc weight, which represents the relative probability of each model within the full set of models in this analysis (Table 3.6).

#	Rank	Model	RSS	n	k	AICc	Δ AICc
26	**1**	separate a, common b, freshet flow, c**umulative # habitat actions**	111	101	11	34.54	0.38
24	**2**	separate a, common b, common brood year effects, **cumulative # habitat actions**	74	101	25	36.03	0.18
28	**3**	separate a, common b, freshet flow, fecundity, **cumulative # habitat actions**	110	101	12	36.40	0.15
27	**4**	separate a, common b, freshet flow, **cumulative # habitat actions**, flow*action interaction	111	101	12	37.11	0.11
2	**5**	separate a, common b	121	101	9	38.33	0.06

In each case, the coefficient of the HABACT index was positive, ranging from 0.21 to 0.29. The coefficients were significant for the top three models ($p<0.05$), but marginally non-significant for the fourth ranked model ($p=0.052$) (Table 3.8). Models that explicitly included the stock by habitat index interaction term had extremely low relative probabilities (ΔAICc <0.01) and the interaction terms were not significant.

Table 3.8. Summary of regression coefficients for the four top ranked models. Coefficients significant at $p<0.05$ are bolded; coefficient marked by the '*' was marginally not significant ($p=0.052$). 'n/a' indicates that particular coefficient was not relevant to that model.

Effect	Model 1	Model 2	Model 3	Model 4
Common Ricker b	-0.04	**-0.10**	-0.04	-0.04
freshet flow	0.00	n/a	0.00	0.00
flow*hab. action interaction	n/a	n/a	n/a	0.00
cumulative # habitat actions	**0.22**	**0.29**	**0.24**	*0.21
fecundity	n/a	n/a	0.00	n/a

Only in the second ranked model, which included the estimated parr common brood year effect, were all of the model terms important (ANOVA, all terms $p<0.05$) (Table 3.8). Although this model had the lowest error sum-of-squares, it had twice as many estimated parameters as the first ranked model and was penalized heavily by the AICc adjustment (Table 3.7). It ranked first under the unadjusted AIC score.

Supplemental diagnostics revealed that there were several influential data points driving the results, particularly the 1998 point for Johnson Creek (Figure 3.9). Despite this, the mean of the bootstrapped habitat coefficients for the top ranked models were similar in magnitude to those estimated from the original data set and their 95% confidence intervals did not include zero (Figure 3.9).

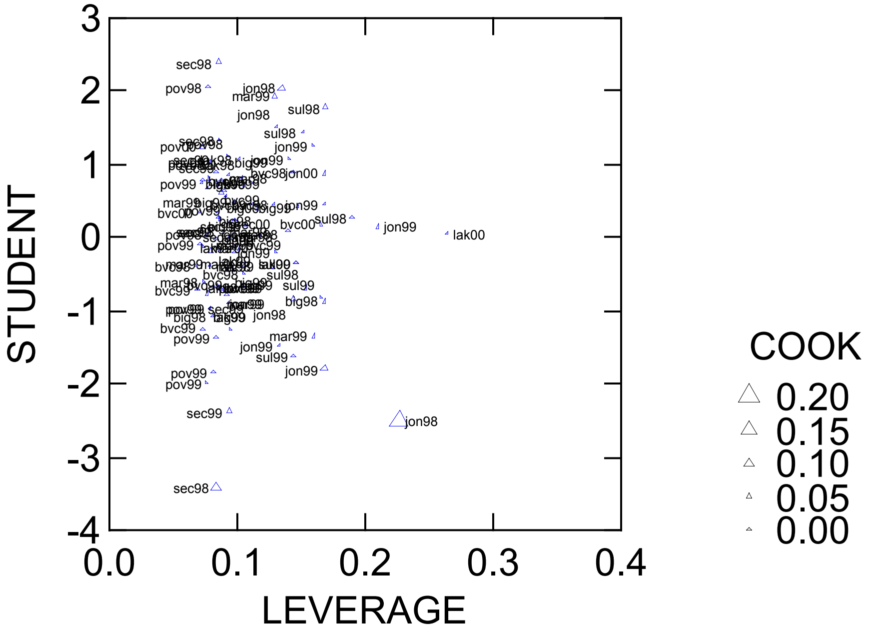


Figure 3.9. Example of influence diagnostics for the top ranked model. STUDENT is studentized residuals, COOK is cook's distance. The size of the symbols represents the size of the cook's distance. Large symbols with high leverage and high or low studentized residuals are particularly influential. See text for description.

Table 3.9: Bootstrap results for the four top ranked models. "Base estimate" row shows the least squares coefficients from Table 3.8.

	Model 1	Model 2	Model 3	Model 4
5th percentile	0.01	0.08	0.06	0.01
Median	0.21	0.30	0.23	0.21
95% percentile	0.38	0.50	0.40	0.38
Mean	0.21	0.29	0.23	0.21
Base estimate	0.22	0.29	0.23	0.21

3.6 Discussion

Our results are interesting because they suggest that streams with more historical habitat restoration actions have higher spring-summer chinook egg-to-parr survival rates. Additionally, our methods provide an example of how retrospective models can be used to combine disparate sources of data to make such inferences and also to help identify important factors for consideration in the development of prospective monitoring programs (e.g., utility of monitoring multiple stocks).

Though there was a negative pair-wise correlation between the raw survival rate (ln(P/R)) and the HABACT index (Table 3.5), this correlation became positive once other covariates were included in the models, which suggests that density dependent effects may mask habitat restoration effects. This is demonstrated by correlating the HABACT index with the residuals from the top ranked model run without the HABACT index, where the residuals are now an index of the density independent survival rate, but one that includes habitat effects. In this case, the correlation is weakly positive (r = 0.159, p > 0.05). This demonstrates that it is important to account for density dependence in the design of monitoring programs for assessing habitat effects. However, the new correlation is only weakly positive and not significant, which suggests that more than density dependent effects influence the overall results.

We can gain more insight into what these other factors are by splitting up the correlations of residuals from the no-HABACT model vs. the HABACT index by subbasin. For the South Fork, the correlation is 0.223, while it is 0.041 for the Middle Fork, though in neither case is it significant. This suggests that the data for the streams of the South Fork Salmon River are driving the overall results. Plots of these data illustrate the correlation results (Figure 3.11). There is a positive slope for residuals vs. HABACT for the South Fork, but no slope in the Middle Fork (right side of Figure 3.11). It is interesting that there appears to be a negative slope to the raw survival rate index vs. HABACT plot for the Middle Fork (left side of Figure 3.11). This may be due to density-dependent effects on the survival rate index, if redd density is increasing over the same period as the HABACT index is increasing. If this is the case, we should see a positive relationship between redd density and HABACT. In fact there is a small, but significant, positive correlation between the redd density index and the HABACT index (Table 3.5).

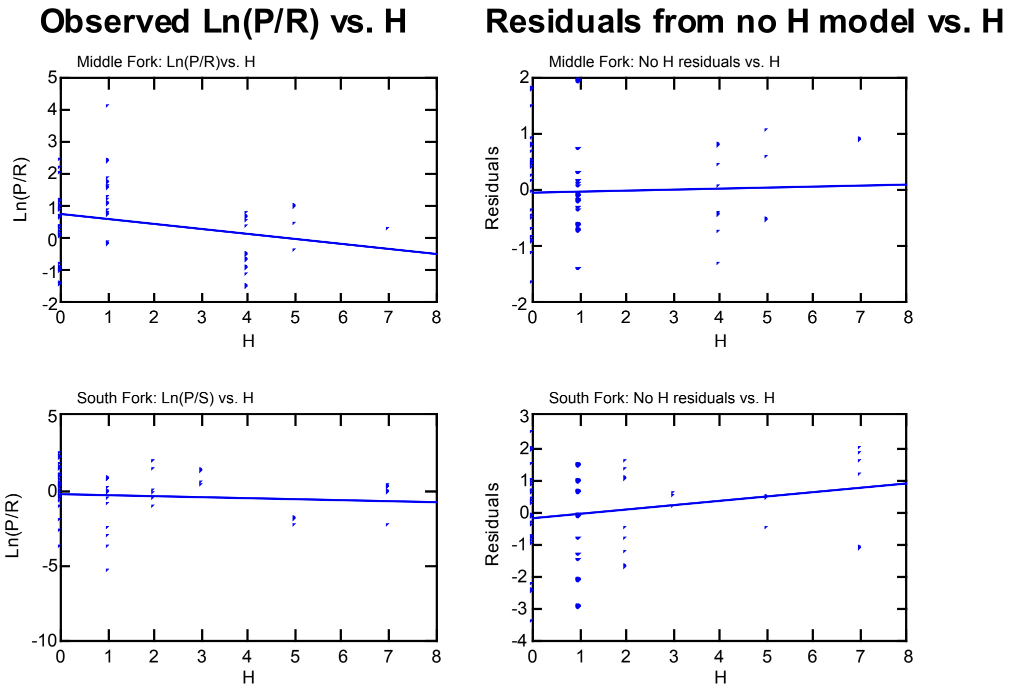


Figure 3.11. Effect of accounting for density dependence on relationship between the survival rate index and the HABACT index (H). The left panels show plots of the raw survival rate index (Ln(P/R) that includes density dependent effects vs. the HABACT index. The right hand plots show a density independent index of survival rate consisting of the residuals from a fit of the top ranked model without the HABACT index vs. the HABACT index.

We can drill down further by looking at correlations between the No-HABACT model residuals and the HABACT index. For the South Fork stocks, Johnson Creek had the highest correlation (r=0.55), followed by Lake Creek (r = 0.197) and Poverty Flat (-0.03). Secesh River had no projects. This order reflects the degree of contrast in the H index over 1986–2001 for each stock (Figure 3.8). For the Middle Fork stocks, Bear Valley/Elk Creek had the highest correlation (r=0.235). The Marsh Creek correlation was negative (r = –0.165). Sulphur Creek and Big Creek had no projects. These results again reflect the degree of contrast in the HABACT index over the time series; Bear Valley Elk Creek had a large increase in projects over 1986-2001, while Marsh Creek had only one project starting near the beginning of the series.

To assess the relative influence of Johnson Creek and Bear Valley Elk Creek on the overall results, we ran the top ranked model without the Johnson Creek data. The coefficient for the HABACT index, while still positive, was not significant and much smaller in magnitude (0.055) than for the base results shown in Table 3.7. We added the Johnson Creek data back in and then ran the model again without the Bear Valley Elk Creek data. In this case, the HABACT coefficient was significant and similar in magnitude to the original value at 0.244. As an alternative approach, we ran the model with all stocks, but reduced the contrast in ln(P/R) for Johnson Creek by lowering the survival index by 50% over brood years 1988-1990. The HABACT index coefficient was still positive (0.119), but not significant. Thus it appears that the estimated HABACT effect for our base results is driven by the data for the Johnson Creek stock.

The advantage of estimating common year effects across stocks rather than using covariates that reflect common influences is shown by applying an analysis similar to that above to our second ranked model. We ran this model with a 50% reduction in the BY88, 89, and 90 survival rate index for Johnson Creek. In this case, the HABACT coefficient remained positive and significant although the estimated effect was smaller (0.168 vs. the base result of 0.29). Thus models that account for common brood year effects can remove more variation and allow detection of smaller H effects and it appears that such models are appropriate for the chinook stocks of the Salmon River subbasin.

Bias to survival rate index from release of hatchery fry and parr:

We examined the potential influence of hatchery releases of fry and parr to Johnson Creek and other streams on our results. Supplementation in the latter part of the time series may have upwardly biased GPM parr counts, and thus the raw survival index (Appendix 3.H). We only found records for releases to Johnson Creek and the Stolle Meadows area of the mainstem South Fork Salmon River (upstream from Poverty Flat). Based on the timing of hatchery releases relative to the timing of IDFG's GPM counts only the data points for the 1996 and 1997 brood years of the Poverty Flat time series were potentially affected.

The brood year 1996 survival index datum may have been influenced by a 1997 parr release under the Idaho Supplementation Studies (ISS) program at Stolle Meadows a month before the GPM counts. This release could have influenced the BY1996 survival index datum. However, this datum is the second lowest in the time series, so any positive bias imparted by the supplementation release would not have adversely affected the regression results.

The 1997 brood year parr density datum was potentially influenced by a 1998 ISS parr release at Stolle Meadows two days prior to the GPM count at Poverty Flat, but after the counts at the Stolle Meadows sites. The brood year 1997 survival index datum is the third highest in the series (Figure 3.4). The GPM density for the Poverty Flat site is midway between that of the Stolle 1 and Stolle 2 sites (Appendix 3.A), but it is possible that the density at the Poverty Flat site is higher than it would have been without the release, thus increasing the overall average density. To explore how this might affect our results we reduced the value of the 1997 parr density datum by 50%, recalculated the survival rate index and re-ran the top ranked base model. The HABACT coefficient decreased slightly from 0.220 to 0.216, but remained significant ($p < 0.05$).

Fry emigration:

Emigration of fry and parr from GPM sites prior to the summer parr counts may bias the egg-to-parr survival rate index downward. This will create a smaller signal and make it more difficult to detect habitat restoration effects if they exist. This bias will be worse if emigration has a density dependent component and increases with increased juvenile abundance. This could happen for example, if habitat actions increase egg-to-parr survival rates, or under higher redd counts. We explored the relationship of emigration rates to juvenile abundance as indexed by redd abundance using screw trap emigration data provided by the Nez Perce Tribe for Secesh River, Lake Creek and Johnson Creek (Appendix 3.I). However, we could not make strong inferences about the relationship of emigration to juvenile abundance or to a physical covariate (freshet flow) because there were few data points and several confounding factors, each of which could have explained the observed patterns. A more detailed and broader consideration of emigration is required.

Flow Indices:

The correlations between the three flow indices are large, positive, and significant. The temporal patterns in the flow indices are similar between gauges and systems (Figure 3.5a-c). Therefore, one flow index may be adequate for capturing the pattern of flow effects and would also avoid problems with collinearity. Models with single flow indices help to show whether the magnitude of flow influences the results. For example, when run without the HABACT index, models with FRESHETQ, FALLQ and WINTERQ ranked 6th, 7th, and 8th respectively, with little difference in AICc score suggesting that any of the three flow indices will do. This ranking follows the magnitude of flows for each index.

Common brood year effects:

In addition to reducing variation and increasing ability to detect habitat effects, estimated common brood year effects are useful for detecting factors that drive large-scale patterns in survival. For example, a plot of the parr common year effects estimated in the second ranked model and the winter flow index, WINTERQ, over time (Figure 3.12) shows little covariation between the two indices. However, the extremely high flow index in brood year 1995 is associated with the lowest parr common year effect. Given the high correlation in this flow index across gauges (Figure 3.5, lower right panel), it would appear this flow event had a negative impact on the survival rate index in both the South and Middle Fork streams. The brood year 1995 winter flow index encompasses the November to March period, the same period during which extreme flood events occurred in 1995-1996. For example, in Fish Creek, Oregon flood events in November 1995 and February 1996 destroyed 50% of the habitat restoration structures built during a study of restoration effects and the 1996 steelhead and coho smolt outmigration was the lowest observed during the study (Reeves et al. 1997).

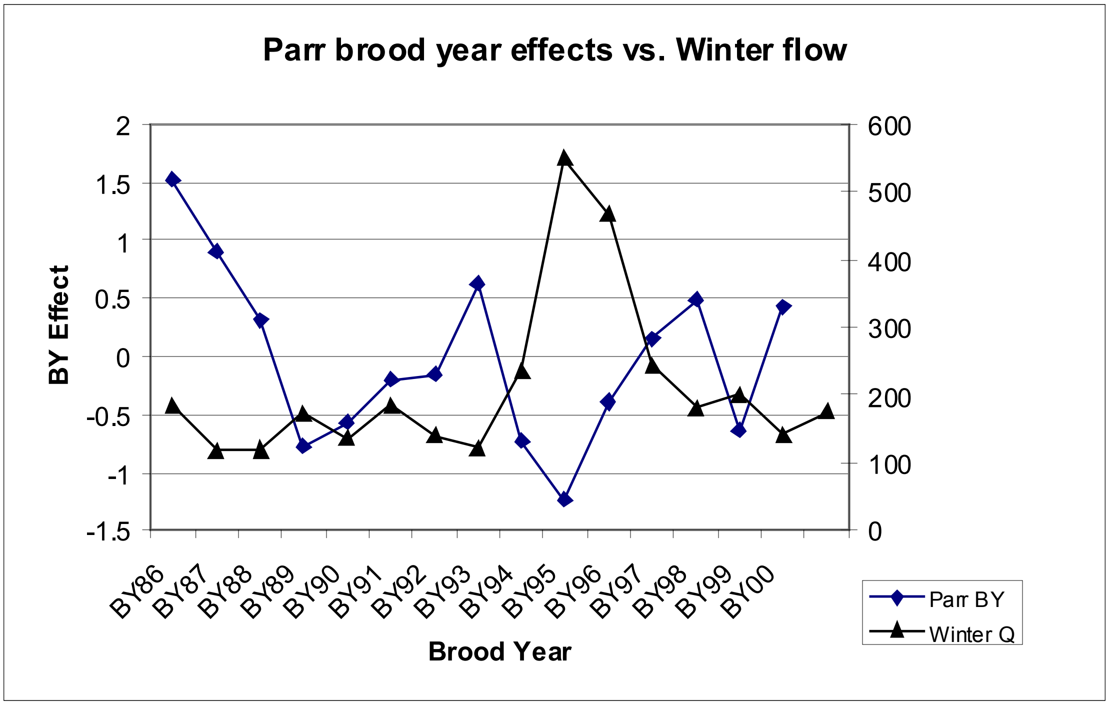


Figure 3.12. Parr brood year effects from the 2nd ranked model (PARR BY) vs. the winter flow index (WINTERQ).

Incorrect parr survival rate index:

It is possible that we did not use the correct parr monitoring sites to create the survival index. We did a test by running the 2nd ranked model using a new Johnson Creek Parr density index that was the average parr density over all GPM B and C channel sites. The Habitat index coefficient was smaller, though still positive (0.127), and no longer significant. This is a topic that should be pursued more rigorously in future.

The GPM parr density may not be a good index of parr abundance when:

- There is bias due to statistically unrepresentative sampling. For example, parr counts do not account for seasonal patterns of habitat usage (e.g., off-channel habitat used during higher flow months (e.g., observations of Rowe et al. 1989 in Bear Valley Creek). This could affect parr density value that are based on averages of early and late sampling events if the first event occurs during a higher water period. Large differences in these counts may reflect emigration or movement from off-channel sites into main channel habitat when higher flows subside.
- Parr sampling sites are not in proximity to redds. Parr sample location with respect to redd location is a major source of variation for trend data (Bowles and Leitzinger 1991). We could not account for this other than to select parr count sites within the reaches or influence by the reaches where redd counts are conducted.
- Parr sampling does not adequately sample preferred rearing habitat. Parr sample location with respect to preferred rearing habitat is a major source of variation for trend data with low sample size such as the GPM program (Bowles and Leitzinger 1991). We tried to account for this by using C channel parr density data only, but this is only a crude approach.

- Models do not account for parental (redd) abundance. Parental spawning escapement is another major source of variability among streams (Bowles and Leitzinger 1991). We have accounted for this by including redd densities as both the denominator of the survival rate index and as an index of density dependence.
- Parr counts are biased at low temperatures (Hillman et al. 1993). Though the GPM program seeks to offset this bias by only snorkeling above 10C (Hall-Griswold and Petrosky 1996), we checked for this bias by plotting parr densities vs. stream temperature over all available density estimates in the GPM database (Appendix A). A positive relationship between density and temperature would suggest that counts were biased lower temperatures. We saw no such relationship.
- There are trends in fecundity. We have tried to account for this using hatchery based fecundity data. However, these data may not reflect wild fecundity trends, for example if there was selection by hatchery staff for larger females, or if second generation hatchery effects resulted in lower than wild fecundity for hatchery fish.

Additionally the purpose of the GPM parr densities was to collect an index of relative abundance. How representative this index is of total abundance could be checked using other total abundance estimates derived from snorkel surveys such as ISS parr abundance estimates in the Salmon River subbasin, or the Shoshone-Bannock Tribe parr abundance estimates in Bear Valley Creek.

Other confounding effects that we have not accounted for are:

- Steelhead parr densities, this information is available in the GPM database.
- Habitat actions overlap in time with downstream management actions (e.g., dam construction, modifications to migration subsequent to dam construction – barging, flow manipulation.
- Habitat actions overlap in time with an increase in the intensity of other research activities (e.g., ISS, GPM, PIT tagging, weirs, etc.).
- Habitat actions may differ in how their ultimate “effects” are expressed. For example, sediment control actions will improve degraded habitat, while in-stream structures or barrier removals generally enhance, or increase the area of, existing habitat. The line is blurry for in-stream structures. Increasing the area of habitat will not necessarily bring a net increase in survival.
- There could be long time lags between the implementation of habitat projects and their impact on survival rates and perhaps the time series of data available to us is not long enough to capture these effects.
- The effects of passive restoration approaches (e.g., implementation of Best Management Plans, e.g., Megahan et al. 1990.), which would not show up in our HABACT index. Especially such actions that occurred prior to the early 1980s when BPA began funding projects. Further research is needed to uncover and described these projects.
- The number of projects tells us nothing about how the quality of habitat has change from before project implementation to present. The degree of impact may have been higher in some streams than other, and therefore it may take longer to see a response.

Additionally, the HABACT index provides no information on which projects or types of projects were most effective. It also does not include information on the relative intensities of projects (e.g., how large they were, or how close to spawning and rearing areas). The HABACT index does not include projects that were implemented prior to 1984, which could have already been effective or continued to become effective over the period considered here. Further research needs to be focused on this index.

3.7 Conclusion and recommendations

Our results support the hypothesis that habitat actions have increased spring-summer chinook egg-to-parr survival rates, at least in Johnson Creek, and show that it is feasible to use multi-stock models to account for variation due to common brood year effects, thereby increasing the probability of detecting habitat effects. While our results provide no information on which types of projects are most effective, or a particular mechanism, they suggest that slow cumulative effects associated with more intensive project work may be associated with improved egg-to-parr survival. This work highlights the value of monitoring of parr and redds in multiple tributaries and illustrates how retrospective data from various sources can be used to explore hypotheses about the effect of habitat restoration action when no project-specific data has been collected. Useful next steps would be:

- Conduct sensitivity analyses to explore different methods for creating parr density data used for survival index (e.g., data for C + B channels, other sites), compare GPM and ISS density estimates.
- Test results by expanding the analysis to include more streams from the Salmon, Clearwater and Grande Ronde watersheds, which could be done with the current habitat index, though parr and redd date would have to be found for The Grande Ronde.
- Include GPM steelhead parr densities as a covariate and seek to address the other confounding factors associated with the habitat actions listed in the discussion section.
- Alternatively, weight individual habitat actions by their expected degree of importance. This could include such factors as time since implementation, proximity to stream, proximity to redds or GPM count site, project size, or project type. These factors should be assigned in consultation with habitat and fisheries scientists familiar with data and tributaries used in future analyses.
- Our results are driven by the contrast in the Johnson Creek data, so the habitat and survival rate indices for this stream should be scrutinized. It would be useful to determine how close the habitat actions are to the GPM parr sites and where redd counts are conducted. Additionally, field checks of the current habitat condition in areas where habitat actions have taken place.
- Develop a GIS database that will allow proponents to view the spatial relationship of existing and ongoing data sets to proposed habitat actions.

3.8 Acknowledgments

We gratefully acknowledge the generous provision of data and time by the many fisheries managers and scientists who participated in this project. In particular, from the Idaho Department of Fish and Game, Russ Kiefer, Charlie Petrosky, Judy Hall-Griswold and Evan Brown, who provided us with data and information for the IDFG Intensive studies, Salmon River subbasin S-R run reconstructions, and the IDFG General Parr Monitoring Program database, and index redd count data. Paul Kucera and Chris Beasely of the Nez Perce Tribe provided data on redd counts and juvenile emigration for Secesh River, Lake Creek and Johnson Creek. Doug Taki (Shoshone-Bannock Tribe) provided reports on the restoration and monitoring work being conducted in Bear Valley Creek. Katie Barnas (NOAA Fisheries) provide GIS and habitat project information for the Salmon River subbasins. Tim Fisher of Fisher Fisheries provided the cumulative habitat index. Additionally, Carl Schwarz (Simon Fraser University) and Charlie Paulsen (Paulsen Environmental Services) provided statistical advice and early feedback on the methods and results presented here.

Section 3 Appendices

Appendix 3.A - Parr density data

The parr density data were extracted from a copy the Idaho Department of Fish and Game's General Parr Monitoring Program (GPM) database we received from Judy Hall-Griswold on July 14, 2003. These data represent summer parr densities as sampling generally occurred over July and August. A description of the GPM program can be found in Hall-Griswold and Petrosky (1996).

We used a pre-set query that came with the database ("qryIan Parnell_GPMdataIDFG85-02") to extract chinook CH 0+ parr density data to an Excel spreadsheet. We then used the Excel "Autofilter" and "Pivot table" tools to summarize the data for the eight streams we used in this analysis: Johnson Creek, South Fork Salmon River, Secesh River, Lake Creek, Big Creek, Sulphur Creek, Bear Valley/Elk Creeks and Marsh Creek. The query calculated the average parr density for each site within a year. For most sites, only one summer parr count was done in a year, but for some sites there were two.

Our goal was to select C channel sampling sites within the index redd count reaches used for the IDFG spawner-recruit run reconstructions. C channel habitat is the preferred rearing habitat for juvenile chinook (Hall-Griswold and Petrosky 1996). For cases where no C channel habitat fell within the redd count reaches, we included C channel sites that we expected to be influenced by the index redds. In one case (Johnson Creek) no C channel habitat fit either criteria and we used B Channel sites.

To locate GPM sites relative to the index redd reaches we compared EPA reach number information associated with each record in the GPM database with the reach description information for the redd count records. The latter included the name of the reach as well as the distance (km) from the mouth for bottom and top of each reach. Additionally, we used information from the NPPC Smolt Density Model database (SDM) (www.streamnet.org) to help interpret the GPM and redd information; the SDM database provides both the EPA reach number and reach length for reaches within the streams we considered here.

In the following sections we present the raw average parr densities for the GPM C and B channel sites in each of the eight streams and the summary average parr density time series we used in the AIC analysis. In some cases, we compare these time series to indices calculated using different combinations of sites or channel types to demonstrate how they can vary based on such choices. We also provide figures showing the temporal pattern of the time series over brood years (brood year = sample year – 1).

3A.1 Summary of parr density data by stream

3A.1.1 Johnson Creek Parr Density Data

Table 3A.1. B Channel summer parr densities (parr/100m^2) for GPM sites within Johnson Creek, South Fork Salmon River. Data source: Idaho Department of Fish and Game's General Parr Monitoring program database.

SpeciesID	17
CHINOOK_CLASS	NSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	B

Average of density	STRATA	SECTION					
	LOWER IV		MID LOWIII	MID UPR II	UPPER	UPPER I	WHISKEY
YEAR	L2	L3	PW3B	PW3A	PIDCR	PW1A	3.0D
1985						1.14	
1986	7.67	7.61				1.04	
1987	7.26	12.10			0.13		
1988	5.28	6.81		47.00		16.58	
1989	0.10	0.17		3.90		2.15	
1990	0.43					0.04	1.63
1991	0.44	0.08					
1992	1.03						
1993	1.51					5.67	
1994	8.33	0.16	0.19	0.17		0.08	
1997	0.50	0.39					
1998	8.62	34.91	0.41				
1999	6.22	19.53					
2000	2.99	5.21	0.42	0.38			
2001	6.15	6.70	0.85				

Table 3A.2. C Channel summer parr densities (parr/100m^2) for GPM sites within Johnson Creek, South Fork Salmon River. Data source: Idaho Department of Fish and Game's General Parr Monitoring program database.

SpeciesID	17
CHINOOK_CLASS	NSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	C

Average of density	STRATA	SECTION						
	UPPER		UPPER I					
YEAR	RUN1	RUN3	M1	M2	M2 SIDE	M3	M3 SIDE	TYNDALL CREEK
1985	1.34	0.72	2.86	0.32		2.34		1.71
1986	0.43	1.69	11.85	22.70		3.85		3.94
1987		1.01	0.82	6.22		1.72		163.24
1988			70.30	100.07		26.29		
1989			4.99	16.60		6.01		
1990			4.78	0.93		0.34		
1993						26.03	27.43	
1994			79.40	20.19	152.39	1.15	32.42	
1997				0.13	1.04	0.07		
1998			1.28					
2000			1.43	5.02	4.10	0.49	1.14	

Table 3A.3. Time series for alternative indices of average summer chinook parr densities for Johnson Creek, South Fork Salmon River. Each index represents a different combination of channel types or site location. "Lower B Only" is the average over the L2 and L3 B Channel sites in the Lower IV section below the index redd count reaches – this is the time series used to derive the survival rate index used for the base AIC analysis. "All B" is the average density over all B channel sites shown in Table 3A.1. "C and B" is the average over all the B and C channel sites shown in Tables 3A.1 and 3A.2. "C Only" is the average density over all C channel sites shown in Table 3A.2. Data source: Idaho Department of Fish and Game's General Parr Monitoring program database.

Johnson Creek					
Brood Year	Sample Year	Lower B Only	All B	C and B	C Only
1984	1985		1.14	1.49	1.55
1985	1986	7.64	5.44	6.75	7.41
1986	1987	9.68	6.50	24.06	34.60
1987	1988	6.04	18.92	38.90	65.55
1988	1989	0.13	1.58	4.85	9.20
1989	1990	0.43	0.70	1.36	2.02
1990	1991	0.26	0.26	0.26	
1991	1992	1.03	1.03	1.03	
1992	1993	1.51	3.59	15.16	26.73
1993	1994	4.25	1.78	29.45	57.11
1994	1995				
1995	1996				
1996	1997	0.44	0.44	0.43	0.41
1997	1998	21.76	14.64	11.30	1.28
1998	1999	12.87	12.87	12.87	
1999	2000	4.10	2.25	2.35	
2000	2001	6.42	4.57	4.57	2.44

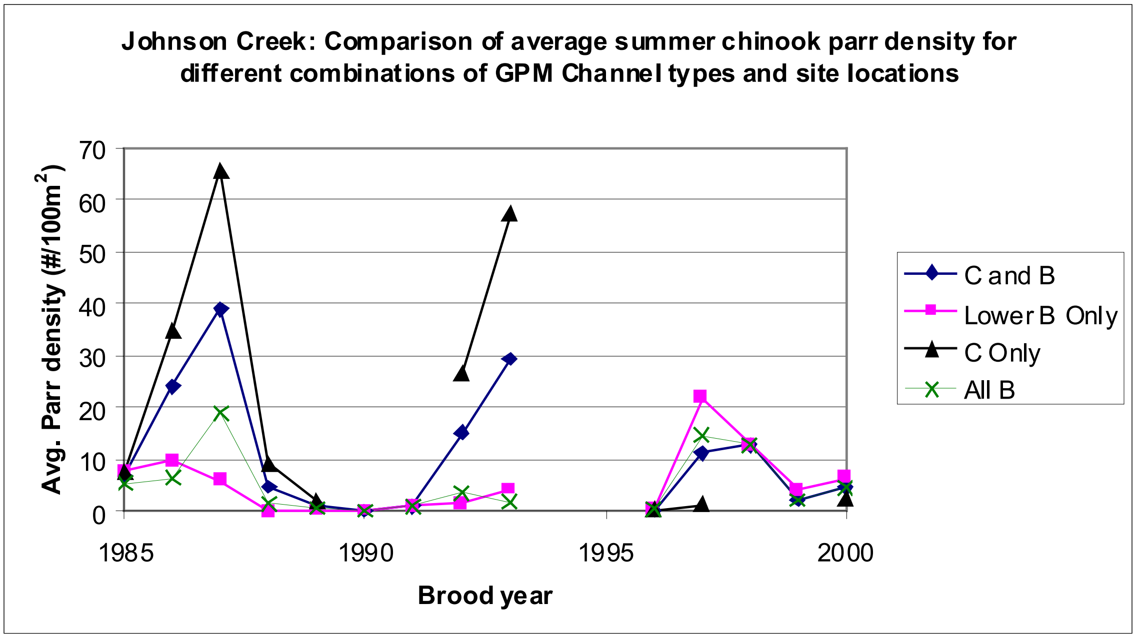


Figure 3A.1. Comparison of time series patterns for alternative indices of average summer chinook parr densities for Johnson Creek, South Fork Salmon River (1985–2000). "Lower B Only" is the time series used to derive the survival rate index for the base AIC analyses. The time series are also listed in Table 3A.3.

3A.1.2 South Fork Salmon River Parr Density Data

Table 3A.4. Average summer chinook parr densities for B channel sites in the South Fork Salmon River. Data source: Idaho Department of Fish and Game's General Parr Monitoring database.

SpeciesID	17
CHINOOK_CLASS	NSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	B

Average of density	SECTION													
YEAR	11	14	16	18	19	20	21	22	24	25	26	28	5	7
1986	17.73	15.53	11.92		1.52	4.07	0.16	0.74	0.03	0.75	0.93	0.11	25.99	27.45
1987	0.20	0.19	0.31		1.32	12.92	1.29	2.84		0.37	0.65		96.85	2.07
1988	5.05	3.96	3.28	0.29	0.80	0.14	0.94	0.55		0.27	0.19	0.05	18.09	38.68
1989	3.50	5.01	10.87										1.34	19.33
1990	12.64	7.04	5.67										11.27	3.06
1991	1.33		0.62										1.79	1.14
1992	1.29	0.26	1.44										14.47	4.13
1993	16.05	0.63	2.45	2.72	5.79	0.22		5.13						
1994	15.59	4.01	2.35										13.18	32.97
1995	6.62	1.25	1.33										70.02	0.59
1996	2.25	0.58	0.06										2.28	1.68
1997													4.75	
1998	29.52	11.20	9.30										40.41	34.37
1999	16.16	5.96	0.85										30.22	35.34
2000	3.60	0.72	0.72										6.21	12.11
2001		3.52	3.33										72.95	276.19

Table 3A.5. Average channel summer chinook parr densities for C channel sites in the South Fork Salmon River. Data source: Idaho Department of Fish and Game's General Parr Monitoring database.

SpeciesID	17
CHINOOK_CLASS	NSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	C

Average of density	SECTION		
YEAR	POVERTY	STOLLE1	STOLLE2
1986		19.11	19.68
1987	2.09	51.73	91.64
1988	20.04		
1989	18.74	17.44	69.54
1990	11.96	3.39	1.73
1991	5.01	2.82	
1992	1.13		
1993	6.78		13.20
1994	27.38	36.98	18.23
1995	5.95	0.06	
1996	1.09	0.47	0.74
1997		0.84	
1998	36.88	43.07	25.82
1999	19.03	10.91	47.19
2000	4.33	0.17	1.92
2001	52.78	43.38	20.78

Table 3A.6. Average summer chinook parr density indices for C and B channel GPM sites in the South Fork Salmon River. Data are shown in Tables 3A.4 and 3A.5. "n C sites" and "n B sites" are the number of C and B channel sites used to calculate the average C and B channel densities.

Brood Year	Sample Year	C Channel	n C sites	B Channel	n B sites
1985	1986	19.39	2	8.23	13
1986	1987	48.49	3	10.82	11
1987	1988	20.04	1	5.56	13
1988	1989	35.24	3	8.01	5
1989	1990	5.70	3	7.93	5
1990	1991	3.91	2	1.22	4
1991	1992	1.13	1	4.32	5
1992	1993	9.99	2	4.71	7
1993	1994	27.53	3	13.62	5
1994	1995	3.01	2	15.96	5
1995	1996	0.77	3	1.37	5
1996	1997	0.84	1	4.75	1
1997	1998	35.26	3	24.96	5
1998	1999	25.71	3	17.71	5
1999	2000	2.14	3	4.67	5
2000	2001	38.98	3	89.00	4

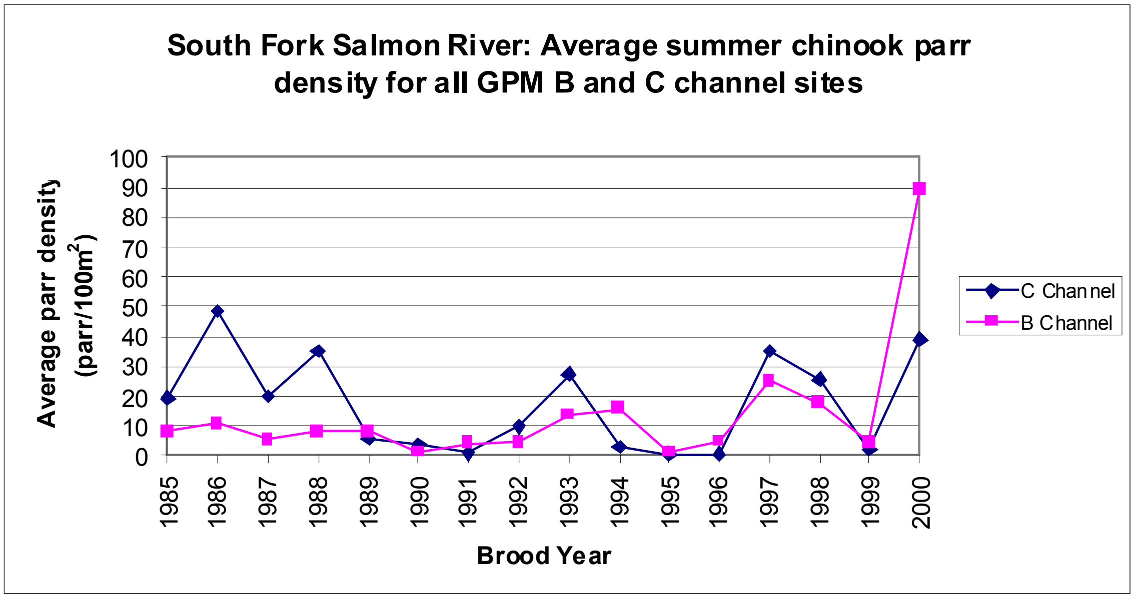


Figure 3A.2. Comparison of time series patterns for indices of average summer chinook parr densities for C and B channel GPM sites in the mainstem South Fork Salmon River (1985–2000). "C channel" is the time series used to derive the survival rate index for the base AIC analyses. The time series are also listed in Table 3A.6.

A.1.3 Secesh River Parr Density Data

Table 3A.7. Secesh River GPM B Channel sites and densities (1987–2001). Data source: Idaho Department of Fish and Game, General Parr Monitoring database.

SpeciesID	17
CHINOOK_CLASS	WSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	B

Average of density	SECTION			
YEAR	6	7	8	GROUSE
1987				5.57
1988				0.28
1990				0.47
1992	1.96	2.22	1.85	2.21
1993				92.89
1994				6.52
1995				0.13
1998	0.26			
1999	1.64			
2001				0.95

Table 3A.8. Secesh River GPM C Channel sites and densities (1987-2001). Data source: Idaho Department of Fish and Game, General Parr Monitoring database

SpeciesID	17
CHINOOK_CLASS	WSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	C

Average of density	SECTION							
YEAR	1	2	3	4	5	LONG-GULCH	L-SCSH-MDW	U-SCSH-MDW
1987						41.59		40.78
1988						24.39		7.40
1989						8.36		2.99
1990						0.15		0.07
1991							2.79	0.79
1992	8.35	9.24	7.07	13.52	7.57	9.14		9.00
1993						8.63		2.02
1994						6.45		3.79
1995						0.18		0.84
1998	0.28							
1999	7.17			0.82				
2001				16.90		2.65		0.61

Table 3A.9. Secesh River GPM summary annual average parr densities for C and B Channel types, brood year 1986–2000. Based on Table 3A.7 and 3A.9.

Brood Year	Sample Year	C Channel	n C Sites	B Channel	n B sites
1986	1987	41.18	2	5.57	1
1987	1988	15.90	2	0.28	1
1988	1989	5.68	2		
1989	1990	0.11	2	0.47	1
1990	1991	1.79	2		
1991	1992	9.13	7	2.06	4
1992	1993	5.32	2	92.89	1
1993	1994	5.12	2	6.52	1
1994	1995	0.51	2	0.13	1
1995	1996				
1996	1997				
1997	1998	0.28	1	0.26	1
1998	1999	4.00	2	1.64	1
1999	2000				
2000	2001	6.72	3	0.95	1

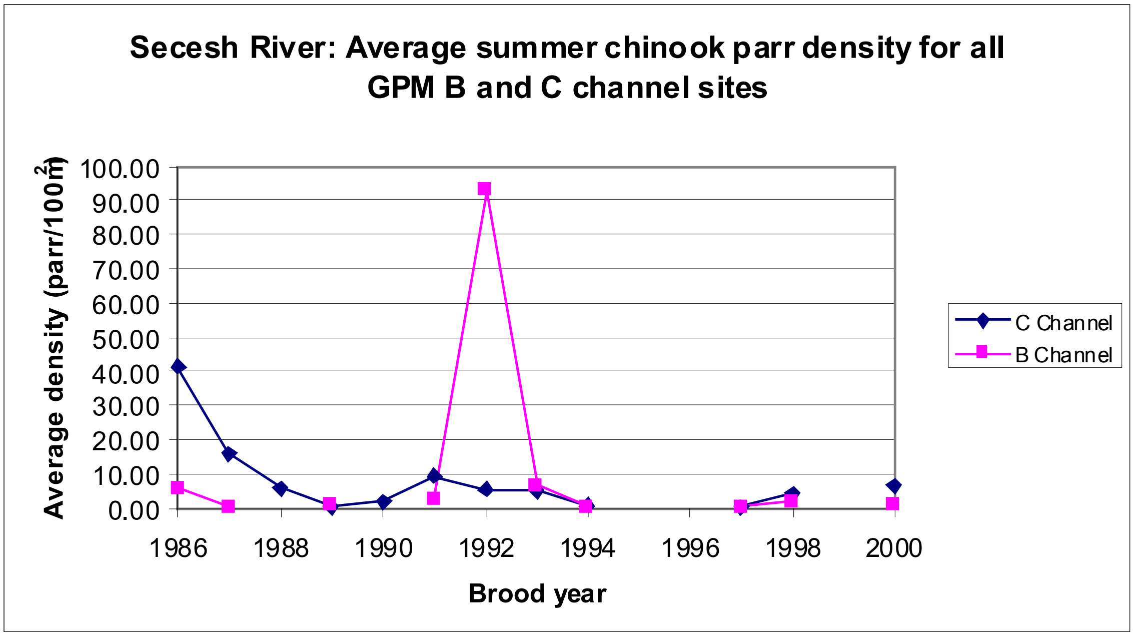


Figure 3A.3. Comparison of time series patterns for C and B Channel based indices of average summer chinook parr densities for Secesh River, South Fork Salmon River (1986–2000). "C Channel" is the time series used to derive the survival rate index for the base AIC analyses.

A.1.4 Lake Creek Parr Density Data

Table 3A.10. Lake Creek GPM C Channel sites and densities for sampling years 1987–2002. Data source: Idaho Department of Fish and Game, General Parr Monitoring database.

SpeciesID	17
CHINOOK_CLASS	WSUM
SName	Chinook Salmon
AgeGrp	0
CHANNEL_TYPE	C

Average of density	SECTION					
YEAR	1	3	4	5	BURGDORF	WILLOW CR
1987					39.50	15.26
1988					3.08	
1989					13.79	1.26
1990					15.05	14.17
1991					12.97	1.69
1992	0.27	5.70	5.32	2.01	11.92	11.48
1993					4.13	1.01
1994					10.56	5.09
1999					25.13	8.18
2001					10.93	33.67
2002						35.21

Table 3A.12. Lake Creek average GPM C Channel densities for brood years 1986–2001. Based on data in Table 3A.11.

Brood Year	Sample Year	C channel	Count
1985	1986		
1986	1987	27.38	2
1987	1988	3.08	1
1988	1989	7.53	2
1989	1990	14.61	2
1990	1991	7.33	2
1991	1992	6.12	6
1992	1993	2.57	2
1993	1994	7.82	2
1994	1995		
1995	1996		
1996	1997		
1997	1998		
1998	1999	16.66	2
1999	2000		
2000	2001	22.30	2
2001	2002	35.21	1

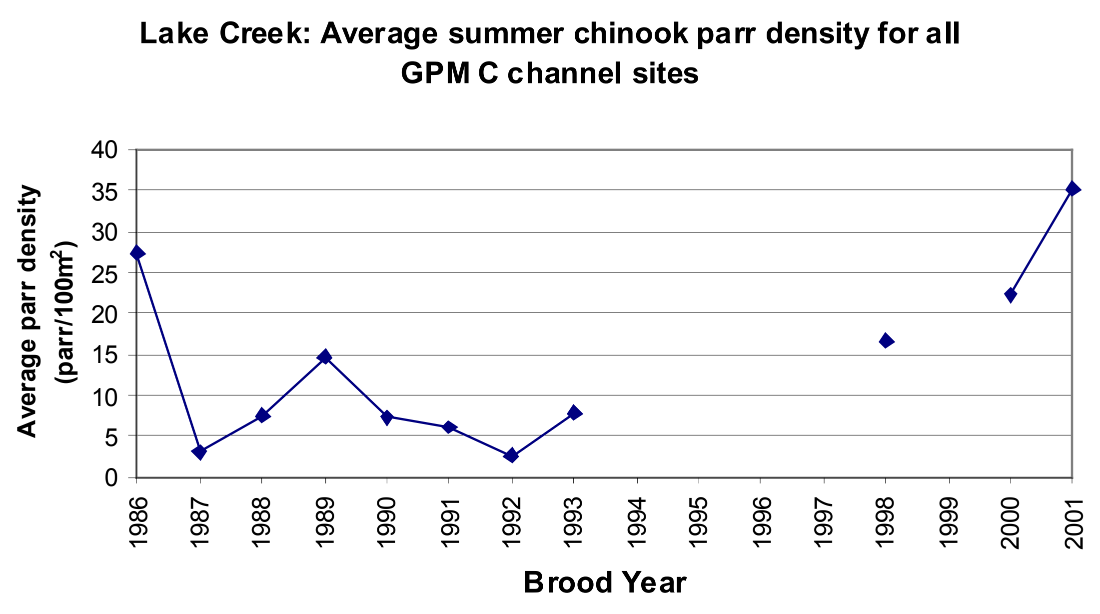


Figure 3A.4. The time series pattern for the C Channel based index of average summer chinook parr densities for Lake Creek, South Fork Salmon River (1986-2001). This is the time series used to derive the survival rate index for the base AIC analyses.

3A.1.5 Bear Valley/ Elk Creek Parr Density Data

Table 3A.13. Bear Valley/Elk Creek GPM C Channel sites and densities for sampling years 1985-2002. Data source: Idaho Department of Fish and Game, General Parr Monitoring database

STREAM	Bear Valley Creek	STREAM	Elk Creek
SpeciesID	17	SpeciesID	17
CHINOOK_CLASS	WSPR	CHINOOK_CLASS	WSPR
SName	Chinook Salmon	SName	Chinook Salmon
AgeGrp	0	AgeGrp	0
CHANNEL_TYPE	C	CHANNEL_TYPE	C
Average of density (parr/100m2)			

	STRATA SECTION						STRATA SECTION				
	2		3	5	7	9	1		2		
Sample year	A	B	A	A	BIG-MDW-L	B	A	B	A	B	C
1985	1.93										
1986	1.95	0.27	4.73	4.10			0.08	1.56	0.48	2.64	
1987	0.89		7.72	1.34	0.52	2.22	0.07	0.03		3.80	
1988	4.15	0.02	5.57	2.88	2.61	2.59	0.13	11.85	0.22	10.03	
1989	0.76	0.42	6.36	4.32		0.95	0.47	5.17	9.38	5.10	
1990		0.02	1.08	1.21			1.04	0.03		0.05	
1991	0.10	0.02	1.60	0.50	0.27	0.29	0.24				
1992	2.40	0.02	0.20		1.54		0.18	0.07		0.14	1.53
1993			4.05	2.14							
1994	0.86	0.54	31.57	76.08	0.44		1.96		0.05	1.28	
1995	0.12		0.23								
1996	0.10										
1997	2.60	0.02	2.69	1.18				0.06			
1998			5.43	2.29			0.16		0.10	4.99	7.75
1999	6.33	2.57	26.36	7.16							
2000			0.12	1.81			0.63	0.54	0.16		0.18
2001	3.88	0.55	12.27	5.51	2.64						
2002	14.93	3.69	25.63	10.65	4.21	1.32					

Table 3A.14. Bear Valley/Elk Creek average GPM C Channel densities for brood years 1984-2001. Based on data in Table 3A.13. The "BVC_ELK" time series was used to derive the survival rate index used in the AIC analysis.

C channel parr densities			
Brood Year	BVC	ELK	BVC_ELK
1984	1.93		1.93
1985	2.76	1.19	1.97
1986	2.54	1.30	2.08
1987	2.97	5.56	4.01
1988	2.56	5.03	3.66
1989	0.77	0.37	0.57
1990	0.46	0.24	0.43
1991	1.04	0.48	0.76
1992	3.09		3.09
1993	21.90	1.10	14.10
1994	0.18		0.18
1995	0.10		0.10
1996	1.62	0.06	1.31
1997	3.86	3.25	3.45
1998	10.60		10.60
1999	0.96	0.38	0.57
2000	4.97		4.97
2001	10.07		10.07

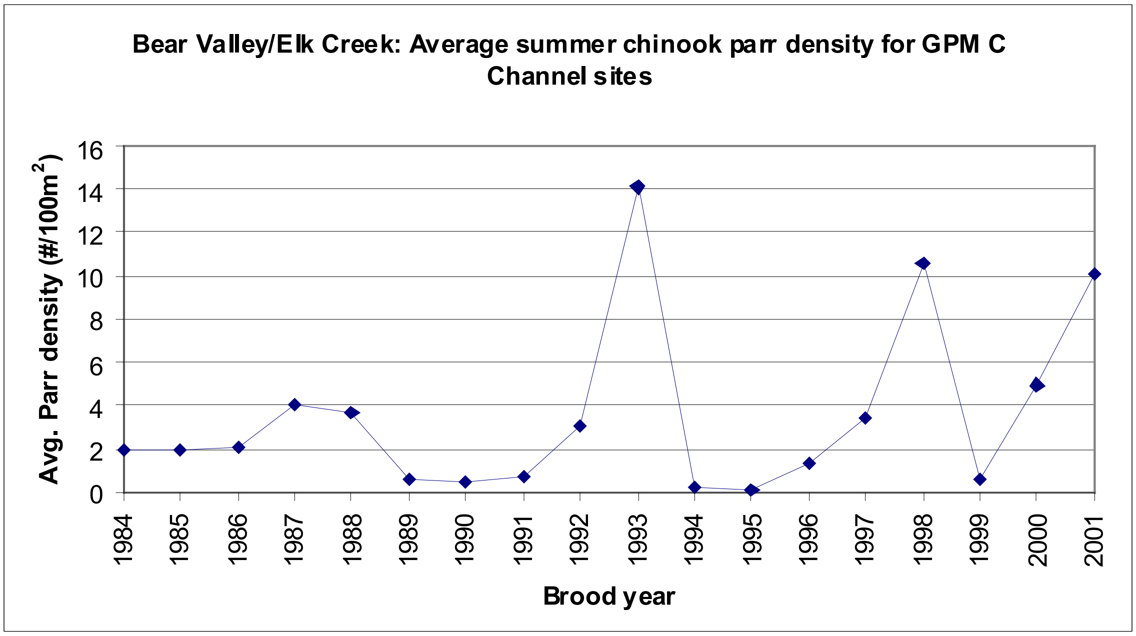


Figure 3A.5. The time series pattern of the C Channel based index of average summer chinook parr densities for Bear Valley/Elk Creek, Middle Fork Salmon River (1984-2001). This is the "BVC_ELK" time series in Table 3A.14 and the same series used to derive the survival rate index for the base AIC analysis.

A.1.6 Big Creek Parr Density Data

Table 3A.15. Big Creek average GPM C Channel densities for sampling years 1986-2001. The C Channel densities used for AIC analyses are shown in the right hand column. These densities are an average over C channel sites in Big Creek and Monumental Creek.

STREAM	**Big Creek**		**Monumental Creek**				
SpeciesID	17		17				
CHINOOK_CLASS	WSPR		WSPR				
SName	Chinook Salmon		Chinook Salmon				
AgeGrp	0		0				
CHANNEL_TYPE	C		C				
Average of density	STRATA	SECTION	STRATA	SECTION			
	MIDDLE	UPPER	-99				
Sample Year	**TAYLOR 1**	**NEAR FORD**	**MON2**	**MON3**	**MON5**	**Brood Year**	**C Channel**
1985	0.56		2.73	0.01	11.87	1984	**3.79**
1986	0.22		0.14	0.51	29.84	1985	**7.68**
1987	2.10			0.19	44.64	1986	**15.65**
1988	1.92				17.87	1987	**9.90**
1989					4.76	1988	**4.76**
1990	0.21		3.12	4.07	1.17	1989	**2.14**
1991	1.13				2.46	1990	**1.80**
1992	1.39	15.49			7.03	1991	**7.97**
1993		16.00			4.04	1992	**10.02**
1994		20.73				1993	**20.73**
1995						1994	
1996						1995	
1997	0.05	0.48				1996	**0.26**
1998		17.33				1997	**17.33**
1999	2.87	11.71	0.73		1.81	1998	**4.28**
2000		1.11		0.61	4.56	1999	**2.10**
2001					6.57	2000	**6.57**
2002						2001	

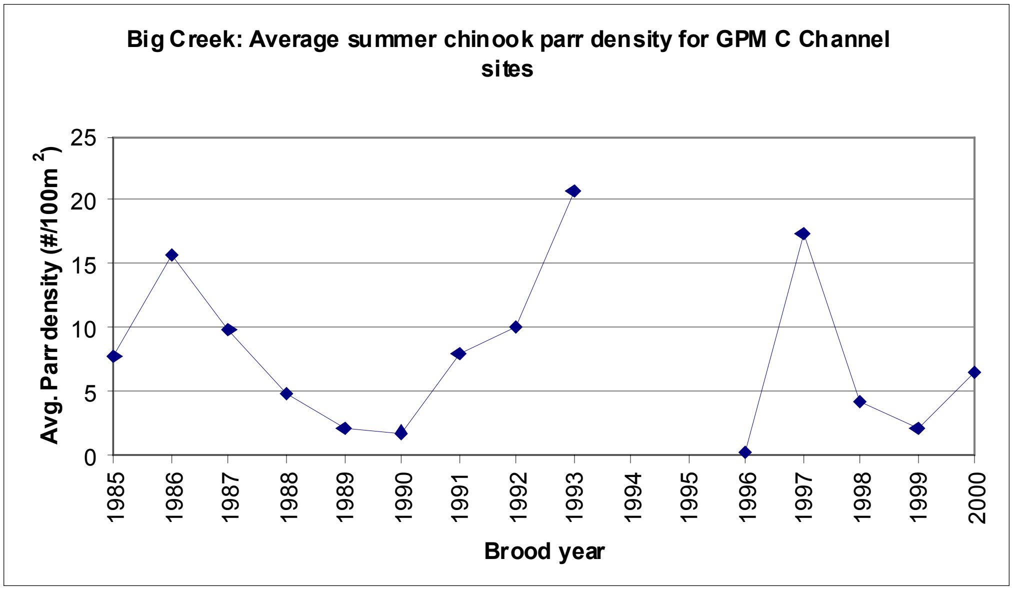


Figure 3A.6. The time series pattern of the C Channel based index of average summer chinook parr densities for Big Creek, Middle Fork Salmon River (brood years 1985-2000). This is the time series used to derive the survival rate index for the base AIC analyses.

A.1.7 Sulphur Creek Parr Density Data

Table 3A.16. Sulphur Creek average GPM C Channel densities for sampling years 1986-2001.

STREAM	Sulphur Creek		
SpeciesID	17		
CHINOOK_CLASS	WSPR		
SName	Chinook Salmon		
AgeGrp	0		
CHANNEL_TYPE	C		
Average of density (# parr/100m^2)			
	STRATA	SECTION	
	2	4	
Sample Year	4A	4A	4C
1986		18.85	
1987		39.96	19.13
1988		24.05	
1989		56.47	
1990		0.47	
1991		5.87	
1992		1.92	
1993			
1994	5.30		
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			

Table 3A.17. Sulphur Creek average GPM C and B Channel densities for brood years 1985-1999. C channel averages based on data in Table 3A.16.

Brood Year	C Channel	B Channel
1985	18.85	28.44
1986	29.55	11.16
1987	24.05	35.39
1988	56.47	78.90
1989	0.47	15.73
1990	5.87	3.21
1991	1.92	3.46
1992		
1993	5.30	7.95
1994		
1995		
1996		
1997		1.45
1998		
1999		0.32
2000		
2001		

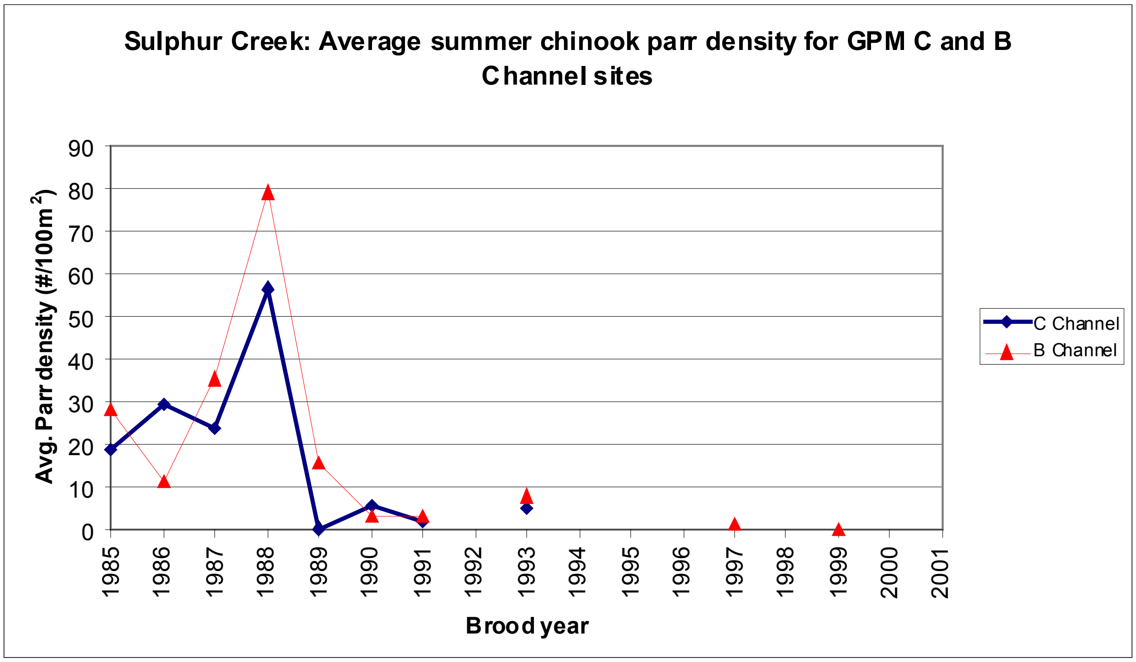


Figure 3A.7. The time series patterns for C and B Channel based indices of average summer chinook parr densities for Sulphur Creek, Middle Fork Salmon River (1985-1999). The C channel index was used to derive the survival rate index for the base AIC analyses.

A.1.8 Marsh Creek Parr Density Data

Table 3A.18. Marsh Creek average GPM C Channel densities for sampling years 1985-2002. Data for Beaver Creek, Cape Horn Creek and Knapp Creek sites.

STREAM	Beaver Creek	Cape Horn Creek	Knapp Creek						
SpeciesID	17	17	17						
CHINOOK_CLASS	WSPR	WSPR	WSPR						
SName	Chinook Salmon	Chinook Salmon	Chinook Salmon						
AgeGrp	0	0	0						
CHANNEL_TYPE	C	C	C						
	STRATA SECTION	STRATA SECTION	STRATA	SECTION					
	3	2	1						
Sample year	B	B	A	B	BEAVERDAM	CAMPSITE	DS DIV	LCKD FENCE	UPCAMPSITE
1985	10.77	48.97	23.60	10.59					
1986	28.61	11.63	7.17						
1987	5.91	97.23	10.39	0.15					
1988	26.83	56.03	11.21	0.16					
1989	6.51	50.67	21.53	0.42					
1990	0.34	28.75	5.36				0.28	0.41	0.12
1991	0.58	36.94	13.85	0.29		2.07	0.84	18.10	
1992	0.42	20.78	12.59			0.34	1.33	8.90	
1993	0.77	21.52	0.66				0.12	1.21	
1994	32.16	93.71	5.66				6.62	36.90	
1995									
1996									
1997		24.92							
1998	15.71	3.39				0.18	2.33		
1999	13.20	62.57	9.61	8.72	1.93	0.56	1.93	3.66	
2000	1.04	0.20						3.66	
2001	1.45	13.52							
2002	0.86	38.21							

Table 3A.19a. Marsh Creek average GPM C Channel densities for sampling years 1985-2002.

STREAM	Marsh Creek							
SpeciesID	17							
CHINOOK_CLASS	WSPR							
SName	Chinook Salmon							
AgeGrp	0							
CHANNEL_TYPE	C							
	STRATA	SECTION						
	1							
Sample year	1	11	19	2	3	5	6	8
1985								
1986								
1987								
1988								
1989								
1990								
1991								
1992								
1993								
1994	17.63	1.92	39.45	11.58	54.83	4.84	2.29	1.73
1995								
1996								
1997								
1998								
1999								
2000								
2001								
2002								

Table 3A.19b. Marsh Creek average GPM C Channel densities for sampling years 1985-2002, continued.

STREAM	Marsh Creek						
SpeciesID	17						
CHINOOK_CLASS	WSPR						
SName	Chinook Salmon						
AgeGrp	0						
CHANNEL_TYPE	C						
	STRATA	SECTION					
	2				3	4	5
Sample year	14	15	4	5	A	B	A
1985					14.08	22.23	35.70
1986					8.29	27.95	40.50
1987					35.94	34.23	89.32
1988					37.90	21.88	64.39
1989					91.09	34.43	28.10
1990					2.03		5.50
1991					2.97	1.70	3.63
1992					38.98	59.53	22.06
1993					8.54	10.32	4.21
1994	79.52	46.95	57.86	22.30	30.91	23.91	15.42
1995						0.74	1.66
1996							
1997							
1998							
1999					21.32	38.70	38.88
2000							
2001							
2002							

Table 3A.19c. Marsh Creek average GPM C Channel densities for sampling years 1985-2002, continued

STREAM	Marsh Creek													
SpeciesID	17													
CHINOOK_CLASS	WSPR													
SName	Chinook Salmon													
AgeGrp	0													
CHANNEL_TYPE	C													
	STRAT,SECTION													
	-99													
Sample year	10	11	12	13	16	17	18	20	3	6	7	8	9	ABVMON1
1985														
1986														
1987														
1988														
1989														
1990														
1991														
1992														
1993														
1994	92.56	48.65	36.63	80.26	28.64	42.52	48.48	27.56	22.08	3.21	2.11	26.18	38.96	22.49
1995														
1996														
1997														
1998														
1999														
2000														
2001														
2002														

Table 3A.20. Summary average parr density time series for Marsh Creek. Columns are the average GPM C Channel densities for sampling years 1985-2002, based on the information in Tables 3A.18 and 3A.20. The "All" time series was used to derive the survival rate index for the AIC analysis.

C channel parr densities					
Brood Year	**Beaver**	**Cape Horn**	**Knapp**	**Marsh**	**All**
1984	10.77	48.97	17.10	24.00	23.71
1985	28.61	11.63	7.17	25.58	20.69
1986	5.91	97.23	5.27	53.16	39.02
1987	26.83	56.03	5.69	41.39	31.20
1988	6.51	50.67	10.98	51.21	33.25
1989	0.34	28.75	1.54	3.77	5.35
1990	0.58	36.94	7.03	2.77	8.10
1991	0.42	20.78	5.79	40.19	18.33
1992	0.77	21.52	0.67	7.69	5.92
1993	32.16	93.71	16.39	32.12	32.54
1994				1.20	1.20
1995					
1996		24.92			24.92
1997	15.71	3.39	1.25		5.40
1998	13.20	62.57	4.40	32.96	18.28
1999	1.04	0.20	3.66		1.63
2000	1.45	13.52			7.49
2001	0.86	38.21			19.54

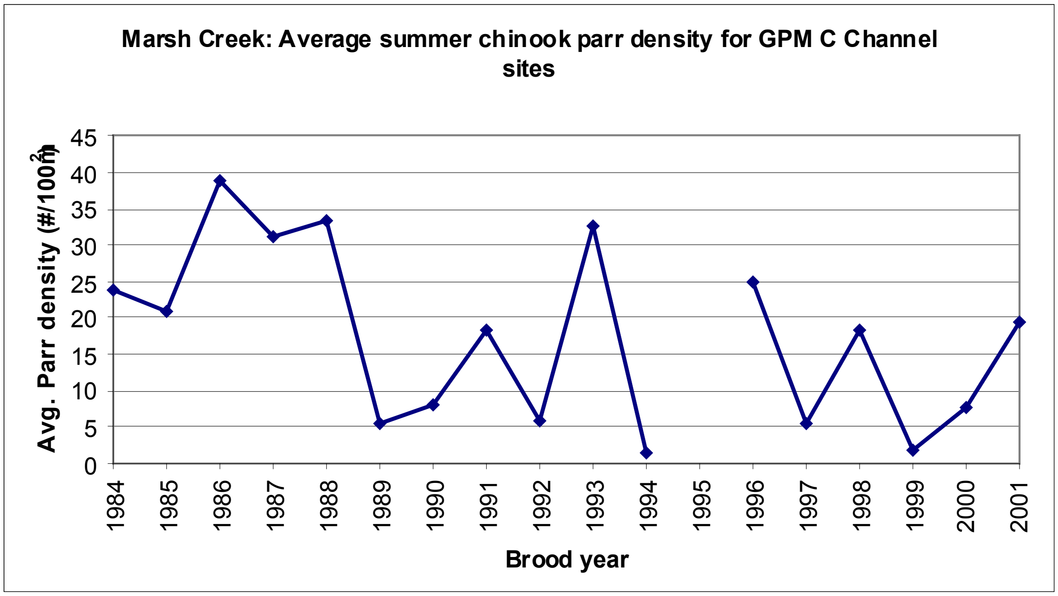
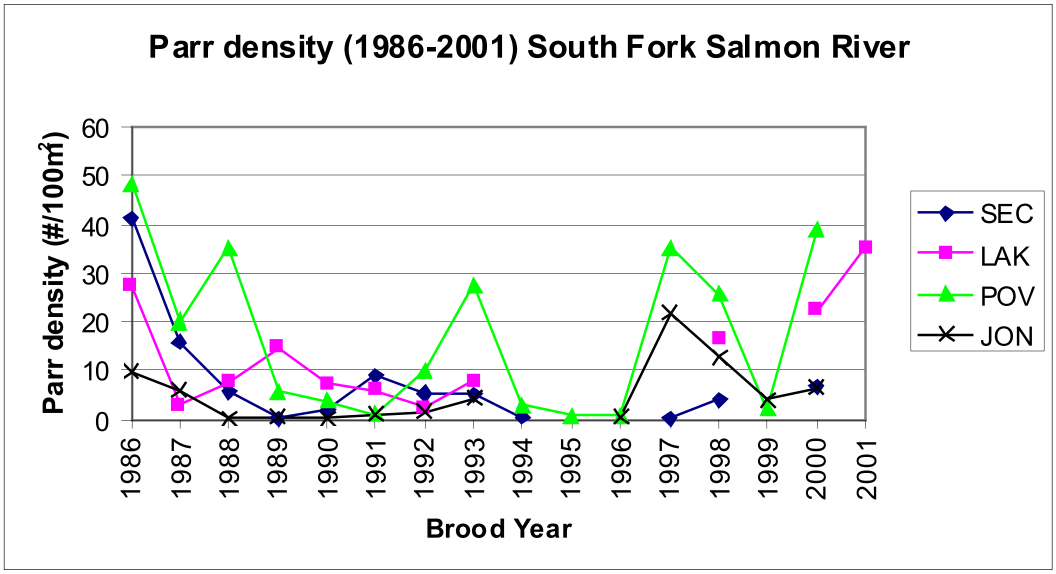


Figure 3A.8. The time series pattern of the C Channel based index of average summer chinook parr densities for Marsh Creek, Middle Fork Salmon River (1984–2001). This is the time series used to derive the survival rate index for the base AIC analyses.

3A.2 Summary parr density comparisons across streams

Table 3A.21. Parr densities (parr/100m2). SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. BY = brood year (sample year – 1).

Parr Density								
BY	SEC	LAK	POV	JON	BVC	MAR	SUL	BIG
1986	41.18	27.38	48.49	9.68	2.08	39.02	29.55	15.65
1987	15.90	3.08	20.04	6.04	4.01	31.20	24.05	9.90
1988	5.68	7.53	35.24	0.13	3.66	33.25	56.47	4.76
1989	0.11	14.61	5.70	0.43	0.57	5.35	0.47	2.14
1990	1.79	7.33	3.91	0.26	0.43	8.10	5.87	1.80
1991	9.13	6.12	1.13	1.03	0.76	18.33	1.92	7.97
1992	5.32	2.57	9.99	1.51	3.09	5.92		10.02
1993	5.12	7.82	27.53	4.25	14.10	32.54	5.30	20.73
1994	0.51		3.01		0.18	1.20		
1995			0.77		0.10			
1996			0.84	0.44	1.31	24.92		0.26
1997	0.28		35.26	21.76	3.45	5.40		17.33
1998	4.00	16.66	25.71	12.87	10.60	18.28		4.28
1999			2.14	4.10	0.57	1.63		2.10
2000	6.72	22.30	38.98	6.42	4.97	7.49		6.57
2001		35.21			10.07	19.54		



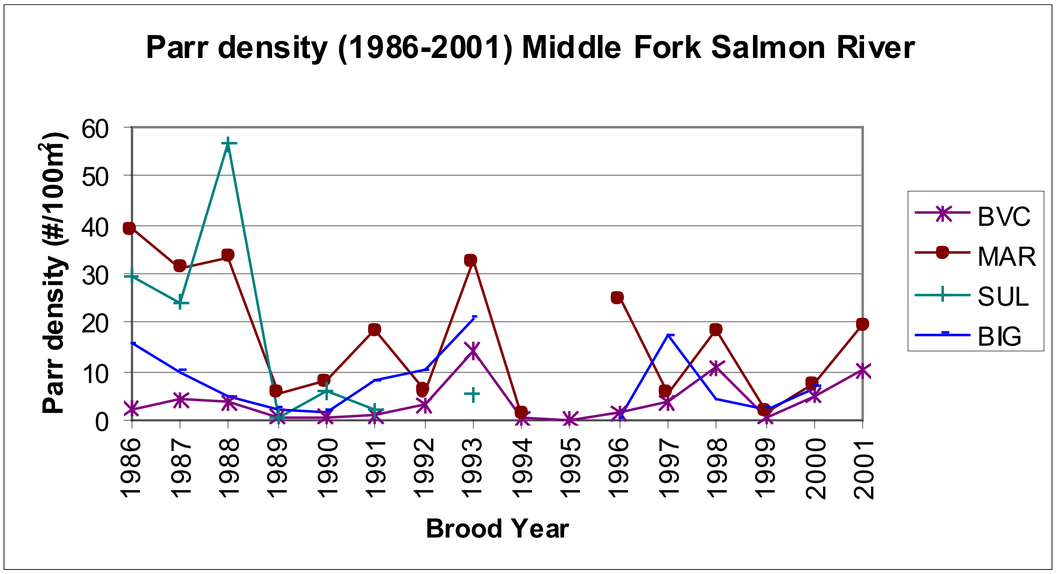


Figure 3A.9. Temporal pattern of average summer parr density (parr/100m^2) for streams in the South Fork Salmon River (top panel) and Middle Fork Salmon River (bottom panel). SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. Brood Year = brood year (sample year –1).

3A.3 Relationship of Parr Counts to Water Temperature

Parr counts may be biased downward water temperatures below 10°C (Hillman et al. 1992). Although GPM protocols required that counts be conducted only above 10°C (Hall-Griswold and Petrosky 1996) the potential for such bias exists and thus water temperature could have been an important covariate to include in our models. To evaluate the temperature bias effect we plotted parr densities vs. water temperature for all CH 0+ points available in the database. A positive relationship between parr density and water temperature would indicate that parr counts tended to be lower at lower water temperatures and provide support for a temperature bias effect. We observed no such relationship (Figure A.10) and concluded it was not necessary to include temperature at time of snorkeling in our models.

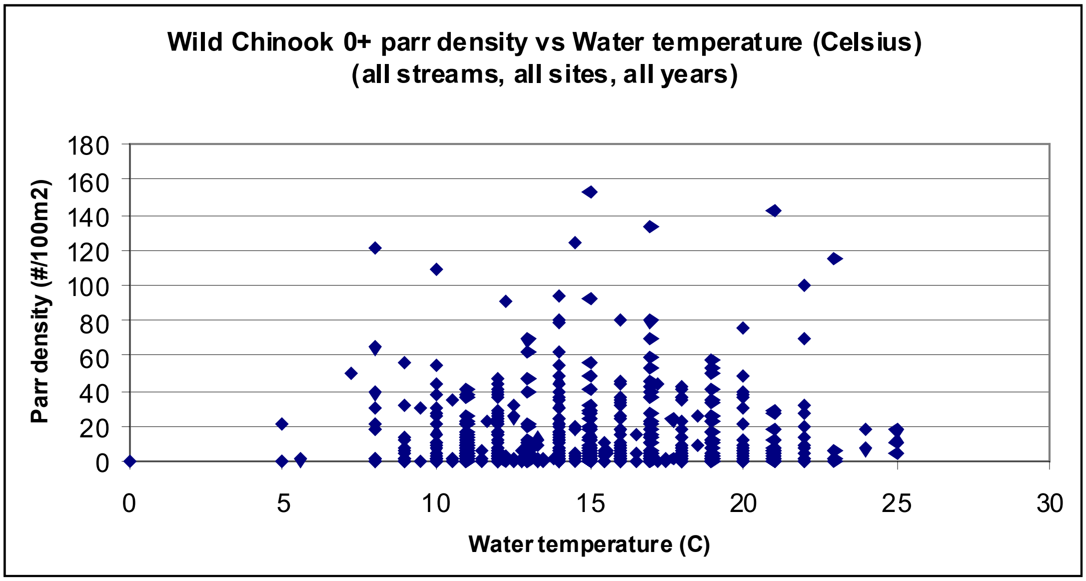


Figure 3A.10. Wild spring-summer chinook summer parr density (0+) vs. water temperature (°C). Data taken from Idaho Department of Fish and Game General Parr Monitoring program database. We deleted records with blanks, -99, -10 recorded in temperature field and assumed that temperatures greater then 30 were F and converted them to C. Records for densities greater than 160 were assumed to be errors and deleted; the area snorkeled was usually less than 5 m^2 in these cases.

Appendix 3.B - Redd density data

We obtained a copy of the Idaho Department of Fish and Game (IDFG) index redd count database in Excel format from Evan Brown, July 28, 2003.

We used the Excel "AutoFilter" and pivot table tools to extract the total number of redds and the total length of stream over which index counts were conducted (km) for each year (index sites indicated where "flagTrend" = TRUE) and cross-checked the results against the IDFG spawner-recruit run reconstruction data set (received from Charlie Petrosky, July 8, 2003). Where there were discrepancies we used the S-R data set redd counts and distances. We expressed redd densities as the number of redds per Km. The time series of redd densities for each of the eight streams in this analysis are listed in Table 3B.1; the temporal pattern is shown in Figure 3B.1.

Table 3B.1. Redd densities (redds/km) based on IDFG index redd counts used for the IDFG spawner-recruit run reconstruction data set. SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. BY = brood year for parr produced by these redds (i.e. parr counted in GPM surveys in the summer of the following year).

Redd Density

BY	SEC	LAK	POV	JON	BVC	MAR	SUL	BIG
1986	4.86	5.16	4.26	11.30	2.46	4.27	12.24	13.09
1987	6.53	3.89	8.81	15.35	4.78	6.34	2.07	7.03
1988	7.47	6.16	13.21	29.21	11.68	9.17	7.72	19.74
1989	5.06	3.53	4.47	8.96	0.95	1.86	0.38	5.86
1990	3.00	1.81	8.88	11.94	1.98	2.41	4.14	3.91
1991	5.45	4.26	8.91	13.65	1.93	1.69	4.90	2.54
1992	6.01	4.99	8.98	16.20	1.87	2.75	0.94	4.30
1993	5.59	3.99	13.49	30.28	7.43	5.07	4.71	10.94
1994	1.60	0.72	3.23	4.26	0.34	0.21	0.00	0.59
1995	0.83	1.27	1.38	1.92	0.17	0.00	0.00	0.39
1996	1.91	3.35	2.52	4.90	0.61	0.42	1.72	0.20
1997	4.08	6.07	5.57	20.04	2.36	2.62	2.25	6.45
1998	2.23	4.80	6.28	10.23	3.95	3.80	6.21	2.93
1999	1.73	1.00	2.73	4.90	0.82	0.00	0.00	1.95
2000	9.93	14.96	5.72	5.33	3.28	1.52	0.66	2.54
2001	10.72	25.02	13.28	37.74	7.45	8.24	5.29	27.36

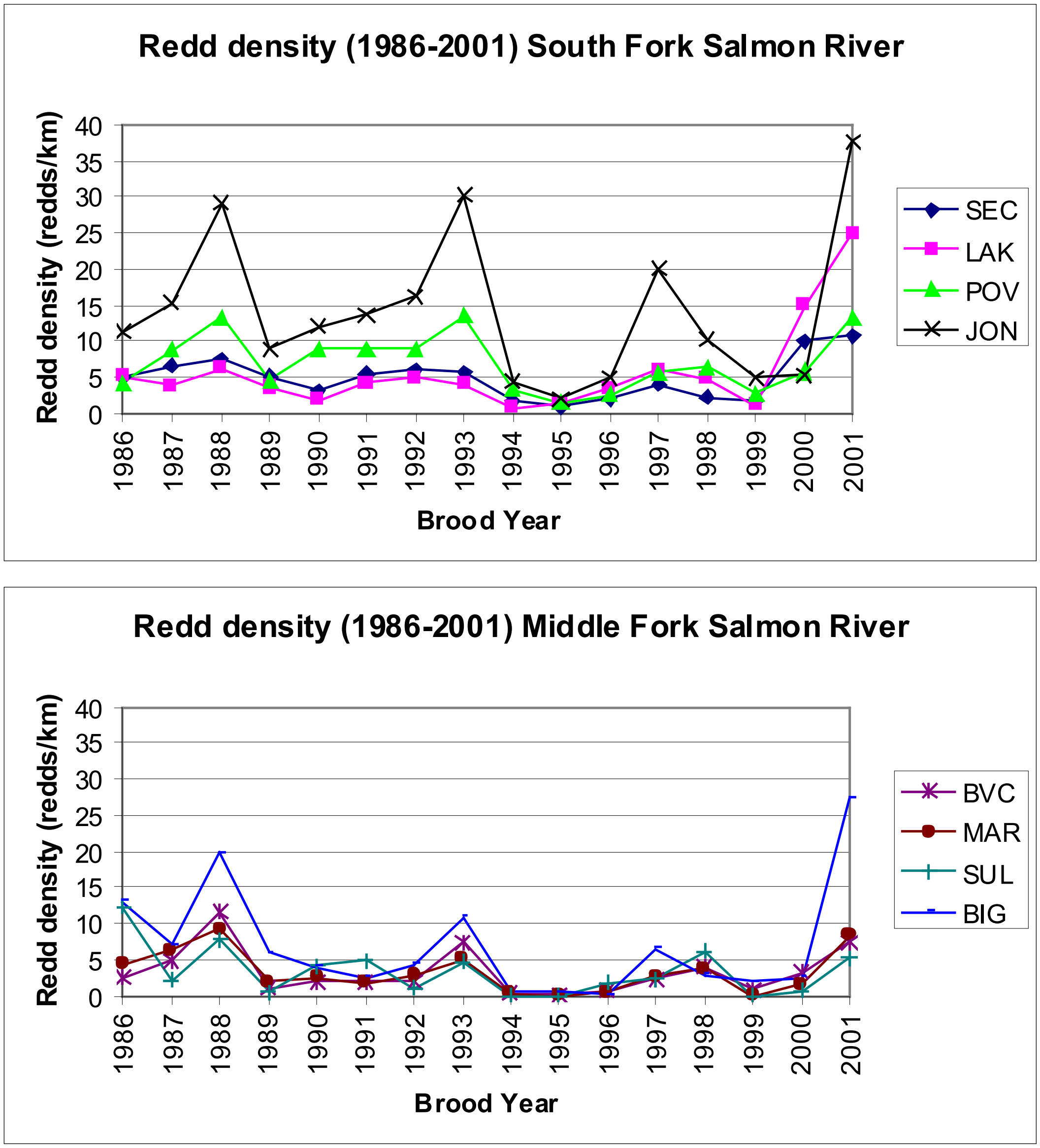


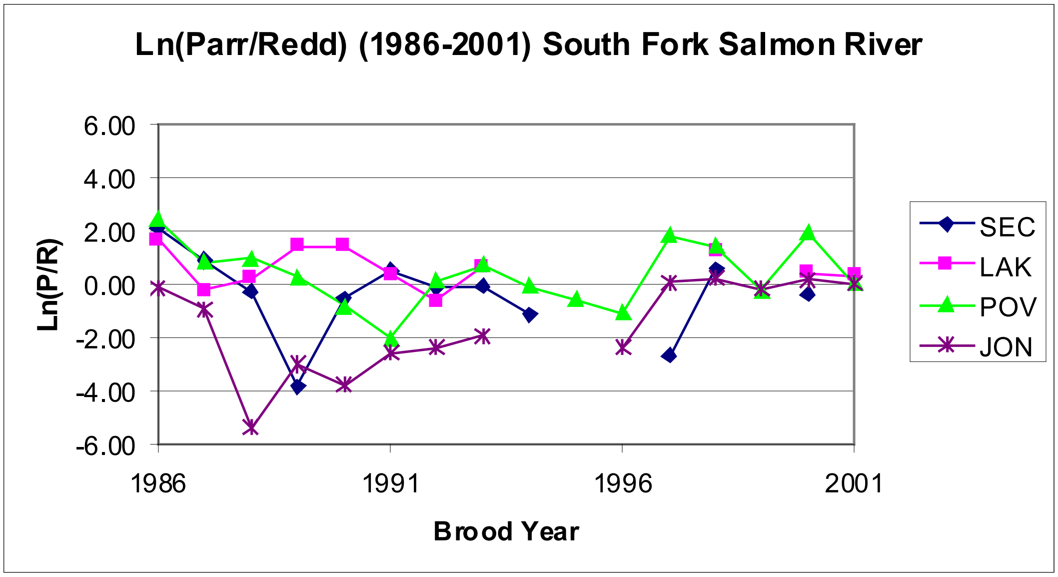
Figure 3B.1. Temporal pattern of redd density (redds/km) for streams in the South Fork Salmon River (top panel) and Middle Fork Salmon River (bottom panel). SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. Brood Year = brood year for parr produced by these redds (i.e. parr counted in GPM surveys in the summer of the following year).

Appendix 3.C - Ln (parr density/redd density) survival rate index

Table 3C.1 and Figure 3C.1 present the Ln(parr density/redd density) survival rate index used for the AIC analysis. These data are also shown in the main text, but are included hear for easier comparison to the information shown in Appendix 3.A (parr density data) and Appendix 3.B (redd density data).

Table 3C.1. Ln (parr density/redd density) survival rate index. SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. BY = brood year (sample year – 1).

Ln(Parr density/redd density)								
BY	SEC	LAK	POV	JON	BIG	BVC	MAR	SUL
1986	2.14	1.67	2.43	-0.15	0.18	-0.17	2.21	0.88
1987	0.89	-0.24	0.82	-0.93	0.34	-0.18	1.59	2.45
1988	-0.27	0.20	0.98	-5.41	-1.42	-1.16	1.29	1.99
1989	-3.85	1.42	0.24	-3.04	-1.01	-0.51	1.06	0.22
1990	-0.52	1.40	-0.82	-3.82	-0.78	-1.52	1.21	0.35
1991	0.52	0.36	-2.07	-2.58	1.14	-0.93	2.38	-0.94
1992	-0.12	-0.66	0.11	-2.37	0.85	0.50	0.77	
1993	-0.09	0.67	0.71	-1.96	0.64	0.64	1.86	0.12
1994	-1.15		-0.07			-0.67	1.74	
1995			-0.59			-0.54		
1996			-1.10	-2.40	0.29	0.76	4.08	
1997	-2.69		1.84	0.08	0.99	0.38	0.72	
1998	0.58	1.24	1.41	0.23	0.38	0.99	1.57	
1999			-0.24	-0.18	0.07	-0.36		
2000	-0.39	0.40	1.92	0.19	0.95	0.42	1.59	
2001		0.34 .	.	.		0.30	0.86	



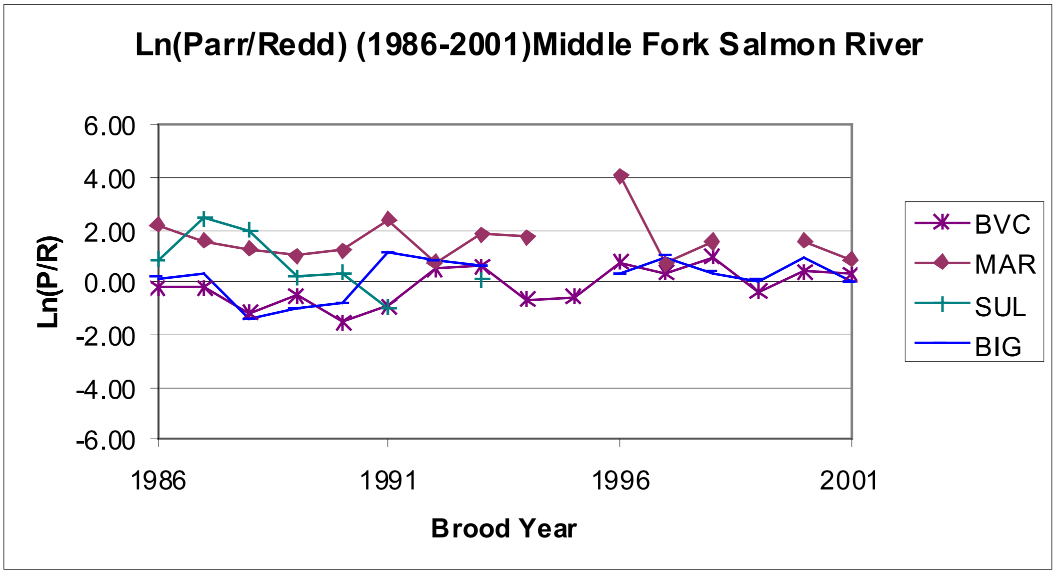


Figure 3C.1. Temporal pattern of Ln(parr density/redd density) survival rate index for streams in the South Fork Salmon River (top panel) and Middle Fork Salmon River (bottom panel). SEC = Secesh River, LAK = Lake Creek, POV = South Fork Salmon River (Poverty Flat area), JON = Johnson Creek, BVC = Bear Valley Elk Creek, MAR = Marsh Creek, SUL = Sulphur Creek, BIG = Big Creek. Brood Year = brood year (sample year –1).

Appendix 3.D - Ancillary data

ISS Data (1992-1996, 2002)

- Parr counts, Redd counts, Spawner abundance, Emigrant trapping (spring parr, summer parr, pre-smolts, spring smolts).
- Parr abundance data may be useful for saying something about how well the parr density data collected in the IDFG GPM program index parr abundance.
- Useful for assessing how well parr densities from GPM may index abundance of parr in streams where the two programs overlap.
- May also be used to create synthetic data sets that combine the GPM and ISS parr densities (e.g. in years where GPM data are missing, but ISS data are present).

NPT Data (Secesh/Lake, Johnson)

- The NPT include estimates of parr density for the Secesh and Lake systems, collected as part of the ISS program. These data span the years 19?? To 19??)
- Emigration estimates for fry, summer parr, pre-smolts and spring smolts from trapping on the Secesh, Lake, and Johnson systems from 996 to 2001.
- Redd counts (independent if IDFG) for Secesh, Lake and Johnson systems from 19?? To 19??

SBT Data (Bear Valley Creek, Middle Fork Salmon River) (1984-2001)

- The SBT carried out actions in the BVC floodplain to reduce sediment input into BVC.
- Extracted parr abundance, parr density and redd counts from annual reports submitted to BPA.
- Parr densities and redd counts were available by strata and year.
- The reports describe the work that was done and provide maps showing the location of the sampling strata. Other habitat and physical information is provided as well.
- Unfortunately, there are only 2 years of before data in contrast to 11 years of After data. The years 1986–1989 are left out of the SBT BA analyses.
- The SBT have carried out BA type analyses of the effect of changes in sediment.

IDFG S-R run reconstruction data (1957-2001)

- We obtained a copy of the most recent index stock S-R data set.
- This provides spawner abundance and recruits by brood year. Spawning abundance is estimated with and without jacks. Recruits are to the mouth of the Columbia and to the spawning ground.

These data are derived from the IDFG index redd counts and the analyses accounts for pre-spawning mortality, hatchery fractions, in-river harvest rates, and upstream conversion rates.

Indices of sediment conditions:

We found three sources of sediment data, that provided four time series of sediment indices. The USFS has collected sediment data in the summer chinook spawning and rearing habitat of the South Fork Salmon River regularly since at least 1977 to 2001 (Rogers et al. 2002). Sediment indices are available in annual reports for Secesh River, Lake Creek, Johnson Creek and the mainstem of the South Fork Salmon

River (e.g. Poverty Flat). We used mean small fines as our sediment index. Platts et al. 1989 provide a figure showing the pattern in volume of sediment input to SFSR from 1966 to 1989 or so. We used this data to extend the length of the sediment time series. We assumed it would apply only to the mainstem SFSR (e.g. Poverty Flat). We also assumed that this index is directly related to the index of mean small fines for the Poverty Flat spawning and rearing area. Platt et al. 1989 also provides a time series of small fines for Poverty Flat (1967–1985). Megahan et al. 1990 discuss the pattern of management actions and provide a time series of small fines averaged over a number of site on the mainstem of the South Fork Salmon River (including Poverty Flat). This series pushes back the USFS data, but is discontinuous, covering 1966–1972 and 1975–1990. There is some overlap between these four data sets, so we looked at overlay plots of all four to assess common patterns in the overlap between these series. Because all sediment data were for the South Fork Salmon River, so we did not include them as terms in the log-linear models. However, we looked at the pattern of the sediment indices relative to model residuals.

Data summary for South Fork Salmon River

Data	Type	Program	Watershed	Tributary	Location	Coverage	Source	Contact	Status	Comment
Emigrant	screw trap, ISS	ISS	South Fork Salmon River	Secesh		1996-2001	NPT	C. Beasely	Have	
Emigrant	screw trap, ISS	ISS	South Fork Salmon River	Lake		1996-2001	NPT	C. Beasely	Have	
Emigrant	screw trap, ISS	ISS	South Fork Salmon River	Johnson Cr		1998-2001	NPT	C. Beasely	Have	
Habitat	Flow (gauge, monthly)		South Fork Salmon River	SFSR	Krassel gauge, Johnson Creek (Yellow Pine) gauge	1966-2002	USGS	http://waterdata.usgs.gov	Have	Other breakdowns possible (e.g. weekly)
Habitat	Restoration actions		South Fork Salmon River	SFSR		1991-2002	NMFS	K. Barnas	Have	
Habitat	Restoration actions		South Fork Salmon River	SFSSR			Subbasin summaries		Have	
Habitat	Restoration actions		South Fork Salmon River	SFSR			BPA project database		Have	
Habitat	Smolt Density Model, snapshot		South Fork Salmon River	Salmon subbasin	Most tribs and reaches	1989	NPPC	www.streamnet.org	Have	qualitative estimates of reach quality for spawning and rearing for Smolt Density Model
Habitat	Summary of projects by Tributary		South Fork Salmon River	SFSR, Secesh, Lake, Johnson Cr, etc.		1984-2003	Tim Fisher, Fisher Fisheries Ltd.	Tim Fisher, Fisher Fisheries Ltd.	Have	Used to create cumulative habitat index.
Habitat	Section area, temperature, visibility	GPM	South Fork Salmon River	SFSR		1987-2001	IDFG	J. Hall-Griswold	Have	site and sampling information associated with GPM snorkel counts
Parr	density, size	GPM	South Fork Salmon River	Secesh		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	South Fork Salmon River	Lake		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	South Fork Salmon River	Johnson Cr		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	South Fork Salmon River	SFSR		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, ISS	ISS	South Fork Salmon River	Secesh		1991-2000	NPT	C. Beasely	Have	Collected as part of IDFG GPM monitoring, can't do abundance.

Data	Type	Program	Watershed	Tributary	Location	Coverage	Source	Contact	Status	Comment
Parr	density, ISS	ISS	South Fork Salmon River	Lake		1991-2000	NPT	C. Beasely	Have	Collected as part of IDFG GPM monitoring, can't do abundance.
Parr	density, ISS	ISS	South Fork Salmon River	SFSR above adult weir	Stratum 0	1992-1997	SBT	SBT ISS Annual Report 2000.pdf	Have	
Parr	density, ISS	ISS	South Fork Salmon River	SFSR above adult weir	Stratum 1	1992-1997	SBT	SBT ISS Annual Report 2000.pdf	Have	
Parr	density, ISS	ISS	South Fork Salmon River	SFSR above adult weir	Stratum 2	1992-1997	SBT	SBT ISS Annual Report 2000.pdf	Have	
Parr	density, ISS	ISS	South Fork Salmon River	SFSR above adult weir	Curtis Creek	1992-1997	SBT	SBT ISS Annual Report 2000.pdf	Have	
Redd	counts by section		South Fork Salmon River	Secesh		1987-2002	NPT	P. Kucera	Have	
Redd	counts by section		South Fork Salmon River	Lake		1987-2002	NPT	P. Kucera	Have	
Redd	counts by section		South Fork Salmon River	Johnson Cr		1987-2002	NPT	P. Kucera	Have	
Redd	counts by section		South Fork Salmon River	SFSR		91, 1996-2002	NPT	P. Kucera	Have	
Redd	Index counts by section		South Fork Salmon River	Lake		1957-2002	IDFG	E. Brown	Have	
Redd	Index counts by section		South Fork Salmon River	Secesh		1957-2003	IDFG	E. Brown	Have	
Redd	Index counts by section		South Fork Salmon River	Johnson Cr		1957-2004	IDFG	E. Brown	Have	
Redd	Index counts by section		South Fork Salmon River	SFSR		1957-2005	IDFG	E. Brown	Have	
Redd	Redds/Km		South Fork Salmon River	Secesh		1992-2001	Lutch et al. 2003		Have	
Redd	Redds/Km		South Fork Salmon River	Lake		1992-2001	Lutch et al. 2003		Have	
Redd	Redds/Km		South Fork Salmon River	Johnson Cr		1992-2001	Lutch et al. 2003		Have	
Redd	Redds/Km		South Fork Salmon River	SFSR		1992-2001	Lutch et al. 2003		Have	
Sediment	core samples		South Fork Salmon River	Secesh		1982-2002	USFS	R. Nelson	Have	several sediment indices
Sediment	core samples		South Fork Salmon River	Lake		1982-2002	USFS	R. Nelson	Have	several sediment indices
Sediment	core samples		South Fork Salmon River	Johnson Cr		1977-2002	USFS	R. Nelson	Have	several sediment indices

Data	Type	Program	Watershed	Tributary	Location	Coverage	Source	Contact	Status	Comment
Sediment	core samples		South Fork Salmon River	SFSR		1977-2002	USFS	R. Nelson	Have	several sediment indices
S-R	reconstuction		South Fork Salmon River	Secesh/Lake		1957-2001	IDFG	C. Petrosky	Have	
S-R	reconstuction		South Fork Salmon River	Johnson Cr		1957-2001	IDFG	C. Petrosky	Have	
S-R	reconstuction		South Fork Salmon River	Poverty Flat		1957-2001	IDFG	C. Petrosky	Have	
Fecundity	average eggs/spawned female		South Fork Salmon River	Upper weir		1980-2001	www.streamnet.org		Have	Data points for 1986 and 2001 are wrong.
Hatchery release	parr and smolt		South Fork Salmon River	Stolle Meadows, Johnson Creek		1985-2002	Regional Mark Information System (RMIS) Coded Wire Tag Database (www.rmis.org)		Have	
Hatchery release	parr and smolt	ISS	South Fork Salmon River	Stolle Meadows, Johnson Creek		1985-2002	Lutch et al. 2003		Have	

Data summary for Middle Fork Salmon River

Data	Type	Program	Watershed	Tributary	Location	Coverage	Source	Contact	Status	Comment
Habitat	Flow (gauge, monthly)		Middle Fork Salmon River	MFSR	MFSR gauge (near Yellow Pine)	1966-2002	USGS	http://waterdata.usgs.gov	Have	Other breakdowns possible (e.g. weekly)
Habitat	Restoration actions		Middle Fork Salmon River	MFSR			Subbasin summaries		Have	
Habitat	Restoration actions		Middle Fork Salmon River	MFSR			BPA project database		Have	
Habitat	Smolt Density Model, snapshot		Middle Fork Salmon River	Salmon subbasin	Most tribs and reaches	1989	NPPC	streamnet.org	Have	qualitative estimates of reach quality for spawning and rearing for Smolt Density Model
Habitat	Summary of projects by Tributary		Middle Fork Salmon River	SFSR, Secesh, Lake, Johnson Cr., etc.		1984-2003	Tim Fisher, Fisher Fisheries Ltd.	Tim Fisher, Fisher Fisheries Ltd.	Have	Used to create cumulative habitat index.
Habitat	Inventory		Middle Fork Salmon River	Upper Middle Fork		1987	Middle Fork of the Salmon River, Aquatic and Riparian Area Inventory, OEA Research			
Habitat	Section area, temperature, visibility	GPM	Middle Fork Salmon River	SFSR		1987-2001	IDFG	J. Hall-Griswold	Have	site and sampling information associated with GPM snorkel counts
Parr	density,size	GPM	Middle Fork Salmon River	Bear Valley Creek		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	Middle Fork Salmon River	Elk Creek		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	Middle Fork Salmon River	Sulphur Creek		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	Middle Fork Salmon River	Marsh Creek		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density, size	GPM	Middle Fork Salmon River	Big Creek		1987-2001	IDFG GPM	J. Hall-Griswold	Have	
Parr	density		Middle Fork Salmon River	Bear Valley Creek		1984-2002	SBT Reports	D. Taki	Have	
Redd	count		Middle Fork Salmon River	Bear Valley Creek		1987-2002	SBT Reports	D. Taki	Have	
Redd	Index counts by section		Middle Fork Salmon River	Bear Valley Creek		1957-2002	IDFG	E. Brown	Have	
Redd	Index counts by section		Middle Fork Salmon River	Elk Creek		1957-2003	IDFG	E. Brown	Have	
Redd	Index counts by section		Middle Fork Salmon River	Marsh Creek		1957-2004	IDFG	E. Brown	Have	
Redd	Index counts by section		Middle Fork Salmon River	Big Creek		1957-2005	IDFG	E. Brown	Have	
Redd	Index counts by section		Middle Fork Salmon River	Sulphur Creek		1957-2006	IDFG	E. Brown	Have	
S-R	reconstuction		Middle Fork Salmon River	Big Creek		1957-2001	IDFG	C. Petrosky	Have	

Data	Type	Program	Watershed	Tributary	Location	Coverage	Source	Contact	Status	Comment
S-R	reconstuction		Middle Fork Salmon River	Bear Valley/Elk Creek		1957-2001	IDFG	C. Petrosky	Have	
S-R	reconstuction		Middle Fork Salmon River	Marsh Creek		1957-2001	IDFG	C. Petrosky	Have	
Fecundity	average eggs/spawned female		Upper Salmon River	Sawtooh Hatchery		1985-2002	www.streamnet.org		Have	

Appendix 3.E - Flow indices

We downloaded average monthly flow data for gauges representative of flows within the South Fork and Middle Fork Salmon River drainages from the United States Geological Survey website (http://waterdata.usgs.gov).

As described in the main text, we used this data to create indices of fall, winter and freshet flows.

The length and continuity of the data sets varied between the gauges (Tables 3E.1 and 3E.2), but because of the high correlation in the indices between data sets we were able to use regression models to interpolate data points for years where data was missing (top panels of Figures 3E.1 and 3E.2). The time series for the Johnson Creek gauge was the most complete and spanned the years covered by the indices for the other two gauges so we used it as the independent variable in the regression models.

Table 3E.1. Comparison of Fall, Winter and Freshet indices for the Krassel and Johnson Creek gauges. "Johnson gauge" columns are the indices derived from the Johnson Creek gage data. "Krassel gauge" columns are the data derived from the Krassel gauge data. "Krassel Synthetic" columns are the indices for the Krassel gauge derived using the regression equations for each index (see top panels in Figure 3E.1). Flows are in cubic feet per second (ft^3/s).

	Johnson gauge			Krassel gauge			Krassel synthetic		
Year	Jon Fall	Jon Winter	Jon Freshet	Fall Flow (Sep-De	Winter Av	Freshet Avg.	Fall Synth	Winter Synth	Freshet Synth
1957	82	74	1350				146	165	1791
1958	99	99	1258				180	234	1668
1959	129	88	994				239	203	1315
1960	79	78	834				140	176	1100
1961	78	74	942				139	165	1245
1962	231	200	964				437	517	1274
1963	104	83	1150				188	189	1524
1964	107	127	1021				195	314	1350
1965	104	82	1686				190	187	2240
1966	61	60	654		157		105	127	859
1967	113	94	1186	174	215	1664	207	222	1572
1968	110	107	728	198	240	1029	201	256	959
1969	80	81	1149	133	193	1521	142	183	1521
1970	127	136	1262	261	321	1744	235	338	1673
1971	98	84	1663	154	223	2310	177	192	2209
1972	88	78	1388	175	198	1835	159	176	1842
1973	127	187	615	283	505	802	235	480	807
1974	92	72	1933	153	145	2519	167	158	2571
1975	148	122	1072	263	244	1560	274	299	1419
1976	91	64	1214	148	120	1615	164	136	1608
1977	103	110	244	207	262	309	188	265	311
1978	96	75	1244	157	137	1609	174	168	1649
1979	66	69	620	129	174	861	115	152	814
1980	109	123	1109	238	315	1495	198	301	1469
1981	103	115	1013	221	351	1240	188	280	1339
1982	142	123	1637	212		2224	264	300	2174
1983	162	152	1366				303	383	1813
1984	104	78	1244				190	175	1649
1985	108	121	708	179	318	918	198	295	932
1986	96	82	1111			1434	173	185	1472
1987	50	57	355				83	118	459
1988	48	58	499		175		79	119	652
1989	78	77	751	130	137	1024	138	173	989
1990	63	63	603	116	122	719	108	135	791
1991	68	81	669	109	151	817	120	185	880
1992	59	65	469	96	130	535	101	139	612
1993	74	59	1164	126	120	1477	131	123	1542
1994	53	100	440	102	273	526	89	237	573
1995	185	212	1283	351	504	1684	347	549	1701
1996	131	182	1503	284	505	1880	242	466	1995
1997	120	102	1662	183	206	2041	221	243	2208
1998	93	80	1057	171	200	1456	167	182	1399
1999	89	87	1260	163	182	1829	160	201	1670
2000	78	66	768	129	117	1009	138	142	1012
2001	72	78	328	132	154	455	127	175	423
2002			797			1106			1051

Table 3E.2. Comparison of Fall, Winter and Freshet indices for Middle Fork Salmon River and Johnson Creek gauges. "Johnson gauge" columns are the indices derived from the Johnson Creek gage data. "MFSR gauge" columns are the data derived from the Middle Fork Salmon River gauge data. "MFSR Synthetic" columns are the indices for Middle Fork Salmon River derived using the regression equations for each index (see top panels in Figure 3E.2). Flows are in cubic feet per second (ft^3/s).

	Johnson gauge			**MFSR gauge**			**MFSR synthetic**		
YEAR	JON Fall	JON Winter	JON Freshe	Fall Flow (Se	Winter Flo	Freshet (M	Synth MFSR Fall	Synth MFSR Winter	Synth MFSR Freshet
1973	127	187	615	746	902	2,197	711	900	2156
1974	92	72	1933	717	562	7,710	566	456	7510
1975	148	122	1072	754	598	4,383	794	651	4013
1976	91	64	1214	603	441	4,549	561	426	4587
1977	103	110	244	458	527	859	611	604	651
1978	96	75	1244	602	472	4,378	582	470	4709
1979	66	69	620	458	421	1,969	458	447	2176
1980	109	123	1109	672	628	4,139	633	653	4163
1981	103	115	1013		781	3,583	611	624	3771
1982	142	123	1637				772	652	6305
1983	162	152	1366				855	767	5207
1984	104	78	1244				616	480	4712
1985	108	121	708				633	645	2534
1986	96	82	1111				579	494	4172
1987	50	57	355				390	401	1100
1988	48	58	499				382	402	1685
1989	78	77	751				505	476	2708
1990	63	63	603				443	424	2107
1991	68	81	669				467	493	2375
1992	59	65	469				428	430	1563
1993	74	59	1164				492	407	4387
1994	53	100	440				402	565	1445
1995	185	212	1283				947	995	4869
1996	131	182	1503				725	882	5761
1997	120	102	1662				681	574	6408
1998	93	80	1057				568	488	3951
1999	89	87	1260	574	533	4,907	552	515	4774
2000	78	66	768	471	404	2,602	506	434	2777
2001	72	78	328	404	389	1,202	483	479	991
2002			797	493		2,697			2896

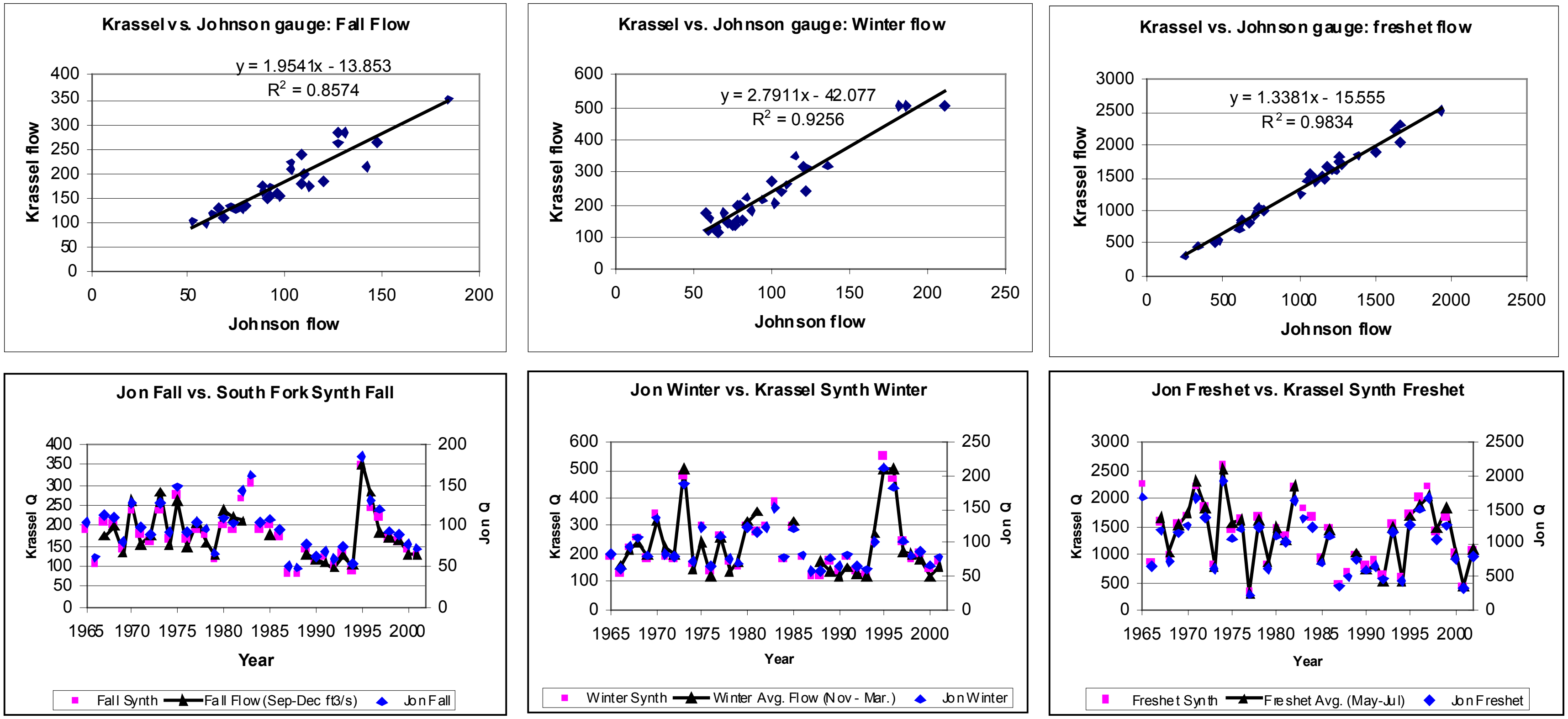


Figure 3E.1. Comparison of Fall, Winter and Freshet indices for Krassel and Johnson Creek gauges. Top panels show the regression of the Krassel gauge indices on the Johnson Creek gauge indices. Bottom panels compare the Krassel gauge index time series (bolded line over triangles), the synthetic index time series for the Middle Fork gauge (squares), and the Johnson Creek gauge index (diamonds). Flows are in cubic feet per second (ft^3/s). Data are listed in Table 3E.1.

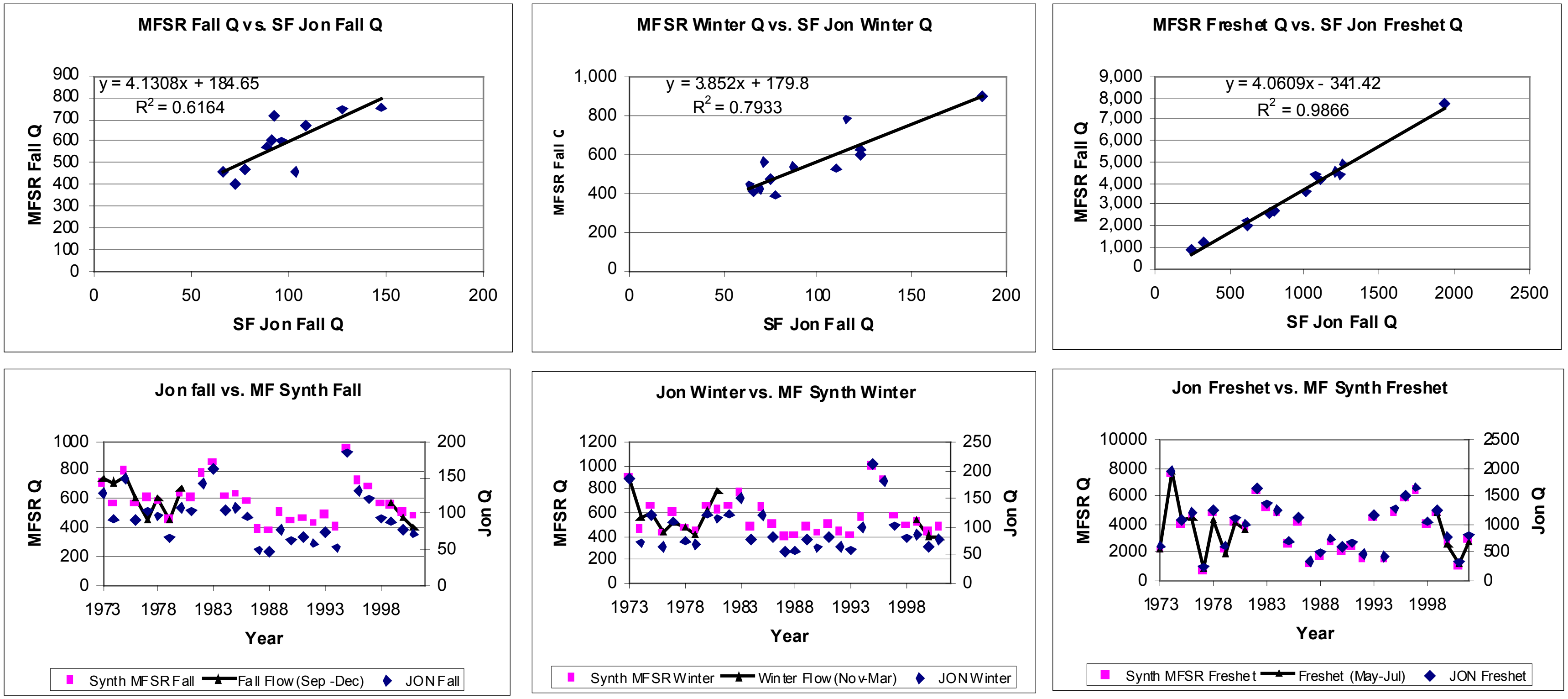


Figure 3E.2. Comparison of Fall, Winter and Freshet indices for Middle Fork Salmon River and Johnson Creek gauges. Top panels show the regression of the Middle Fork Salmon gauge indices on the Johnson Creek gauge indices. Bottom panels compare the Middle Fork gauge index time series (bolded line over triangles), the synthetic index time series for the Middle Fork gauge (squares), and the Johnson Creek gauge index (diamonds). Flows are in cubic feet per second (ft^3/s). Data are listed in Table 3E.2.

Appendix 3.F - Fecundity index

We used an index of fecundity to account for possible trends in fecundity that might mask, or enhance, changes in the egg-to-parr survival rate index arising from changing habitat conditions. For example, a negative trend in fecundity could mask increased survival due to improving habitat conditions because the survival rate is a function of both the number of females (indexed in this analysis by the number redds) and their average fecundity.

The fecundity index was calculated as the average number of eggs/spawned female data from Sawtooth and McCall hatcheries. Sawtooth hatchery spring chinook females are predominantly Age 5 spawners and were used as a surrogate for Middle Fork spring salmon (MFSR), which are also predominantly Age 5 spawners. McCall hatchery summer chinook are predominantly Age 4 spawners and their fecundity was used as a surrogate for wild summer chinook in the South Fork Salmon River (SFSR) streams used in this analysis. McCall hatchery collects their summer chinook spawners at the weir upsteam of the Poverty Flat spawning and rearing area. We downloaded the hathcery data from www.streamnet.org and corrected obvious outliers, where possible, using the hatchery reports referenced by that source. We got these reports from streamnet.org.

We recognized that using average hatchery fecundity as a surrogate for the fecundity of wild fish from MFSR and SFSR could be problematic because negative trends in average fecundity could arise due to variation in age-at-return rather than . Presumably Age 4 fish have lower fecundity than Age 5 fish so if the proportion of fish at Age 4 increases over time, then you could see a drop in the average fecundity over time. This is supported by the results presented in Figure 3.6d (main text) which compare the average hatchery fecundities for the predominantly Age 5 Sawtooth hatchery fish to the predominantly Age 4 McCall hatchery fish; the average fecundity over the available time series is higher for the Sawtooth hatchery fish.

Additionally, there may be an inherent hatchery effect, such that second generation hatchery fish have lower fecundity than their wild ancestors. However, this bia may not be of great concern since it such a downward bias in fecundity may apply equally to both Sawtooth and McCall data since both are hatcheries; in this case, while magnitude of fecundity patterns may differ from wild fish, the pattern of fecundity over time may be the same, which means the hatchery fecundities would still be suitable for exploring the impact of potential fecundity trends on the survival rate index.

There were at least two ways by which we could to try to address these concerns. First, the number, or proportion, of Age 4 and Age 5 spawners for each stream could be included as terms in our models. Second, it might be possible to get the average Age 4 and 5 fecundity data along with the proportion returning at each of those ages from the hatcheries. The data required for the first approach are available from the IDFG South Fork and Middle Fork Salmon River spawner-recruit run reconstruction data sets, for wild fish. While we did not actually include these data in our models, we did plot them versus both the hatchery fecundity indices and egg-to-parr survvial rate indices. The data for the second approach may be available from the Sawtooth and McCall hatcheries, but we did not have it at the time of this analysis.

For the ***Sawtooth hatchery*** data (Table 3F.1), there is no linear trend in fecundity over time (Figure 3.6a, main text), nor was there a significant relationship between Sawtooth hatchery average fecundity data (1985–2001) and the proportion at Age 5 for Marsh Creek spring chinook (from the IDFG S-R data set).

For the ***McCall hatchery*** data (Table 3F.2), there was also no trend in fecundity over time (Figure 3.6b, main text). An XY plot of McCall hatchery average fecundity data (1982-2002) vs. the proportion returning at Age 4 for Poverty Flat summer chinook (from the S-R data set) had small negative slope, but a regression of fecundity on proportion returning at Age 4 was significant (r2 = 0.21, p=0.041).

Plots of parr density vs. fecundity and ln(Parr/Redd) vs. fecundity yielded no convincing consistent pattern suggestive of fecundity related effects. There were either too few data, the parr indices were too crude, there was no fecundity effect, the fecundity effect varies between streams, or hatchery fecundities are inadequate for detecting wild fecundity effects. Additionally, plots of the proportion-at-age and abundance-at-age data showed no trend over the period for which we had parr data. Given these results there seemed little to be gained by adding models to our analysis that included the S-R data set proportion-at-age, or abundance-at-age data as covariates.

The series of fecundities from the two hatcheries were weakly and positively correlated (Figure 3.6c, main text).

Table 3F.1. Sawtooth Hatchery fecundity data. Bold value for 1987 is a corrected value. See Figure 3.6a for temporal patterns in this data. The middle columns of the table show the IDFG S-R proportion-at-age data used in the analyses. The right hand columns show an assumed number-at-age breakdown for hatchery females based on the IDFG S-R proportions

Sawtooth Hatchery data				IDFG S-R data		Estimated hatchery females at age	
Year	# Females	#Eggs	Eggs/Female	Prop. Age 4	Prop. Age 5	#Age 4 Female	# Age 5 Female
1985	313	1418920	4533	0.42	0.58	132	181
1986	360	2035535	5654	0.35	0.61	127	221
1987	426	2721399	**6388**	0.43	0.56	184	240
1988	513	3120668	6083	0.10	0.90	50	463
1989	137	733365	5353	0.35	0.65	48	89
1990	318	1431360	4501	0.47	0.53	148	168
1991	166	861830	5192	0.25	0.73	42	121
1992	104	468300	4503	0.60	0.37	62	38
1993	68	340494	5007	0.15	0.85	10	58
1994	7	31500	4500	0.33	0.65	2	5
1995	2	7377	3689	0.33	0.65	1	1
1996	10	52332	5233	0.66	0.31	7	3
1997	53	227752	4297	0.49	0.46	26	25
1998	27	139469	5166	0.02	0.92	0	25
1999	12	63642	5304	0.33	0.65	4	8
2000	89	417709	4693	0.96	0.04	85	4
2001	382	1804892	4725	0.93	0.03	356	10
2002	194	1037558	5348				
Average			5009				

Table 3F.2. McCall Hatchery fecundity data. Bold value for 1986 is a corrected value. Grayed number for 2001 is an uncorrected outlier. See Figure 3.6b for temporal patterns in this data. The middle columns of the table show the IDFG S-R proportion-at-age data used in the analyses. The right hand columns show an assumed number-at-age breakdown for hatchery females based on the IDFG S-R proportions.

McCall Hatchery data				IDFG S-R data		Estimated hatchery females at age	
Year	# Females	# Eggs	Eggs/Fema	Prop Age 4	Prop Age 5	Age 4 Females	Age 5 Females
1982	147	648520	4412	0.58	0.33	85	49
1983	180	750634	4170	0.23	0.76	41	137
1984	353	1613392	4571	0.58	0.33	205	117
1985	477	2073546	4347	0.65	0.34	309	163
1986	428	2148727	**5020**	0.68	0.29	293	122
1987	662	3110229	4698	0.60	0.36	400	238
1988	555	2834364	5107	0.27	0.67	149	372
1989	150	801319	5342	0.69	0.23	103	34
1990	257	1111400	4325	0.69	0.31	178	79
1991	138	704016	5102	0.44	0.50	61	69
1992	318	1428819	4493	0.85	0.12	272	39
1993	356	1731515	4864	0.43	0.57	152	204
1994	139	689203	4958	0.30	0.70	41	97
1995	57	238344	4181	0.59	0.28	33	16
1996	111	486644	4384	0.75	0.23	83	26
1997	561	2523059	4497	0.71	0.28	401	159
1998	299	1433237	4793	0.09	0.74	26	223
1999	427	1892572	4432	0.84	0.07	361	28
2000	361	1487809	4121	0.89	0.03	323	11
2001	1069	1793667	1678	0.93	0.03	995	29
Average			4475				

Appendix 3.G – Adult condition index

Ian J. Parnell and Charles M. Paulsen

The adult condition index is the time series of common brood year effects estimated from the best spawner-to-spawner model in our analysis of the relationship of an index of spawner-to-spawner survival rate to conditions within the South Fork Salmon River watershed, specifically changing sediment conditions.

3.G.1 Derivation of adult condition index from Spawner-to-Spawner models

To derive or survival rate index we used spawner abundance estimates from the Idaho Department of Fish and Game spawner-recruit run reconstruction data sets (Charlie Petrosky, IDFG, unpublished data) for the same eight streams used for the parr density/redd density analysis. The index of overall survival is the natural logarithm of the ratio of the abundance of the returning spawners for a brood year to the abundance of the spawners that produced them, Ln(S/S). There were over 40 years of data available for each of the streams. Beamesderfer et al. 1997 describe the methods used to derive this data set. Earlier versions of this data set have been used in a number of analyses (e.g., Schaller et al. 1999; Deriso et al. 2001; Hinrichsen 2001; Paulsen and Hinrichsen 2002).

We fit a set of seven multi-stock Ricker-type models (Table 3G.1) to the data that explored a series of biological and management hypotheses. Model 1 hypothesized separate Ricker a and b terms. Model 2 hypothesized a common Ricker a term and separate Ricker b term. Model 3 hypothesized a separate Ricker a’s, separate Ricker b’s and a common brood year effect. Model 4 hypothesized a common Ricker a term, separate Ricker b’s and a common brood year effect. Model 5 hypothesized a common Ricker a, separate Ricker b’s and a fork specific common brood year effects. Model 6 hypothesized a common Ricker a term, separate Ricker b terms, common brood year effects and a sediment (SED) effect. The SED effect was either “ON” or “OFF” for different streams. In this case, only the South Fork Salmon River mainstem and Johnson Creek were considered sediment impacted, so the SED effect was “ON” for the entire time series. Model 7 was the same as model 6, but considered a time x treatment interaction.

Estimating common year effects may account for common sources of variation that can mask habitat effects. Additionally, the time series pattern of these effects shows years of relatively better and poorer common survival, which may be helpful in looking for other factors. Estimating common year effects will be particularly useful here because these stocks do show high covariation over time in indices of overall productivity and survival (Botsford and Paulsen 1998). The common brood year effect term in these models includes common effects during freshwater rearing, downstream passage as smolts, ocean residence, and upstream passage as adults and thus include hydrosystem effects during the downstream and upstream passage stages. For this reason, it may be difficult to unambiguously attribute patterns seen in the years effects to a single factors (e.g., flow conditions) unless they are the driving factor affecting survival in all years, which is unlikely to be the case. Year effects estimated from other models that account more explicitly for conditions outside of the spawner and rearing areas (e.g., Deriso et al. 2001) may be more powerful when looking for explanatory factors (e.g., ocean conditions) not explicitly included in the model.

We fit log-linear regression models to the data using both SYSTAT V9 GLM and SAS V7. We used the same Information-theoretic model selection methods as for the parr analysis. The results (Table G.1) show that the highest support is given to Model 4 (common Ricker a, separate Ricker b’s and the common brood year effect) with 67% relative probability. Model 6, that included the SED effect, ranked second with 28% relative probability, but this effect was not significant ($p > 0.05$). The SED BY interaction in Model 7 was also not significant and this model did not have an AICc weight >0.05.

Given these results, the time series of common brood years effects from Model 4 were used as the adult condition index in the parr analysis (Figure 3.7, main text). A further exploration of Sp-Sp type models in the context of specific habitat actions is described in Chapter 5.

Table 3G.1. Spawner-to-spawner models, their residual sum of squares (RSS), number of observations (n), number of estimable parameters (k) and calculated AICc values and AICc weights (Wt) and percent of maximum weight (% max Wt). AICc values and AICc weights are calculated after Thompson and Lee 1999. Corr2 is the average squared pearson r across stocks for the residuals from each model fit, this is included to demonstrate how the common year-effect term accounts for common variation.

	Model	RSS	n	k	AICc	Wt	% max Wt	$corr^2$
1	$Ln(S/S) = a_i + b_i*S$	293.36	277	14	45.50	0.00	0.00	0.47
2	$Ln(S/S) = a + b_i*S$	295.54	277	8	34.48	0.00	0.00	0.46
3	$Ln(R/S) = a_i + b_i*S + Y_t$	85.37	277	53	-194.36	0.05	0.08	
4	$Ln(S/S) = a + b_i*S + Y_t$	89.47	277	47	-199.35	**0.67**	1.00	0.17
5	$Ln(S/S) = a + b_i*S + Fork_j*Y_t$	236.14	277	47	69.49	0.00	0.00	0.15
6	$Ln(S/S) = a + b_i*S + Y_t + Sed_k$	89.08	277	48	-197.61	**0.28**	0.42	
7	$Ln(S/S) = a + b_i*S + Y_t + Sed_k*Y_t$	69.92	277	87	-126.34	0.00	0.00	

3.G.2 Survival rate vs. sediment indices

We also compiled several overlapping indices of sediment conditions within the South Fork Salmon River watershed for comparison with residuals from Model 4, to look for patterns that might indicate a relationship between the stream specific density and year effect independent survival rate index and the sediment indices. In particular we selected the Poverty Flat residuals as this area is generally reported to have been heavily impacted by sedimentation in the early 1960s (e.g., Beamesderfer et al. 1997) (Figure 3G.1).

The sediment indice shown in Figure G.1 vary in how closely tied they were to condition in spawning and rearing areas and in the period of time they spanned. SED 1 is a measure of small fines (<6.33mm) in the Poverty Flat spawing and rearing area collected by the USFS (Nelson 2002). SED 2 is also a measure of small fines, but at a different cutoff (<4.75mm). This time series is estimated from Figure 2c of Platts et al. 1989. SED 3 is a modeled estimated of the volume of sediment introduced to the South Fork Salmon River due to poor forestry practices, it is estimated from Figure 1 of Platts et al. 1989 and is the has the loosest connection to spawning and rearing habitat of the four indices. SED 4 is another measure of small fines (<4.75mm) estimated from Figure 15.3 of Megahan et al. 1992.

None of the four indices spanned the entire time series of Poverty Flat residuals. And while there was a lot of overlap between series for the mid-range of the residual data set, only SED 3 provide information over the early years (1957–1965) when the greatest sediment impacts are reported to have occurred and only SED1 spanned the last years of the data set. However, where the indices do overlap they appear to be agreement; in short, sediment levels consistently decline over the period from about 1965 to the early 1980s, but do not decline much, if at all, from the early 1980's to 2002. The latter period is the period over which the parr/redd data set extends, which suggests that any major sediment effects may have occurred before parr monitoring began — another explanation for the weak positive effects of habitat actions observed in that analysis.

On the other hand the residuals show an early decline (1957–1965) followed by and increase in variability over the period from 1966-1996, a period which includes both the highest and lower residuals. While the decline in residuals over early part of time series is consistent with the increase in the sediment index (1957–1965) with the lowest residual over this period (about 1965) following the highest sediment input year (about 1962), which is suggestive of sediment impacts on Sp-Sp survival, the subsequent period (1966–1996) is not as consistent with the pattern of the sediment indices. In this case the effects of sediment reduction actions (e.g., 1965 moratorium and subsequent improvement to forest management practices) may be masked by the impact of the hydrosystem. Therefore, the year effects estimated from Model 4 may not be as useful for comparing to sediment indices as those derived by Deriso et al. (2001) which explicitly took into account dam effects.

To explore this we compared poverty residuals from Deriso et al. 2002 to the same sediment indices shown in Figure 3G.1 (Figure 3G.2). In this case, the residuals have both common year effects and dam effects removed. The latter part of the residual time series is more consistent with exceptions for the improving (declining) sediment conditions suggested by the sediment indices as the residuals (survival rate indices) show more of an increasing trend over the period during which the sediment indices decline. This analysis should be repeated by running the Deriso et al. (2001) model for the updated run reconstruction data sets and using Sp-Sp indices instead of R-Sp indices to more properly reflect freshwater conditions.

It is unfortunate that we have no clear idea of what habitat actions occurred during the period prior to 1984, other than that there was a logging moratorium in 1965 and that logging practices improved over time. A clearer understanding of what occurred, when it occurred and who did the work would greatly improve our interpretation of the sediment and residual patterns used in this analysis.

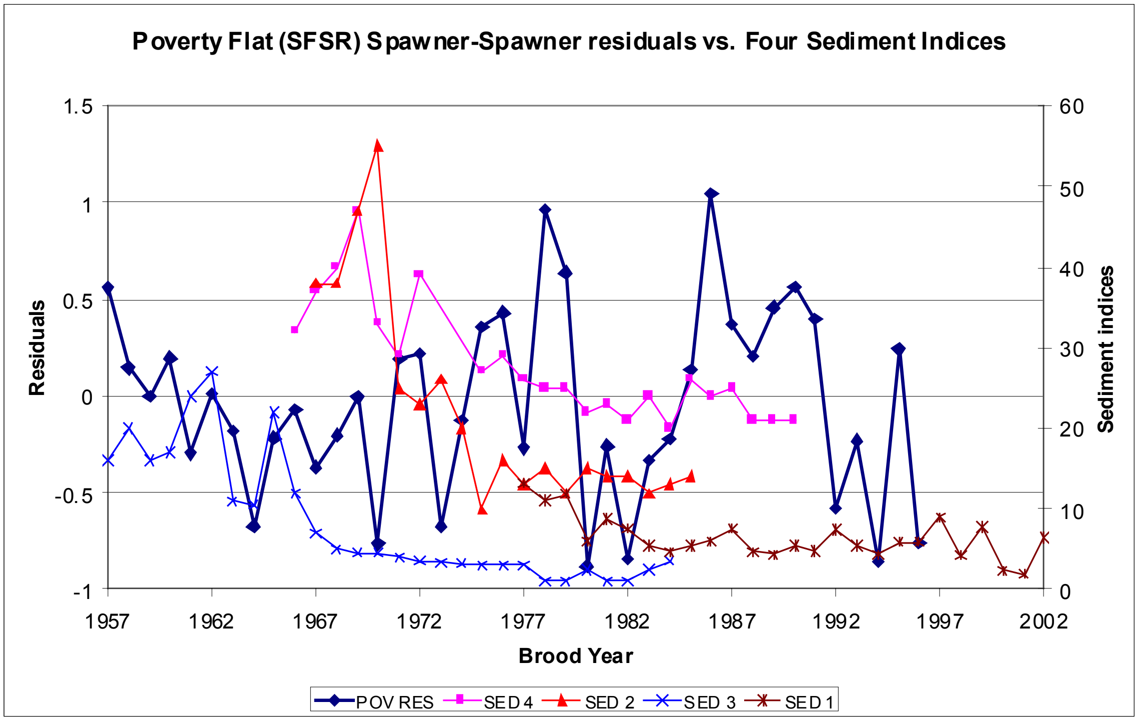


Figure 3G.1. Comparison of Poverty Flat residuals from Model 4 (Table 3G.1) to four time series of sediment indices. SED 1 is small fines (<6.33 mm) measured in Poverty Flats spawning and rearing area by the US Forest Service (Nelson et al. 2002). SED 2 is small fines (<4.75mm) for Poverty Flat (Figure 2c, Platts et al. 1989). SED 3 is the estimated annual sediment production from surface erosion of temporary logging roads in SFSR watershed (m^3, 1000's) (from Figure 1, Platts et al. 1989). The SED 3 time series actually begins in about 1947 and shows a sharp rise in sediment production from 1947-1957. SED 4 is average percent fines (<4.75mm diameter) over Stolle, Glory Hole, and Poverty Flats spawning areas as estimated from Figure 15.3 of Megahan et al. 1992. Note that although the SED indices are shown on the same Y axis, they do not all have the same scale of measurement.

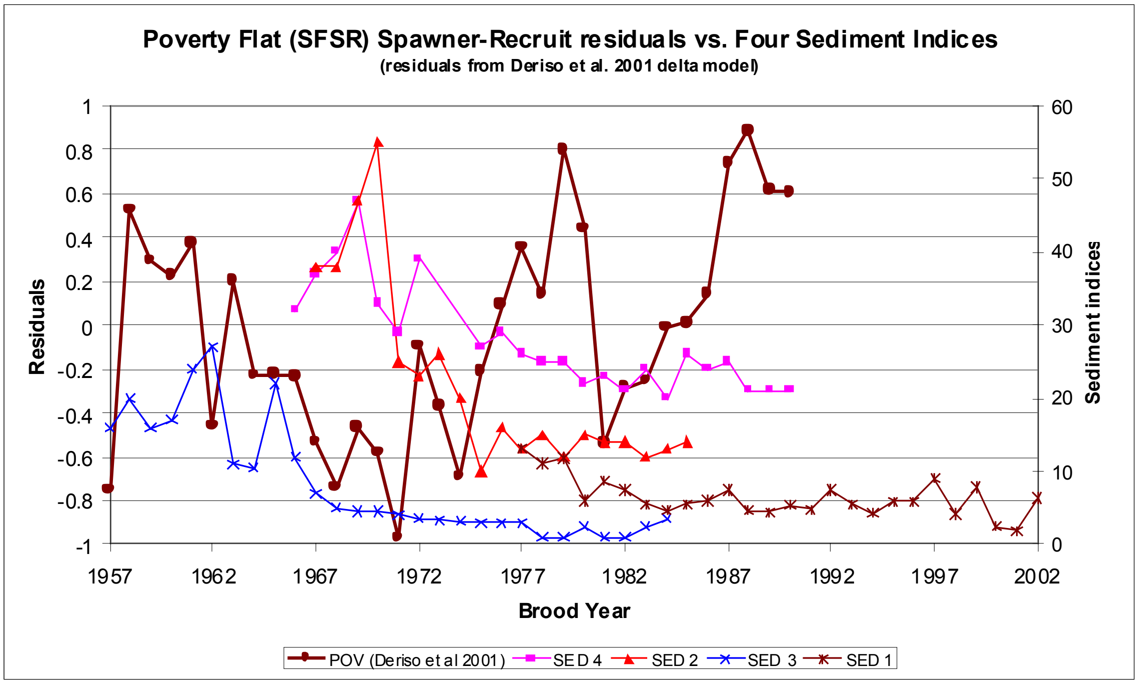


Figure 3G.2. Comparison of Poverty Flat recruits-per-spawner residuals from Deriso et al. 2001 to the four time series of sediment indices. See caption of Figure 3G.1 for descriptions of the indices. Note that although the SED indices are shown on the same Y-axis they are not all measured on the same scale.

Appendix 3.H – Effect of hatchery releases on survival index and model results

We examined the potential for the influence of hatchery releases of fry and parr to Johnson Creek and other streams on our results. Supplementation in the latter part of the time series may have upwardly biased GPM parr counts, and thus the raw survival index.

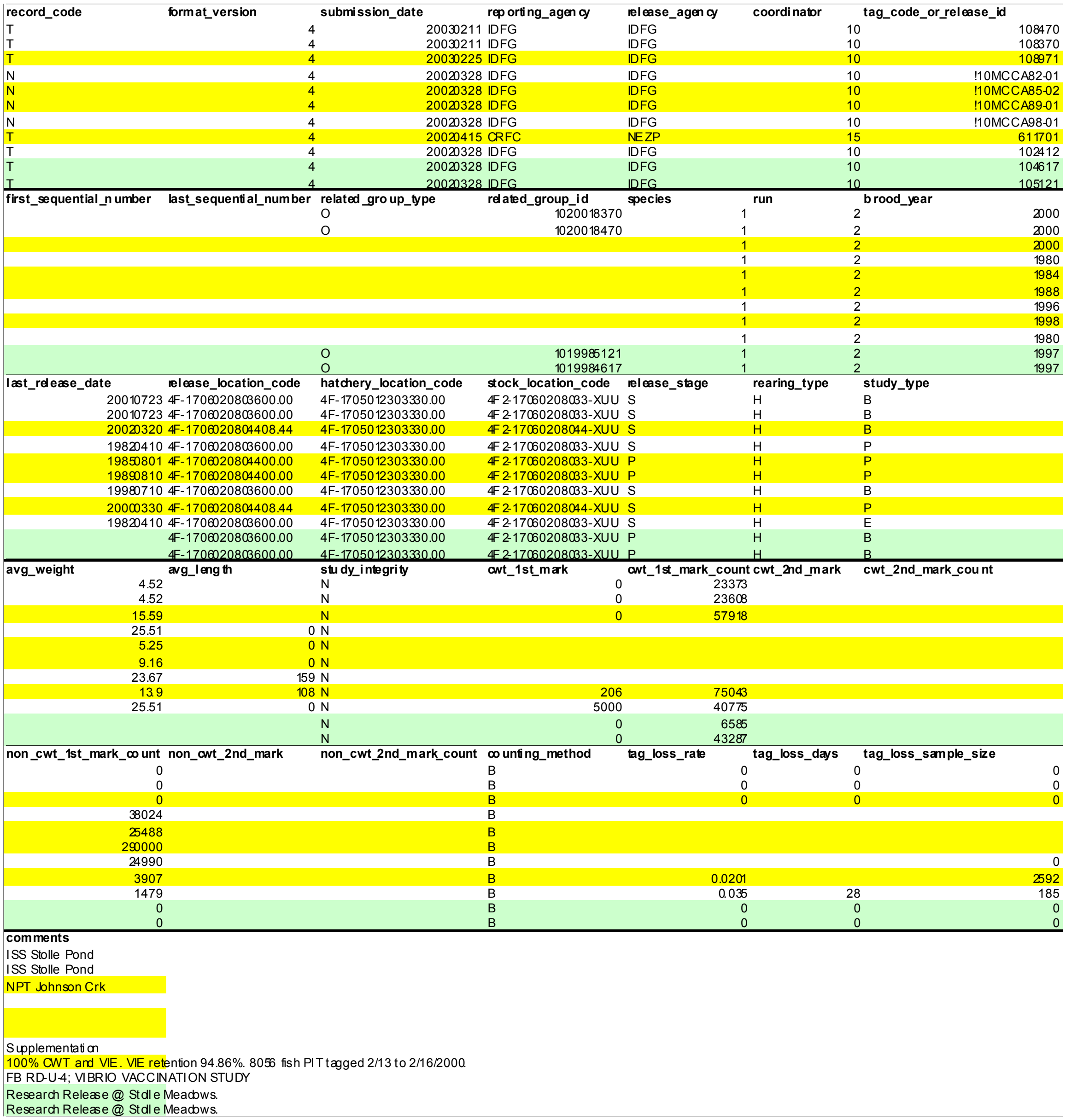
We found 11 records for hatchery releases in the South Fork and Middle Fork Salmon River in the Regional Mark Information System (RMIS) Coded Wire Tag Database (www.rmis.org) (Table 3H.1). All 11 records were for the South Fork Salmon River: four for Johnson Creek and seven for Stolle Meadows in the upper South Fork (upstream of Poverty Flat). Two of the records for Johnson Creek were for smolt releases in March of 2000 and 2002, which would not have affected the GPM parr counts used for our analysis. The other two Johnson Creek records were for parr releases on August 1 1985 and August 9 1989. In 1985, the GPM parr counts were conducted in Johnson Creek between August 7 and 10, so it is possible that the 1985 parr release could have influenced parr counts in that year. However, those parr would have been assigned to brood year 1984, which was not included in our models. Our survival index was only for brood years 1986 to 2001. In 1989, the GPM parr counts were conducted in Johnson Creek between July 11th and 25th, which was prior to the parr release, so it could not have influenced the GPM parr counts. Regardless, the brood year 1988 survival rate index was the lowest in the Johnson Creek time series (Figure 3.4 main text).

We also checked the supplementation records under the Idaho Supplementation Studies (ISS) program (Table 3H.2), which records releases for the South Fork Salmon River, but not the Middle Fork Salmon River. Although both the mainstem South Fork Salmon River and Johnson Creek are listed as ISS treatment sites, the ISS data record no parr releases for Johnson Creek from 1991 to 1999 (Table 3H.2), but it is reported that supplementation began with juvenile releases for brood year 1998 (Lutch et al. 2003). A further check of supplementation releases as part of the Nez Perce Tribe Johnson Creek Artificial Propagation Enhancement Monitoring and Evaluation Project (Jay Hesse, unpublished data) listed two smolt releases in 1998 and 2000 respectively. Since the RMIS data show parr releases in Johnson Creek only prior to 1991, we assumed that all parr releases listed in Table 3H.2 were in the mainstem South Fork Salmon River. The exact location of release is not known to us, though it may be at the weir above Poverty Flat and below Stolle Meadows (e.g., Table 3.3.1 of Bowles and Leitzinger 1991).

Based on these findings, it is possible that hatchery parr releases could also have affected the Poverty Flat summer GPM parr counts. The RMIS database has records for two parr releases in Stolle Meadows on Aug 3, 1998 (brood year 1997) (Table 3H.1). Lutch et al. 2003 report four parr release events in 1994, 1997, 1998, and 2000 (Table 3H.2). The 1998 ISS release appears to correspond to the RMIS records as they occur on the same release date, however the ISS records do not specify a release location within the South Fork Salmon River. Additionally, approximately 1500 fewer parr were released in the ISS records than in the RMIS records. The GPM counts for 2000 were conducted at least a month before the supplementation releases and would not have been affected by them. In 1998, the GPM counts at the Stolle1 and Stolle2 GPM sites took place prior to the supplementation releases there and would not have been affected by them. However, it is possible the releases affected counts downstream at the Poverty Flat site where the GPM counts were conducted two days after the supplementation release date. The 1997 supplementation release was a month before the Stolle meadows GPM counts and thus may have affected them. The 1994 supplementation release would not have affected GPM counts since they took place 8 days before the release date.

The 1998 ISS release would have influenced the 1997 brood year survival index datum, which is the third highest in the series (Figure 3.4 main text). The Poverty Flat density value was midway between the values for Stolle 1 and Stolle 2 (Appendix 3.A). It is possible that the release increased densities in Poverty Flat such that the overall average parr density was higher than it would have been without the release. To see how this would affect our results we reduced the value of the 1997 parr density datum by 50%, recalculated the survival rate index and then ran the top ranked base model. The HABACT coefficient decreased slightly from 0.220 to 0.216, but remained significant ($p < 0.05$). The 1997 release would have influenced the 1996 brood year survival index datum, which is the second lowest point in the time series, so any positive bias imparted by the supplementation release would not have adversely affected the regression results.

Table 3H.1. Regional Mark Information System Coded Wire Tag Database (**www.rmis.org**) hatchery releases for South Fork Salmon River. Yellow bars represent Johnson Creek releases; green bars (bottom two rows of each block) represent Stolle Meadows releases.



record_code	format_version	submission_date	reporting_agency	release_agency	coordinator	tag_code_or_release_id
T	4	20030211	IDFG	IDFG	10	108470
T	4	20030211	IDFG	IDFG	10	108370
T	4	20030225	IDFG	IDFG	10	108971
N	4	20020328	IDFG	IDFG	10	!10MCCA82-01
N	4	20020328	IDFG	IDFG	10	!10MCCA85-02
N	4	20020328	IDFG	IDFG	10	!10MCCA89-01
N	4	20020328	IDFG	IDFG	10	!10MCCA98-01
T	4	20020415	CRFC	NEZP	15	611701
T	4	20020328	IDFG	IDFG	10	102412
T	4	20020328	IDFG	IDFG	10	104617
T	4	20020328	IDFG	IDFG	10	105121

first_sequential_number	last_sequential_number	related_group_type	related_group_id	species	run	brood_year
		O	1020018370	1	2	2000
		O	1020018470	1	2	2000
				1	2	2000
				1	2	1980
				1	2	1984
				1	2	1988
				1	2	1996
				1	2	1998
				1	2	1980
		O	1019985121	1	2	1997
		O	1019984617	1	2	1997

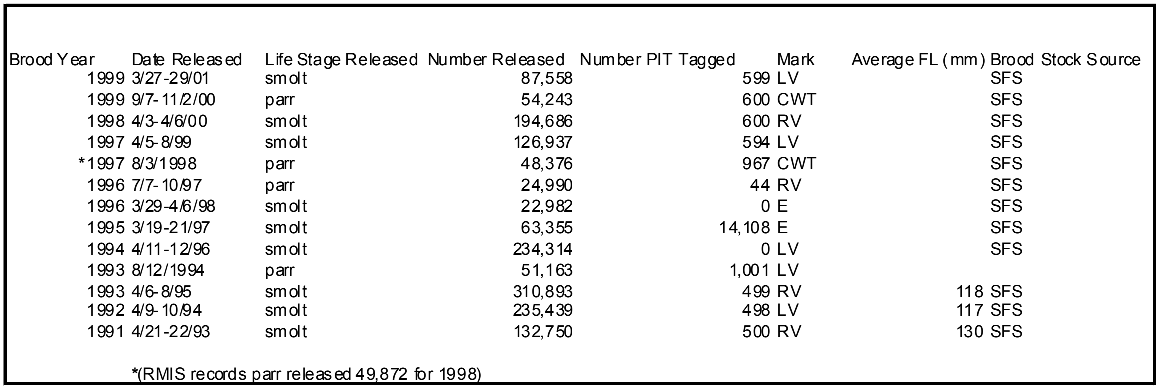
last_release_date	release_location_code	hatchery_location_code	stock_location_code	release_stage	rearing_type	study_type
20010723	4F-17060208036 00.00	4F-170501230333 0.00	4F2-17060208033-XUU	S	H	B
20010723	4F-17060208036 00.00	4F-170501230333 0.00	4F2-17060208033-XUU	S	H	B
20020320	4F-1706020804408.44	4F-17050123033 30.00	4F2-17060208044-XUU	S	H	B
19820410	4F-17060208036 00.00	4F-17050123033 30.00	4F2-17060208033-XUU	S	H	P
19850801	4F-1706020804400.00	4F-17050123033 30.00	4F2-17060208033-XUU	P	H	P
19890810	4F-1706020804400.00	4F-17050123033 30.00	4F2-17060208033-XUU	P	H	P
19980710	4F-17060208036 00.00	4F-17050123033 30.00	4F2-17060208033-XUU	S	H	B
20000330	4F-1706020804408.44	4F-17050123033 30.00	4F2-17060208044-XUU	S	H	P
19820410	4F-17060208036 00.00	4F-17050123033 30.00	4F2-17060208033-XUU	S	H	E
	4F-17060208036 00.00	4F-17050123033 30.00	4F2-17060208033-XUU	P	H	B
	4F-17060208036 00.00	4F-17050123033 30.00	4F2-17060208033-XUU	P	H	B

avg_weight	avg_length	study_integrity	cwt_1st_mark	cwt_1st_mark_count	cwt_2nd_mark	cwt_2nd_mark_count
4.52		N	0	23373		
4.52		N	0	23608		
15.59		N	0	57918		
25.51	0	N				
5.25	0	N				
9.16	0	N				
23.67	159	N				
13.9	108	N	206	75043		
25.51	0	N	5000	40775		
		N	0	6585		
		N	0	43287		

non_cwt_1st_mark_count	non_cwt_2nd_mark	non_cwt_2nd_mark_count	counting_method	tag_loss_rate	tag_loss_days	tag_loss_sample_size
0			B	0	0	0
0			B	0	0	0
0			B	0	0	0
38024			B			
25488			B			
290000			B			
24990			B			0
3907			B	0.0201		2592
1479			B	0.035	28	185
0			B	0	0	0
0			B	0	0	0

comments
ISS Stolle Pond
ISS Stolle Pond
NPT Johnson Crk
Supplementation
100% CWT and VIE. VIE retention 94.86%. 8056 fish PIT tagged 2/13 to 2/16/2000.
FB RD-U-4; VIBRIO VACCINATION STUDY
Research Release @ Stolle Meadows.
Research Release @ Stolle Meadows.

Table 3H.2. Brood year specific supplementation releases for the Idaho Supplementation Studies in the South Fork Salmon River, brood years 1991–1999. (Source: Lutch et al. 2003, Appendix 1.1).



Brood Year	Date Released	Life Stage Released	Number Released	Number PIT Tagged	Mark	Average FL (mm)	Brood Stock Source
1999	3/27-29/01	smolt	87,558	599	LV		SFS
1999	9/7-11/2/00	parr	54,243	600	CWT		SFS
1998	4/3-4/6/00	smolt	194,686	600	RV		SFS
1997	4/5-8/99	smolt	126,937	594	LV		SFS
*1997	8/3/1998	parr	48,376	967	CWT		SFS
1996	7/7-10/97	parr	24,990	44	RV		SFS
1996	3/29-4/6/98	smolt	22,982	0	E		SFS
1995	3/19-21/97	smolt	63,355	14,108	E		SFS
1994	4/11-12/96	smolt	234,314	0	LV		SFS
1993	8/12/1994	parr	51,163	1,001	LV		
1993	4/6-8/95	smolt	310,893	499	RV	118	SFS
1992	4/9-10/94	smolt	235,439	498	LV	117	SFS
1991	4/21-22/93	smolt	132,750	500	RV	130	SFS

*(RMIS records parr released 49,872 for 1998)

Appendix 3.I - Fry Emigration

Summary

We used data on spring parr emigration for Lake Creek and Secesh River and parr outmigration for Johnson Creek (C. Beasley, Nez Perce Tribe, unpublished data) to assess potential bias to the ln(Parr density/Redd density) survival index for these streams, relationships to redd numbers and flow indices, and hoped to draw some general inferences for other streams. The flow index used here is only a gross indication of flow patterns over the 'freshet' season (March to July), it does not address finer scale stream specific variation in flows that could affect emigration and/or screw trap operations. In general, there were too few data points to draw strong inferences and the observed patterns could possibly be explained by one or all of several confounding factors. Tentative observations are that the relationships between fry emigration and juvenile abundance (as indexed by redd abundance) vary between streams and that Johnson Creek appears to show that emigration is positively associated with both juvenile abundance and freshet flows.

Detailed results

Emigration does take place prior to the summer parr counting period. However, a relatively constant emigration rate (i.e. does not change with juvenile abundance) will be less important that an emigration rate that increases with juvenile abundance (i.e. is density dependent). We used ln(#parr out /#redds) as an index of emigration to standardize for redd effects (e.g., more eggs leads to more fry emigrating) (Table 3I.1). We concluded there was no density dependent emigration if a regression line fit through the data did not have a positive slope. Our conclusions are very tenuous given the very few data points.

For Lake Creek there is a positive relationship between the emigration index and the number of redds (Figure 3I.1, top panel). This relationship is still positive for Secesh River, but much weaker (Figure 3I.2, top panel). There is also a strong positive relationship between emigration and redd numbers for Johnson Creek (Figure 3I.3, top panel). These results suggest a density dependent component to emigration prior to the summer parr counts, a downward bias which could make improved egg-to-parr survival due to improved habitat more difficult to detect.

However, other factors may be influencing these results:

- Rotary trap detection efficiencies may be lower at low juvenile abundance, thus biasing estimates of emigration abundance downward.
- Rotary trap efficiency and operations may be compromised at high freshet flows, biasing estimates of emigration abundance downward. This could happen, for example, if the screw trap could not be operated over a portion of the emigration period.
- Trap operations may have been less efficient in the earlier years, but improved over time as trap operators learned about the system. Thus earlier estimates of emigration could be biased low.

There were no estimates of trap efficiency with the data we reviewed so we could not address the first bullet, but we used the freshet flow index (Appendix 3.E) to address the second bullet (Figures 3I.1-3, bottom panels). There was a strong negative relationship between the emigration index and the freshet flow index for both Lake Creek and Secesh River (bottom panels of Figures 3I.1 and 3I.2 respectively). The opposite was the case for Johnson Creek, which had a strong positive relationship between the emigration index and flow (Figure 3I.3, bottom panel). Note that for all three streams, the lower redd counts and higher flows occurred together in the earlier years when learning about trap operation would have been occurring, thus all these factors could operate together to bias the early trap emigration estimates low. Thus for Lake Creek and Secesh River we cannot rule out that the observed positive relationship between emigration and juvenile abundance is an artifact that results from lower juvenile abundance, inefficiencies or inability to operate the trap due to high flow, or trap inefficiencies during early operations. It is interesting that of the three streams, emigration from Johnson Creek is positively related to both redd abundance and freshet flow, so both factors may be important here.

Table 3I.1: Screw trap emigration estimates (Source: C. Beasley, Nez Perce Tribe, unpublished data).

Lake Creek

Year	redds	FresehtQ	spring parr	Lower CI (0.05)	Upper CI (0.05)	Standard Error	spring parr/redd
1996	31	1,995	4	4	14	3	0.13
1997	55	2,208	28	7	58	14	0.51
1998	50	1,399	348	206	573	93	6.96
1999	24	1,670	4,557	3,294	6,615	874	189.88
2000	177	1,012	138,136	113,555	171,423	15,288	780.43
2001	329	423	93,841	76,725	115,015	9,935	285.23

Secesh River

Year	redds	FreshetQ	spring parr	Lower CI (0.05)	Upper CI (0.05)	Standard Error	spring parr/redd
1996	71	1,995	3,424	2,257	5,467	836	48.23
1997	140	2,208	1,288	918	1,805	230	9.20
1998	115	1,399	6,477	4,519	9,572	1336	56.32
1999	66	1,670	20,742	12,192	36,157	7081	314.27
2000	321	1,012	181,522	145,138	227,412	21106	565.49
2001	692	423	105122	84861	128919	11320	151.91

Johnson Creek

BY	redds	FreshetQ	parr out	95% CI	Parr out/redd
1996	21	1503			
1997	84	1662	101,106	4,368	1203.64
1998	69	1057	34,172	8,449	495.25
1999	23	1260	10,149	1,494	441.26
2000	29	768	8,869	1,454	305.83

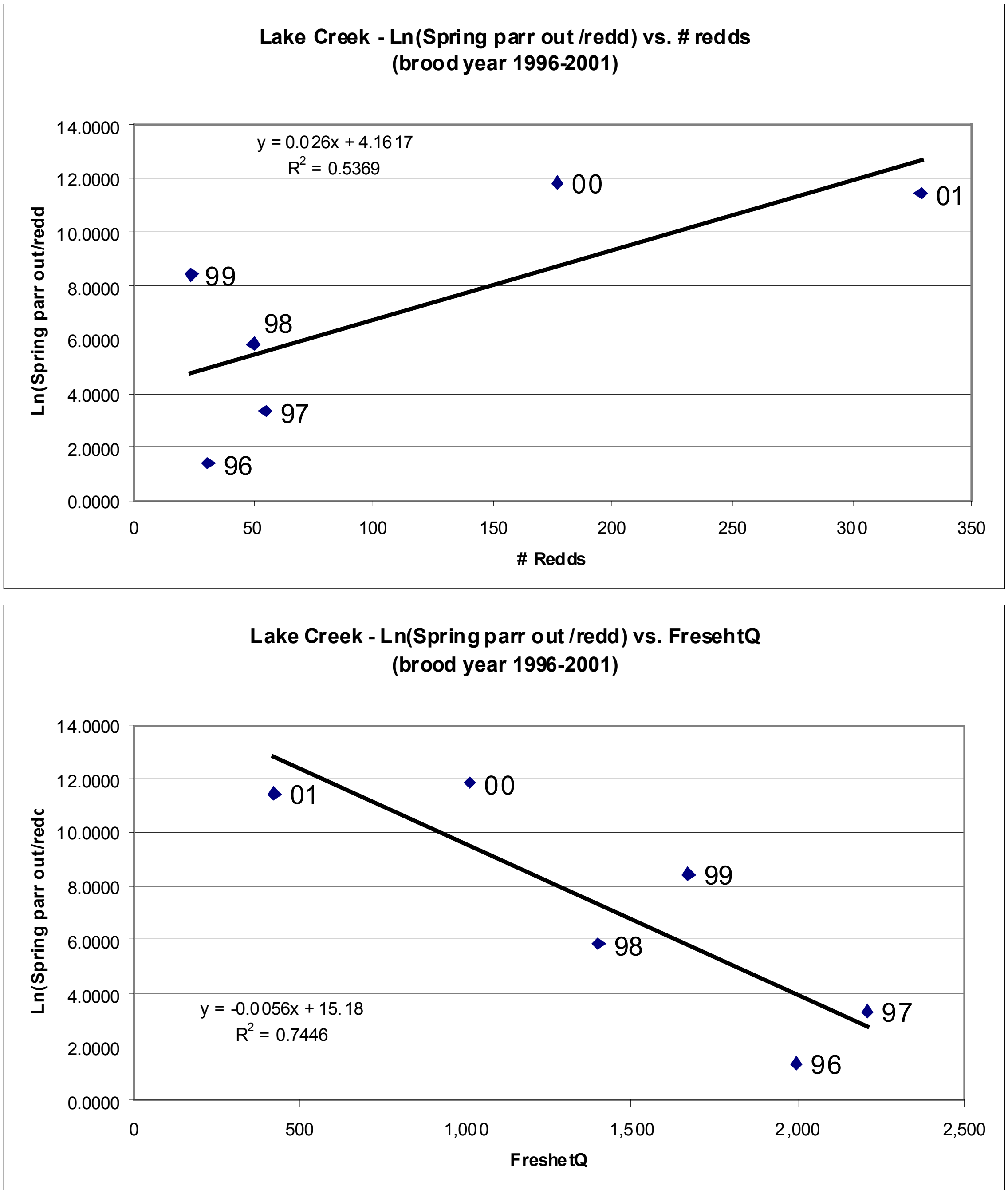
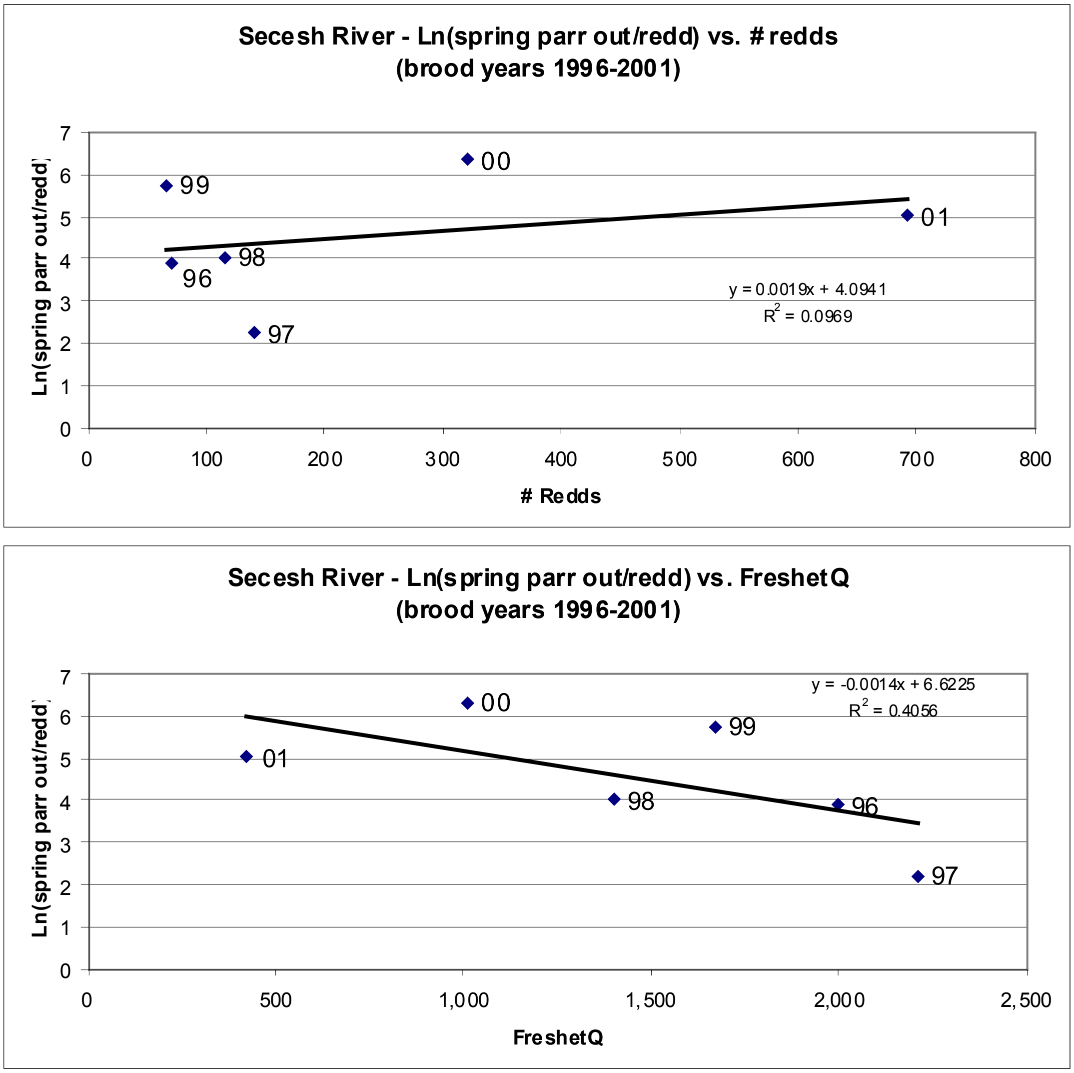


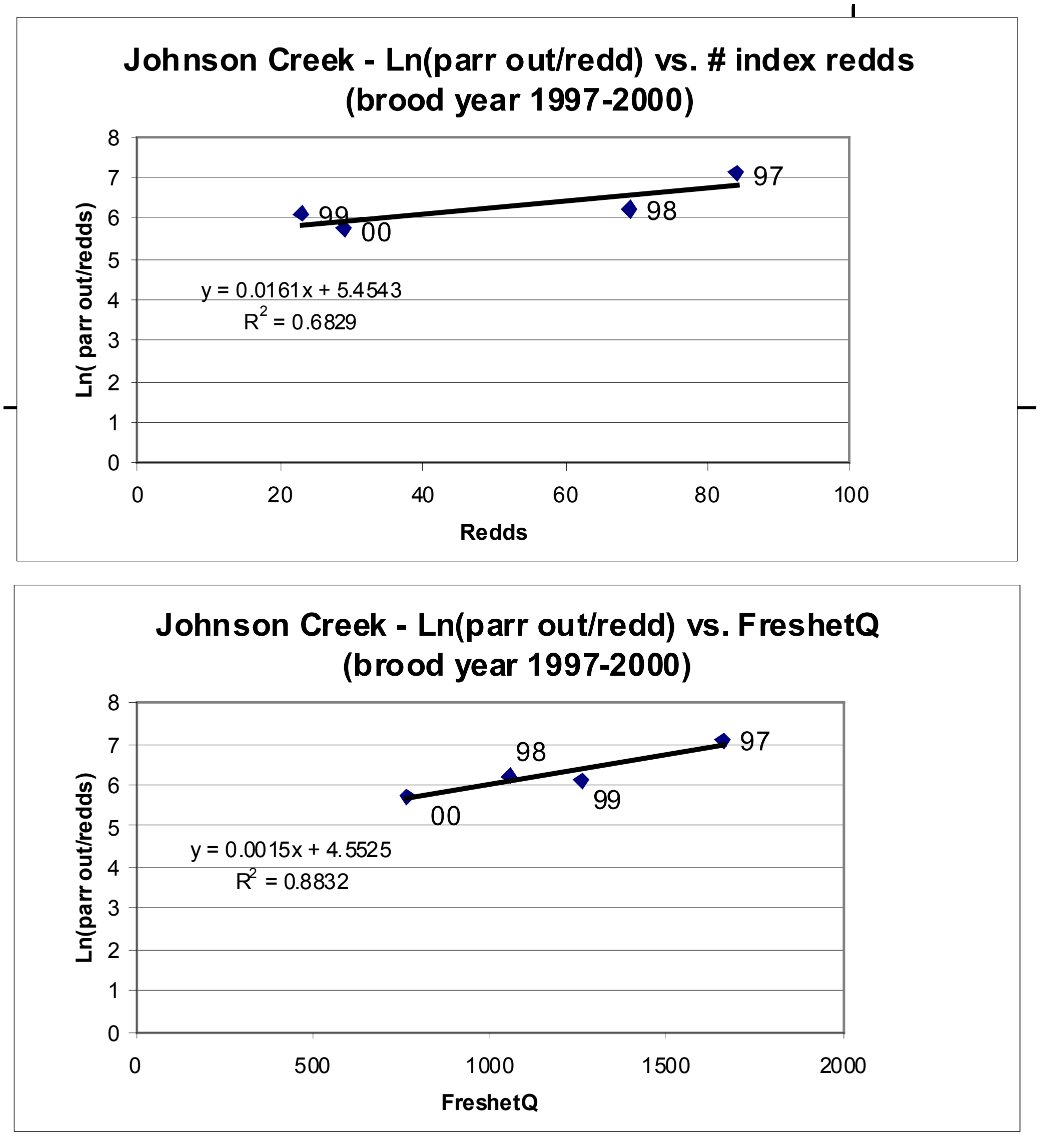
Figure 3I.1: Estimated brood year spring parr outmigration for the Lake Creek vs. number of redds (top panel) and an index of freshet flows (bottom panel). (Source: C. Beasley, Nez Perce Tribe, unpublished data). Data points are labeled with brood year.



Secesh River - Ln(spring parr out/redd) vs. # redds (brood years 1996-2001)

Secesh River - Ln(spring parr out/redd) vs. FreshetQ (brood years 1996-2001)

Figure 3I.2: Estimated brood year spring parr outmigration for the Secesh River vs. number of redds (top panel) and an index of freshet flows (bottom panel). (Source: C. Beasley, Nez Perce Tribe, unpublished data). Data points are labeled with brood year.


Johnson Creek - Ln(parr out/redd) vs. # index redds (brood year 1997-2000)

Johnson Creek - Ln(parr out/redd) vs. FreshetQ (brood year 1997-2000)

Figure 3I.3: Estimated brood year parr emigration for Johnson Creek vs. number of redds (top panel) and an index of freshet flows (bottom panel). (Source: C. Beasley, Nez Perce Tribe, unpublished data). Data points are labeled with brood year.

4. Relationship of Parr to Smolt Survival to the Number of Habitat Restoration Projects

(Charles M. Paulsen and Timothy R. Fisher)

4.1 Abstract

Using eleven years of parr-to-smolt survival estimates from 32 sites in the Snake River, we demonstrate that, despite a number of confounding factors, higher numbers of past habitat actions are associated with higher juvenile survival of endangered spring/summer chinook. Information-theoretic weights were applied to help distinguish between statistical models based on their relatively plausibility. In the models with the highest weights among those estimated, habitat actions showed a clear, positive association with increased survival. However, because habitat actions are not sited randomly on the landscape, and because they may also influence other, potentially important covariates, it is difficult to separate their effects from those of other important factors. Results for a subset of stocks and years using smolt-to-adult survival rates (**Appendix 4C**) show a similar relationship between survival and habitat actions: more actions are associated with higher smolt-to-adult survival.

4.2 Introduction

A recent US National Marine Fisheries Service (NMFS) Biological Opinion on Endangered Species Act listed chinook salmon (*Oncorhynchus tshawytscha*) requires that Bonneville Power Administration (BPA) and the US Army Corps of Engineers increase survival rates for juvenile salmon and steelhead rearing in tributaries (NMFS 2000). It also requires that the agencies demonstrate that egg-to-adult survival rates have increased, and do so in a manner that is statistically defensible. One might think that many examples would be available in the literature to demonstrate likely changes in survival rates, but this is not the case. For example, a recent literature survey of over 2000 references (Bayley 2002) uncovered only a handful of studies that used statistically rigorous experimental designs to demonstrate the effects of habitat modifications on salmonid survival. While there are a few recent exceptions (e.g., Solazzi et al. 2000), empirical studies in this arena are very rare.

Recent work by Paulsen and Fisher (2003) suggests that one can detect the effects of habitat actions on parr-to-smolt survival relatively quickly. For example, using five control sites and three randomly assigned treatment sites, we showed that it is possible, in principle, to detect a 30% multiplicative survival rate increase within seven to nine years with a power of 80% and an α (alpha) of 5%, while larger effects could be detected in as little as a year or two. In the current work, we instead ask a related, but very different question: is it possible to detect the effects of past habitat actions on parr-to-smolt survival using existing information? As one might expect, a number of potential problems arise when using information on actual projects.

First, of course, sites for real habitat actions were not chosen at random. Instead, locations for projects were selected because of perceived local problems, ease of access for work crews, availability of funding, and a host of other reasons. In fact, it could be that sites with large number of actions have lower survival that those with none, not because the actions are ineffective, but because survival was initially very low at action-intensive sites. In addition, land use/land cover, found to be important to survival in a previous analysis (Paulsen and Fisher 2001) may also be important in decisions on where to undertake habitat actions. For example agricultural and grazing lands, which one would expect to have low survival rates (Paulsen and Fisher 2001) has been the setting for much of the habitat work in the Snake River basin since the majority of habitat remediation projects in spawning and rearing areas focus on water withdrawal sites and privately owned pasture land (see the Grande Ronde Model Watershed Program (GRMWP); www.fs.fed.us/pnw/modelwatershed, and Upper Salmon Basin Watershed Project (USBWP); modelwatershed.org web sites for general description and location information of projects carried out in these two heavily agricultural basins).

Second, in the power analysis (Paulsen and Fisher 2003) we assumed that actions would not affect covariates that were important in explaining survival rates (e.g., size of fish at tagging and parent spawner abundance). However, actions may have some affect on juvenile size, since improved habitat may contain more food, and so increase growth rates. Further, one would hope that actions will result in increased spawner abundance.

Third, the power analysis assumed that a before-after-control-impact (BACI) design (*sensu* Osenberg et al. 1996) was possible, wherein all sites would have a "before" period, with no actions, and only a subset of sites would have actions occurring after an experiment was initiated, with the remainder serving as untreated controls. In fact, however, the real world is not run by researchers, and many sites used in the present analysis have had actions occurring continuously, from prior to the time that the first survival estimates are possible (in the early 1990s) to the present. Therefore, a BACI design is not possible with the data at hand.

Finally, in the absence of both designed experiments and observational studies that have examined the effects of actions on juvenile survival (Bayley 2002), it is impossible to say with confidence how one should try to relate action intensity to survival. For example, is a simple linear relationship any more or less likely than a piece-wise linear function, monotonic non-linear relationship, or something more complex? More generally, the form of the relationship between survival and plausible independent variables (site-specific land use/land cover, climate, fish size, etc.) cannot be specified in advance based on past analyses.

We use an information-theoretic framework (Burnham and Anderson 1998) to address these and related issues. Briefly, the method consists of estimating a number of plausible models, and comparing the results using their Akaike Information Criterion scores. Within the framework, the models' information-theoretic weights may be interpreted as their probability, given the data and the suite of models estimated. This allows one to make strong inferences about their relative importance, even in the face of the challenges described above.

Because this effort is the first of its kind, the results should be taken with several grains of salt. While the problems noted above are real ones, they only hint at the confounding in the independent variables. This analysis makes opportunistic use of data collected for many other purposes to test hypotheses which the original research efforts did not contemplate. While we believe this is a useful step in assessing the survival effects of habitat actions, and may provide guidance for carefully designed experiments, it cannot substitute for them.

4.3 Data

Since the data and estimates of survival for tagged parr — the dependent variable in the models — are an extension of those developed in Paulsen and Fisher (2001), we briefly summarize the methods used therein, and present updated estimates of parr-to-smolt survival. We then describe the independent variables we employed.

Since the late 1980s, BPA and NMFS have sponsored PIT tagging studies on Snake River origin salmon and steelhead populations. In late summer and early autumn, age zero wild spring/summer chinook salmon parr (progeny of the previous year's spawners) are collected, tagged, and returned to their natal streams. These rearing areas are headwater streams and small rivers in Idaho and Oregon upstream from Lower Granite Dam (LGR) — the uppermost dam on the Snake River through which these stocks migrate as adults and juveniles (Figure 4.1). Over 600,000 wild chinook parr had been tagged through 2002. Note, however, that the motivations for tagging vary widely, from estimating arrival time at LGR (Achord et al. 1997) to comparing survival rates of hatchery and wild-origin fish (Berggren et al. 2002), but to our knowledge no parr were tagged to estimate the effects of specific habitat actions.

The sites used in this analysis consist of 32 locations above LGR (Figure 4.1), each of which has had at least 100 spring/summer chinook age-0 parr tagged in at least five of the eleven years between 1992-2002, inclusive (Table 4.1). Data are drawn from the Pit Tag Information System (PTAGIS; PSMFC, 2002). Many site-year combinations are missing, due to few or no fish being tagged, so we have 271 observations (out of 352 possible), with an observation consisting of estimated survival for all parr tagged at a given site in a given year, and associated independent variables. The study sites have had over 400,000 parr tagged in total in the past 11 years. Based on detections of surviving juveniles at dams the following spring, one can estimate over-winter survival rates for fish released at each site and year, and associated measurement error (see next section). The natural logarithms of these survival rates are the dependent variables in the regression models.

The number of fish tagged at each site varies from just over 100 to almost 9000, with the mean number tagged varying between 1000 and 2000 in most years (Figure 4.2a). Although the overall log of survival is relatively constant, the minima and maxima vary between -4.2 and -0.5, depending on the year, with 2002 having the lowest survival rates overall (Figure 4.2b). In natural (untransformed) units, survival ranges from just over one percent to almost 50 percent. The coefficient of variation (CV) of estimated *ln*(survival) is also highly variable, ranging between 0.02 and 0.40, due to measurement error or variability (Figure 4.2c).

With the exception of habitat actions, the selection of independent variables is based on previous publications (Paulsen and Fisher 2001, Paulsen and Hinrichsen 2002, Paulsen and Fisher 2003). The independent variables can be divided in three groups. The first group is used to characterize each site, and does not change over time. We use a suite of variables developed by the Interior Columbia Basin Ecosystem Management Project (ICBEMP, Quigley and Arbelbide, 1997), that estimated basic geological information (e.g. elevation, stream density), average climatic conditions, land use, and vegetation cover (Table 4.2). ICBEMP estimated them for 6th field hydrologic unit codes (HUC's). These variables were used in previous work (Paulsen and Fisher 2001) as land use-land cover clusters to help explain variation in juvenile survival rates. Here, we use them directly, as averages for the HUC's where chinook spawn and parr are tagged at each site.

The second group of independent variables is biological information on the fish at each site. This consists of average size (length) of the parr at tagging, and adult spawner density. As with the number tagged and survival rates, size varies widely among sites and over time, from a minimum of about 60 mm to a maximum of over 110 mm (Figure 4.3). Length is recorded when the parr are tagged. Redd survey information (redds counted and miles surveyed) was obtained from various sources for the spawning streams (P. Keniry, ODFW, 107 20th Street LaGrande OR 97850, personal communication, 2002 and 2003 [Grande Ronde and Imnaha River basins] and Hassemer 1993; Elms-Cockrum 2001, updated by S. Keifer, IDFG, 600 S Walnut St. Boise ID 83707, personal communication, 2002, and E. Brown, IDFG, 600 S Walnut St. Boise ID 83707, personal communication [Clearwater and Salmon River basins]). Redd density is also highly variable, from near zero to over 60 redds per mile (Figure 4.4). Note that Figure 4.4

displays redds in the year of tagging; brood year (parent stock) redd densities were always greater that zero.

The third group is consists of abiotic factors that vary among sites and over time. The first variable in this group is the Palmer drought severity index (PDSI). Because it is calculated based on state climate divisions (Table 4.1) it varies among sites for any given year, and obviously varies over time (Figure 4.5). It is calculated by State Climate Division (NOAA 2002) and uses temperature and rainfall information in a formula to determine dryness. It uses a 0 as normal (mean), and drought is indicated by negative numbers; for example, -2 is moderate drought, -4 is severe drought, and -6 is extreme drought. Thus 2001 was an extreme drought year, while 1995 was extremely wet.

The second variable in this group is habitat actions. Total habitat actions also vary among sites and over time (Table 4.2 and Figure 4.6). Habitat actions were those remediation, mitigation, and other actions taken with the intent of improving habitat for anadromous salmonids. These actions were carried out over a span of at least 25 years, by various Federal, State, and private entities. See Appendix B for more details.

We used our best judgment to narrow the list of habitat actions to those which would most likely effect parr to smolt survival of spring/summer chinook salmon (Table 4.2) These were generally actions targeted at improving riparian and/or instream habitat, sediment reduction and general water quality, and juvenile passage conditions, and which occurred near the principal spawning and rearing areas of the stocks. In calculating the number of actions, we assumed that any action, once taken, would be effective from the time it was implemented through the end of 2002. This of course may not be correct, and we return to the assumption later.

4.4 Methods

In this section, we first outline how the survival estimates are obtained, and then discuss at length the model selection methods employed.

As noted, each site/year combination had at least 100 wild spring/summer chinook parr tagged with passive integrated transponder (PIT) tags in late summer to early autumn. Each of the PIT tags implanted in the parr has a unique serial number (Achord et al. 1997). Therefore, subsequent capture histories for each fish can be recorded at detectors installed in the juvenile bypasses at mainstem hydroelectric dams. Tagging and detection data are available for download from the Columbia Basin PIT Tag Information System (PTAGIS; PSMFC 2002). The following spring (from roughly April through June), the tagged smolts are detected at LGR, Lower Monumental, and Little Goose Dams on the lower Snake River, and McNary, John Day, and Bonneville Dams on the lower Columbia River, as they migrate to the Pacific Ocean. Survival from tagging to LGR can be estimated from the numbers of fish released at upstream locations and recaptured at the dams (Smith et al. 1994; Paulsen and Fisher 2001).

The fish from each site/year were then placed into five mutually exclusive categories: 1) never seen after release; 2) seen only at LGR and returned to the river; 3) seen only at dams downstream from LGR; 4) seen at both LGR and one or more downstream dams; and 5) transported at LGR to below Bonneville Dam. The counts for fish released from each site and year were then used to estimate the proportion of fish surviving from tagging in the spawning streams each summer to LGR the following spring. Essentially, the method consists of estimating the gross proportion of fish tagged that are detected at LGR, then correcting for the fact that the detection apparatus at LGR detects considerably less than 100% of the fish passing the dam. Details on maximum likelihood estimates of survival rates can be found in Paulsen and Fisher (2001).

The general retrospective or base-case statistical log-linear model to summarize the past data is:

$$\ln(\hat{s}_{i,t}) = b_0 + R_i + Y_t + \gamma\, L_{i,t} + \delta\, D_{i,t} + \lambda\, D_{i,t-1} + \upsilon\, C_{i,t} + \sum_{j=1}^{22} \rho_j \eta_{i,j} + \theta H_i + \varepsilon_{i,t} \qquad [1]$$

where "i" indexes tagging site and "t" denotes year of tagging. $\mathrm{Ln}(\hat{s}_{i,t})$ is the natural log of survival to LGR, the R_i are factor or classification variables (dummy variables for region or site), the Y_t are year-specific classification variables common to all sites, $L_{i,t}$ is the average length of each group of parr at tagging (mm), $D_{i,t}$ are redd densities (redds per km) in year of tagging, $D_{i,t-1}$ are redd densities in the previous (brood) year, the $C_{i,t}$ is the climate index (PDSI), the $\eta_{i,j}$ are the 22 ICBEMP variables (specific to each site), and the H_i are habitat actions, expressed either as the cumulative total or as quartiles. The error terms ($\varepsilon_{i,t}$), a combination of process and measurement error, are assumed to be independently and normally distributed (0, σ^2). The terms b_0 (for the intercept), R_i , Y_t , γ, δ , υ, ρ_j, and θ are estimated parameters. Where quartiles are used for the habitat actions, each quartile will have its own parameter estimate (θ_k) in the model. The "^" or hat term on the survivals is retained to emphasize the fact that they are estimated with measurement error. Each observation is weighted by the inverse of the coefficient of variation (CV) of ln ($\hat{s}_{i,t}$), giving more weight to those observations where the survival estimate has lower measurement variability or error. We applied a variety of common diagnostic techniques to the models with the highest information-theoretic weights (see Results section).

As noted in the previous section, we selected the independent variables based on recently published analyses for the stocks in question. While stepwise regression is often used in similar circumstances, we instead used an information-theoretic approach (Burnham and Anderson 1998) to address this issue. We did so both because the approach gives a formal accounting for the relative plausibility of the models estimated, and because we hoped that it would be helpful in sorting out the confounding among independent variables. Thompson and Lee (2002) have applied similar information-theoretic approaches to Snake River chinook spawner-recruit models.

The information-theoretic approach is described at length in Burnham and Anderson (1998), and a complete explanation is beyond the scope of this paper. Briefly, the method consists of the following steps: 1) Identify a candidate set of models *a priori*, using information on scientifically plausible relationships between candidate independent variables and the dependent variable of interest; 2) Estimate the regression models using the same dataset (the 271 observations described above); 3) For each model, calculate the Akaike Information Criterion (AICc), corrected for the number of estimated parameters; 4) Among the candidate models, select the model with the lowest AICc. Subtract the lowest AICc from each of the candidate models, yielding a "delta" which will be zero by definition for the model with the lowest AICc; and 5) Calculate "AICc weights" for each model, using a simple exponential function of the deltas.

The weights are normalized to sum to one, and their values may be interpreted as the relative probability of each model, given the data and the set of candidate models. The models may be non-nested, as is the case here, without affecting the comparisons.

4.5 Results

Correlations between the natural log of survival, total (cumulative) number of habitat actions, and the continuous independent variables are shown in Table 4.3. There is a positive, significant correlation between habitat actions and survival, a hopeful sign for habitat managers. Note, however, that there are also many significant correlations between both survival, habitat actions, and many of the potential independent variables. For example, both survival and total actions are positively correlated with length at tagging, proportion of private/BLM land, and transitional vegetation. These are symptomatic of the confounding noted in the introduction: habitat actions may affect independent variables such as juvenile size, and are not scattered randomly across the landscape.

The 36 models estimated are shown in Table 4.4. Site-specific information that does not change over time is treated in one of four ways. In models 1-9, the 32 sites are used as classification or dummy variables. In models 10-18, the five subbasins are employed as classification variables. Models 19-27 use the 22 ICBEMP land use/land cover variables, while models 28-36 do not use any location-specific classification or continuous variables.

The effects of habitat actions are treated in one of three ways: as total actions (models 4-6, 13-15, etc.), as quartiles (models 1-3, 10-12, etc.) or they are excluded from the models (7-9, 16-18, etc.). Other time varying factors are estimated using year effects (classification variables) common to all sites (models 1, 4, 7, …), or using the PDSI, length at tagging, and redds densities (models 2, 5, 8, etc) or are excluded (models 3, 6, 9, …). Ignoring interaction terms (e.g., Subbasin * year effects), we thus estimated models using all combinations of location, habitat, and time-varying effects. These range from extremely simple models (e.g., 36 has only an intercept term) to very high-parameter models (e.g., model 1 has 47 parameters, including the variance term, σ).

The table also indicates whether the estimated parameters are significantly different from zero. The site classification variables are significant in all models where they appear, while the subbasin variables are significant in five of the nine models where they are employed. The ICBEMP variables (as a group) are always significant, as are the common year effects and the PDSI, etc.

The pattern of significance for the habitat terms are both more complex and more intriguing, due to the correlations and confounding already mentioned. First, in no case was habitat significant in models with the site classification variables (models 1-9). Second, they were almost never significant in models using the PDSI, length at tagging, and redd density (models 2, 5, 8, …), the one exception being model 29, where no site-specific information was used. Among the nine models using subbasin classification variables (models 10-18), habitat was significant only once (model 15), when no time-varying parameters were included. For models using the ICBEMP variables, however, habitat was important in four of the nine models (19, 21, 22, and 24) – in fact, for all models where habitat parameters were estimated and the PDSI, etc. was not included. For models 28-36, which did not use site-specific information, habitat was significant in four of the six models where it appears.

Of perhaps more interest than statistical significance is the fact that for nearly all models where habitat is important, the signs on the estimated coefficients are what proponents of habitat enhancement would expect: habitat actions are almost always positively related to survival. The one exception is model 29, which includes the PDSI, etc. In this model, there is a negative relationship between actions (expressed as a series of dummy variables for the four quartiles). In the other eight models where the estimated coefficients are significant, increased numbers of habitat actions are associated with increased survival.

The AICc scores can be helpful in sorting through this confounded mess of results. 33 of the 36 estimated models are highly implausible, with probabilities rarely exceeding 1/1000 (Table 4.5), subject to caveats noted in the methods section. As can be seen in Table 4.5, however, three models (bolded in the table) have the overwhelming majority of the AICc weighting: 19, 22, and 25. They have weights (the w(i) values) of 0.539, 0.306, and 0.117, respectively, accounting for about 96 percent of the probability among the models estimated. All three models use the ICBEMP data on land use/land cover and year effects common to all stocks. Model 19, the top-rated model, uses habitat action quartiles, #22 uses total habitat actions, and #25 does not use habitat actions (or, equivalently, assumes that their coefficients equal zero). Details of the parameter estimates for the three models are shown in Table 4.6. The vegetation cover variables (defined in Table 4.3), *wv_b* through *wv_i*, and the common year effects have similar coefficients for all three models, and are always significant. The habitat quartiles are significant for model 19, while the coefficient on total habitat actions is likewise significant for model 22.

While the AICc weights are helpful in choosing among the models, they of course do not eliminate the confounding among land use, habitat actions, etc. This is illustrated nicely by examining two parameters for model 25 — which does not use habitat actions — to the parameter estimates for models 19 and 22, which do. For model 25, *Wpr* (proportion of private land and BLM range land) and *Wfw* (Forest-service managed wilderness) both have larger, statistically significant parameters, while neither variable is important for models 19 and 22. *Wpr* has a correlation of 0.547 with total habitat actions, while *Wfw* has a correlation of -0.151 (Table 4.3). It appears that some of the variability in survival that is "explained" by habitat actions in the two top-weighted models is instead explained by land management in the 3rd-weighted model, again as a result of correlation and confounding among the variables: all three have adjusted r-squares of 0.60-0.61.

How can one interpret the fact that none of the models using tagging site as classification variables show significant relationships between habitat actions and survival? One possibility, of course, is that habitat actions really are not very important, but this is not supported very well by the AICc weights. A alternative interpretation is suggested by Figure 4.7. Here, we plot the coefficients estimated for each site against the average number of habitat actions from 1992–2002, for model 7, the highest-weighted among the "site" models. Obviously, there is a positive correlation (about 0.29) between the number of actions and the site coefficients. While much of this is driven by one site (the Lemhi, with an average of about 140 actions), the general pattern is clear: higher site coefficients — and hence higher survival rates — are associated with higher numbers of habitat actions.

Influence diagnostics (Belsley et al. 1980) revealed 5-10 moderately influential observations, with absolute values of studentized residuals greater that 2.1, for models 22 and 19. Eliminating these observations had no appreciable effect on the parameter estimates, in that estimated coefficients did not change by more than one standard deviation. While there were small departures for the assumption of normality for the residuals for both models, eliminating the suspect observations made for very modest changes in the parameter estimates and associated standard errors. We also dropped each year of data in sequence, with little change in the parameter estimates. Dropping each site in sequence also made little difference, with one curious exception: eliminating the Lemhi, which has the largest number of actions, roughly doubled the parameter estimate on total habitat actions for model 22 from 0.0019 to 0.0040.

4.6 Discussion

An obvious question, in light of the apparent statistical importance of habitat actions, is whether or not they are biologically important: do they make a real difference in parr-to-smolt survival rates? The overall average survival rate (in natural units) is about 20–25 percent, and, according to model 19, stocks having zero (1st quartile) or 1–3 (2nd quartile) actions have survival rates (in log units) of about 0.2 less than those having 24+ actions (4th quartile), (Table 4.6). In natural units, this is $e^{0.2}$ or about 22%, so having lots of habitat actions results in about a 1.22 multiplicative increase in survival rates. Using similar logic, and the results for model 19 (using total habitat actions) the difference in survival for a stock having 100 habitat actions versus one having none is also about 20% (i.e., 100 * 0.0019). This may not seem terribly high, but according to the NMFS Biological Opinion (NMFS 2002), changes to the hydrosystem, costing many millions of dollars per year, are only expected to increase survival of spring-summer chinook smolts migrating in-river by about 10%. In light of the confounding highlighted in previous sections, one should not push this result too far, but it at least suggests that if the regression relationships have a causal component, then substantial increases in juvenile survival rates may be feasible for many stocks.

Confounding aside, several additional caveats are in order. First, for sites in wilderness areas (e.g., much of the Middle Fork Salmon), logistical and legal constraints may well preclude much by way of habitat manipulation. Therefore, even if habitat actions are indeed quite effective, many sites may never benefit from them. Second, it's possible that sites with many actions, like the Lemhi, may be reaching a point of declining marginal returns — witness the doubling in the model 19 coefficient when the Lemhi was excluded from the analysis. Finally, of course, the analysis focuses exclusively on parr-to-smolt survival, and many types of actions are aimed at egg-to-fry, fry-to-parr, or pre-spawning life stages.

How, then, might one improve on the analysis? An obvious starting point would be a series of on-the-ground inspections to test our assumption that habitat actions, once taken, remain effective indefinitely. Streams are dynamic, and it seems highly unlikely that all actions have remained effective for 10+ years. A second possibility, albeit somewhat more labor-intensive, would be a systematic assessment of the habitat where the actions occur. That is, it would be useful to obtain a measure of the percentage of problematic habitat that has been improved by past actions, and how much poor-quality habitat remains. Using the Lemhi again as an example, it is at least possible that, despite having had 226 actions to date (Table 4.1), the site still has hundreds of other problematic locations. Similarly, the fact that many sites have had no actions may not mean that they have no locations that are causing problems for juvenile chinook. Systematic habitat assessments, of the sort underway by the Northwest Power Planning Council (NPPC 2002) would be useful in the regard.

An implicit assumption, up to this point, has been that habitat actions do, in fact, result in habitat improvements, as distinct from increases in juvenile survival. Plans are underway to begin broad-scale, systematic habitat monitoring at both action sites and comparable, untreated control sites (Jordan et al. 2003). These should help resolve this issue, and may lead to more direct assessments where survival is a function of habitat conditions, not just the number of actions that have occurred.

Finally, as noted in the introduction, any analysis that examines the effects of past habitat actions is limited by the fact that the actions are not scattered randomly across the landscape. If habitat managers and researchers could coordinate their efforts, so that actions were sited in a stratified-random fashion, with simultaneous monitoring of similar control sites, this would greatly ease the attempt to disentangle the effects of the actions from the effects of the many other potential covariates.

4.7 Acknowledgements

The work was supported by contracts with the US Department of Energy, Bonneville Power Administration. The views are those of the authors. W. Thompson, USDA Forest Service, generously shared SAS code for estimating the AICc weights. We also thank the biologists who conducted the PIT tagging studies and the tagging crews from IDFG, ODFW, and NPT. C. Stein of PTAGIS provided assistance with access to the tagging data.

Table 4.1. Site names, subbasin, climate division, years of survival estimates, and number of habitat actions.

Subbasin	Site Name	PTAGIS Site ID	State Climate Division	Years of survival estimates	Minimum number of habitat actions	Maximum number of habitat actions
Clearwater	American R.	AMERR	1004	5	0	0
	Clear Creek	CLEARC	1004	8	0	1
	Crooked Fork Creek	CROOKC	1004	11	1	1
	Crooked R.	CROOKR	1004	7	9	9
	Legendary Bear Creek	PAPOOC	1004	5	3	3
	Lolo Creek	LOLOC	1004	10	4	9
	Meadow Creek (Selway)	MEADOC	1004	5	0	0
	Newsome Creek	NEWSOC	1004	5	2	2
	Red R.	REDR	1004	10	19	24
NE Oregon	Catherine Creek	CATHEC	3508	11	3	49
	Imnaha R.	IMNAHR	3508	11	9	64
	Looking Glass Creek	LOOKGC	4510	7	0	3
	Lostine R.	LOSTIR	3508	11	3	31
	Minam R.	MINAMR	3508	11	0	4
	Upper Grand Ronde R.	GRANDR	3508	8	14	44
Middle Fork Salmon	Bear Valley Creek	BEARVC	1004	9	2	3
	Big Creek	BIGC	1004	7	0	0
	Camas Creek	CAMASC	1004	5	1	2
	Cape Horn Creek	CAPEHC	1004	5	0	0
	Elk Creek	ELKC	1004	8	2	4
	Loon Creek	LOONC	1004	6	0	0
	Marsh Creek	MARSHC	1004	9	1	3
	Sulfur Creek	SULFUC	1004	5	0	0
South Fork Salmon	Johnson Creek	JOHNSC	1004	7	5	7
	Lake Creek	LAKEC	1004	11	1	3
	Secesh R.	SECESR	1004	11	0	0
	South Fork Salmon R.	SALRSF	1004	11	1	2
Upper Salmon	E. Fork Salmon R.	SALREF	1008	6	6	54
	Herd Creek	HERDC	1008	7	2	29
	Lemhi R.	LEMHIR	1008	11	10	226
	Pahsimeroi R.	PAHSIR	1008	10	1	47
	Upper Salmon R.	SALR	1004	10	17	55
	Valley Creek	VALEYC	1004	8	5	34

Table 4.2. ICBEMP variables used in the analysis.

Variable name	Description	Minimum	Mean	Maximum
Geological:				
Wdrnden	Drainage density, Km per Km^2	0.53	1.27	1.73
Whucorder	# of 6th field HUCs upstream	0.00	4.10	15.76
Wstreams	Total 1:100K streams	14.10	38.44	55.43
Welev	Mean elevation, ft	264.4	671.5	903.6
Road density:				
Wgeodens	Geometric mean road density, km per km^2	0.01	0.86	2.95
Average climate:				
Wmtemp	Annual average temp, Degrees C	1.1	3.4	8.5
Wpprecip	Prism precipitation, mm	304.6	926.2	1309.3
Wsolar	Solar radiation/ watts per m^2	255.2	316.0	355.9
Land use types (proportions):				
Wpr	Private and BLM rangeland	0	0.032	0.372
Wfg	FS forest and range, mod impact grazed	0	0.237	1
Wpf	Private land and FS forest land	0	0.121	1
Wfm	FS forest, hi-mod impact, no grazing	0	0.173	1
Wbr	BLM rangeland	0	0.072	1
Wfw	FS-managed wilderness	0	0.210	1
Vegetation cover (proportions):				
wv_b	Moist forest, under story re-initiation	0	0.117	1
wv_d	desert shrub	0	0.028	1
wv_e	Transition	0	0.274	1
wv_f	Young dry forest	0	0.063	1
wv_h	Young spruce-fir-lodgepole	0	0.381	1
wv_i	Old spruce-fir-lodgepole	0	0.005	0.278
wv_l	Moist forest, stem exclusion	0	0.081	1

Table 4.3. Pearson correlations between ln(survival), total habitat actions, and continuous independent variables. Bolded number indicate a significant correlation at 0.01.

	ln(survival)	**Total habitat actions**
Independent variable		
Total habitat actions	**0.218**	**1**
Length at tagging	**0.521**	**0.484**
Brood year redd density	**-0.359**	-0.117
Tag year density	-0.108	-0.065
Palmer drought severity index	**0.417**	**0.258**
Drainage density, km per km^2	**-0.311**	**-0.177**
# 6th field HUCs upstream	**0.335**	**0.524**
Total 1:100K streams	**-0.184**	0.021
Mean elevation, ft	-0.073	0.03
Geometric mean road density, km per km^2	-0.023	-0.011
Annual average temp, Degrees C	**0.12**	**0.139**
Prism precipitation, mm	**-0.151**	**-0.493**
Solar radiation, watts per m^2	-0.065	0.114
Private and BLM rangeland	**0.309**	**0.547**
FS forest and range, mod impact grazed	**-0.134**	0
Private land and FS forest land	0.07	**0.178**
FS forest, hi-mod impact, no grazing	-0.058	-0.101
BLM rangeland	0.076	**0.141**
FS-managed wilderness	0.116	**-0.151**
Moist forest, under story re-initiation	-0.096	**-0.154**
desert shrub	-0.034	-0.002
Transition	**0.238**	**0.325**
Young dry forest	0.096	-0.028
Young spruce-fir-lodgepole	-0.077	**-0.206**
Old spruce-fir-lodgepole	**0.218**	-0.068
Moist forest, stem exclusion	**-0.208**	**-0.12**

Table 4.4. Summary of results of 36 estimated models. A “x” denotes that the variable is included in the model, but that the estimated parameter(s) was/were not significant. An “X” denotes a significant result at alpha = 0.05. A blank denotes that the variable(s) was/were not included in the model.

	Location		Habitat			Time-varying	
Number	Site	Subbasin	ICBEMP	Total	Quartiles	Year effects	PDSI, etc.
1	X				x	X	
2	X				x		X
3	X				x		
4	X			x		X	
5	X			x			X
6	X			x			
7	X					X	
8	X						X
9	X						
10		x			x	X	
11		X			x		X
12		x			x		
13		X		x		X	
14		X		x			X
15		x		X			
16		X				X	
17		X					X
18		x					
19			X		X	X	
20			X		x		X
21			X		X		
22			X	X		X	
23			X	x			X
24			X	X			
25			X			X	
26			X				X
27			X				
28					x	X	
29					X		X
30					X		
31				X		X	
32				x			X
33				X			
34						X	
35							X
36							

Table 4.5. AICc weights. The three models with the highest weights – numbers 19, 22, and 25 – are bolded.

Model	Number of parameters	AICc	Delta	w(i)	w(i) rank	Adjusted R-square
1	47	188.438	13.066	7.84E-04	6	0.62
2	41	208.738	33.367	3.06E-08	13	0.57
3	37	344.664	169.292	9.34E-38	30	0.27
4	45	184.179	8.807	6.59E-03	5	0.62
5	39	201.572	26.201	1.10E-06	11	0.58
6	35	341.659	166.287	4.20E-37	29	0.27
7	44	181.113	5.741	3.05E-02	4	0.62
8	38	200.577	25.205	1.81E-06	10	0.58
9	34	339.317	163.946	1.35E-36	28	0.28
10	19	282.399	107.027	3.10E-24	24	0.36
11	13	212.915	37.543	3.79E-09	15	0.49
12	9	387.161	211.79	5.52E-47	36	0.02
13	17	265.524	90.152	1.43E-20	20	0.40
14	11	209.648	34.276	1.94E-08	14	0.50
15	7	374.739	199.367	2.75E-44	31	0.06
16	16	277.55	102.179	3.50E-23	21	0.37
17	10	208.64	33.269	3.22E-08	12	0.50
18	6	386.261	210.889	8.66E-47	34	0.01
19	**36**	**175.372**	**0**	**0.539**	**1**	**0.61**
20	30	197.948	22.577	6.75E-06	9	0.56
21	26	329.361	153.99	1.96E-34	26	0.27
22	**34**	**176.507**	**1.135**	**0.306**	**2**	**0.60**
23	28	191.894	16.523	1.39E-04	8	0.57
24	24	328.985	153.614	2.37E-34	25	0.26
25	**33**	**178.426**	**3.054**	**0.117**	**3**	**0.60**
26	27	190.446	15.074	2.87E-04	7	0.57
27	23	331.984	156.612	5.29E-35	27	0.25
28	15	279.734	104.363	1.17E-23	23	0.36
29	9	257.721	82.35	7.07E-19	16	0.39
30	5	384.051	208.679	2.62E-46	33	0.02
31	13	265.521	90.15	1.43E-20	19	0.39
32	7	261.515	86.144	1.06E-19	18	0.38
33	3	374.817	199.446	2.65E-44	32	0.04
34	12	278.427	103.055	2.26E-23	22	0.35
35	6	260.684	85.313	1.61E-19	17	0.38
36	2	387.074	211.703	5.77E-47	35	0.00

Table 4.6. Parameter estimates for models 19, 22, and 25. Parameters that are significant at 0.05 are bolded.

Model number	#19 - top-ranked			#22 - 2nd ranked			#25 - 3rd ranked		
Parameter	**Estimate**	**S. E.**	**Prob. > t**	**Estimate**	**S. E.**	**Prob. > t**	**Estimate**	**S. E.**	**Prob. > t**
Intercept	**-2.99**	**1.14**	**0.009**	**-3.65**	**1.12**	**0.001**	**-4.00**	**1.11**	**0.000**
WDRNDEN	0.08	0.15	0.577	0.07	0.14	0.614	0.03	0.14	0.823
WHUCORDER	0.02	0.01	0.083	0.02	0.01	0.125	0.02	0.01	0.184
WSTREAMS	0.00	0.00	0.180	0.00	0.00	0.435	0.00	0.00	0.955
Welev	0.00	0.00	0.568	0.00	0.00	0.944	0.00	0.00	0.895
Wgeodens	-0.08	0.06	0.193	-0.08	0.06	0.157	-0.08	0.06	0.152
Wmtemp	0.07	0.06	0.224	0.05	0.06	0.379	0.05	0.06	0.356
Wpprecip	0.00	0.00	0.788	0.00	0.00	0.277	0.00	0.00	0.426
Wsolar	0.00	0.00	0.505	0.00	0.00	0.999	0.00	0.00	0.625
Wpr	1.25	0.69	0.071	1.13	0.74	0.128	**1.71**	**0.69**	**0.013**
Wfg	-0.09	0.11	0.424	-0.07	0.11	0.495	-0.02	0.11	0.824
Wpf	-0.18	0.20	0.349	-0.11	0.18	0.550	-0.07	0.18	0.707
Wfm	0.03	0.12	0.819	0.14	0.11	0.213	0.16	0.11	0.164
Wbr	-0.23	0.32	0.468	0.06	0.31	0.858	0.02	0.31	0.942
Wfw	0.16	0.13	0.209	0.20	0.13	0.125	**0.26**	**0.13**	**0.046**
wv_b	**1.09**	**0.26**	**<.0001**	**0.98**	**0.25**	**0.001**	**0.93**	**0.25**	**0.000**
wv_d	**1.15**	**0.31**	**0.000**	**0.93**	**0.29**	**0.001**	**0.93**	**0.29**	**0.002**
wv_e	**1.16**	**0.27**	**<.0001**	**1.11**	**0.26**	**<.0001**	**1.04**	**0.26**	**<.0001**
wv_f	**1.31**	**0.36**	**0.000**	**1.26**	**0.35**	**0.000**	**1.23**	**0.35**	**0.000**
wv_h	**1.06**	**0.23**	**<.0001**	**0.96**	**0.23**	**<.0001**	**0.88**	**0.23**	**0.000**
wv_i	**4.60**	**0.68**	**<.0001**	**4.13**	**0.65**	**<.0001**	**4.02**	**0.65**	**<.0001**
wv_l	0.63	0.33	0.057	0.55	0.33	0.090	0.57	0.33	0.081
Total habitat actions	N/A	N/A	N/A	**0.0019**	**0.00**	**0.042**	N/A		
Q1 0 actions	**-0.20**	**0.09**	**0.021**	N/A			N/A		
Q2 1 to 3 actions	**-0.19**	**0.08**	**0.019**	N/A			N/A		
Q3 3-23 actions	-0.04	0.07	0.585	N/A			N/A		
Q4 24+ actions	N/A						N/A		
1992	**0.44**	**0.09**	**<.0001**	**0.43**	**0.09**	**<.0001**	**0.40**	**0.09**	**<.0001**
1993	**0.64**	**0.08**	**<.0001**	**0.62**	**0.08**	**<.0001**	**0.58**	**0.08**	**<.0001**
1994	**0.33**	**0.08**	**<.0001**	**0.31**	**0.07**	**<.0001**	**0.29**	**0.07**	**0.000**
1995	**0.67**	**0.10**	**<.0001**	**0.66**	**0.10**	**<.0001**	**0.65**	**0.10**	**<.0001**
1996	**0.70**	**0.12**	**<.0001**	**0.70**	**0.12**	**<.0001**	**0.69**	**0.12**	**<.0001**
1997	**1.11**	**0.09**	**<.0001**	**1.10**	**0.09**	**<.0001**	**1.10**	**0.09**	**<.0001**
1998	**0.72**	**0.07**	**<.0001**	**0.72**	**0.08**	**<.0001**	**0.71**	**0.08**	**<.0001**
1999	**0.71**	**0.08**	**<.0001**	**0.70**	**0.08**	**<.0001**	**0.70**	**0.08**	**<.0001**
2000	**0.76**	**0.08**	**<.0001**	**0.76**	**0.08**	**<.0001**	**0.77**	**0.09**	**<.0001**
2001	**0.43**	**0.08**	**<.0001**	**0.44**	**0.08**	**<.0001**	**0.44**	**0.08**	**<.0001**
2002	N/A			N/A					

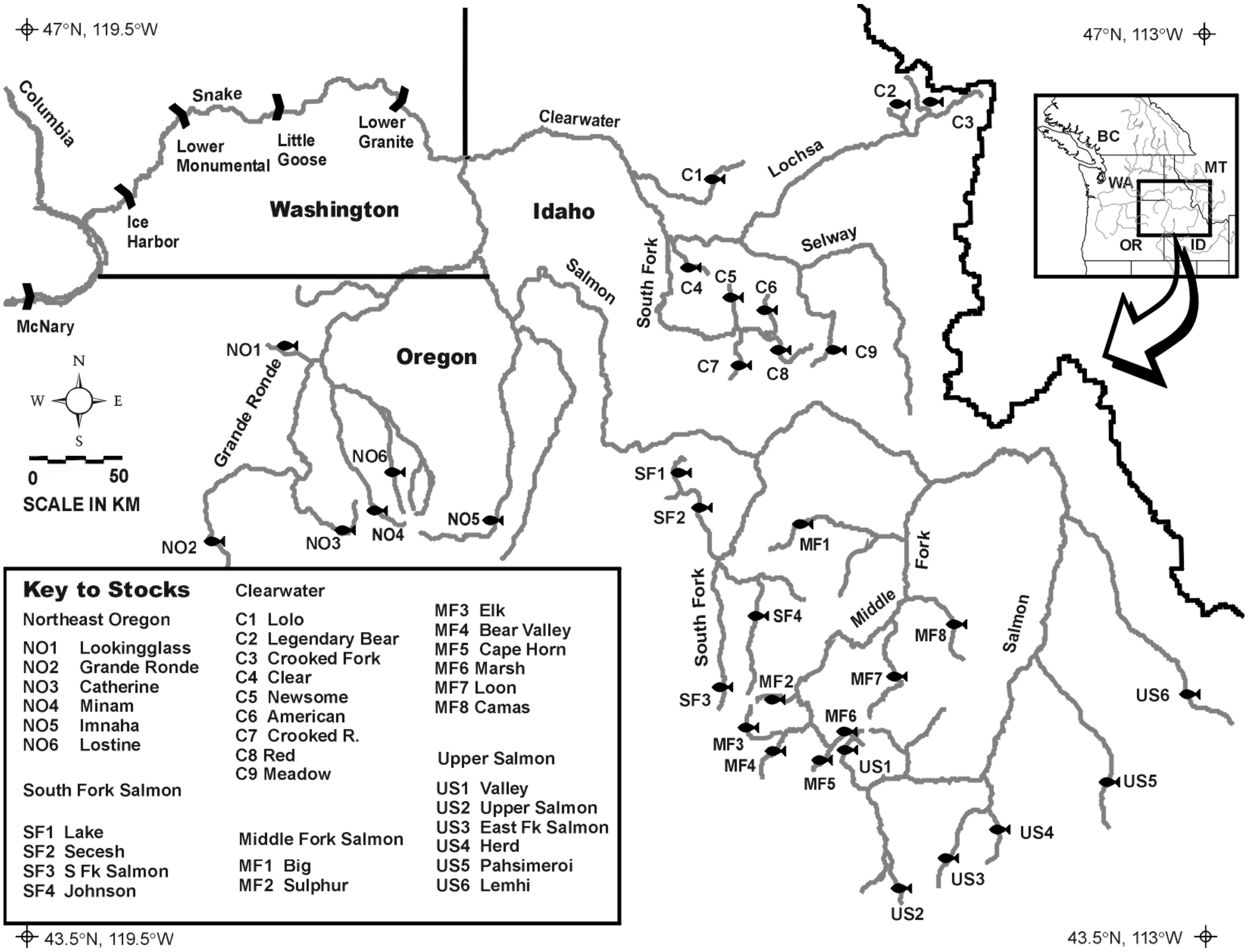


Figure 4.1. Map of study area. Symbols indicate tagging locations for each stock.

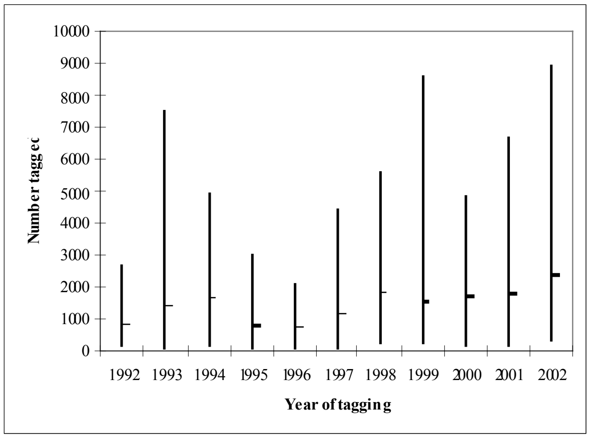


Figure 4.2a. Number of parr tagged at each site. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

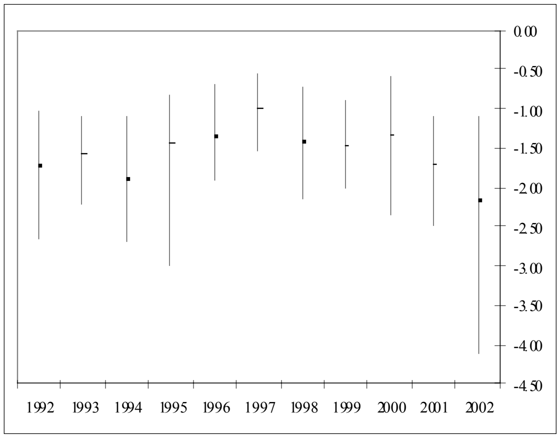


Figure 4.2b. Natural log of survival. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

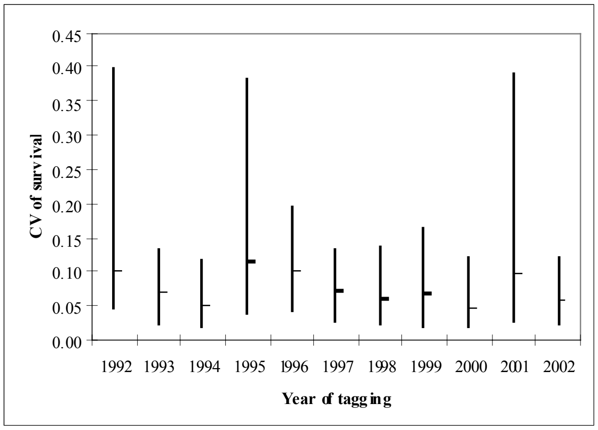


Figure 4.2c. Coefficient of variation of survival. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

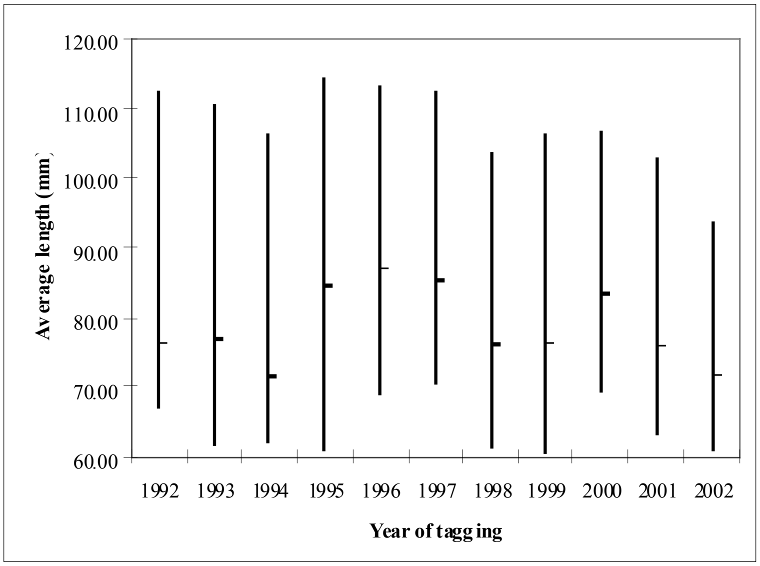


Figure 4.3. Length at tagging, mm. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

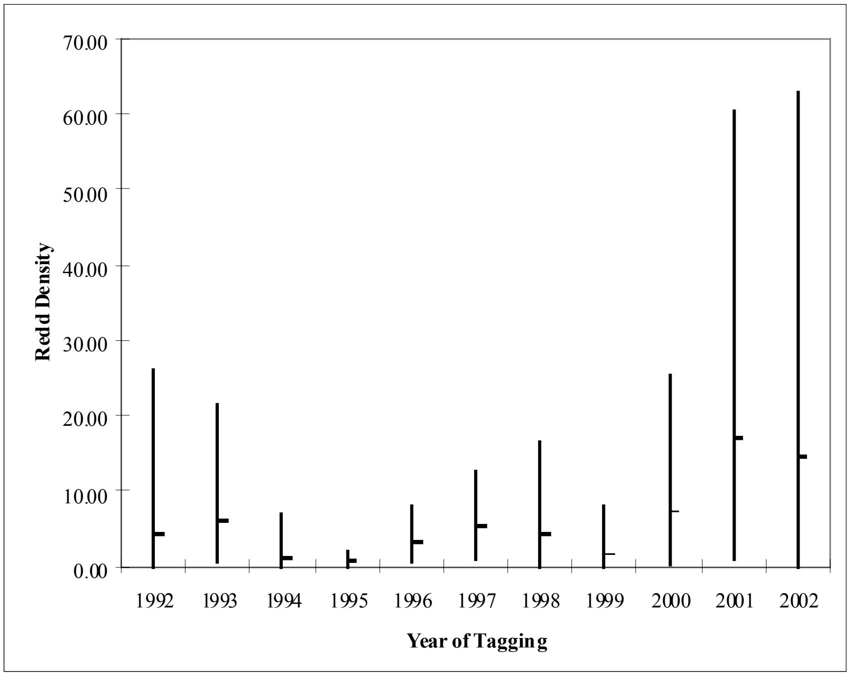


Figure 4.4. Redd density (redds per mile), year of tagging. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

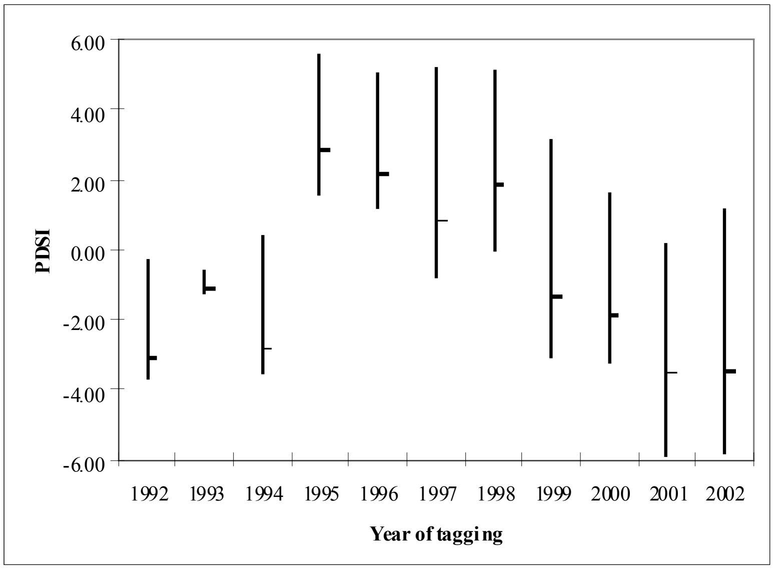


Figure 4.5. Palmer drought severity index (PDSI), September-December, year of tagging. Extent of bars indicate minima and maxima, horizontal dash indicates mean.

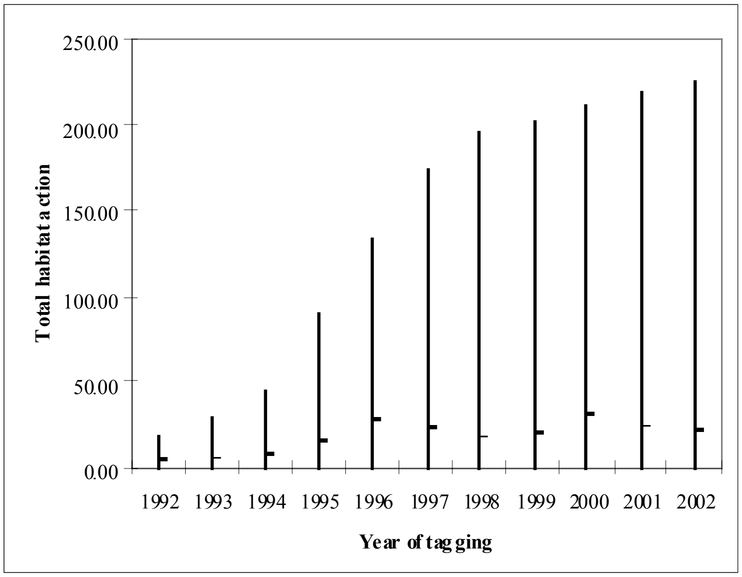


Figure 4.6. Total habitat actions thought to affect parr-to-smolt survival, year of tagging. Extent of bars indicate minima and maxima, horizontal dash indicate mean.

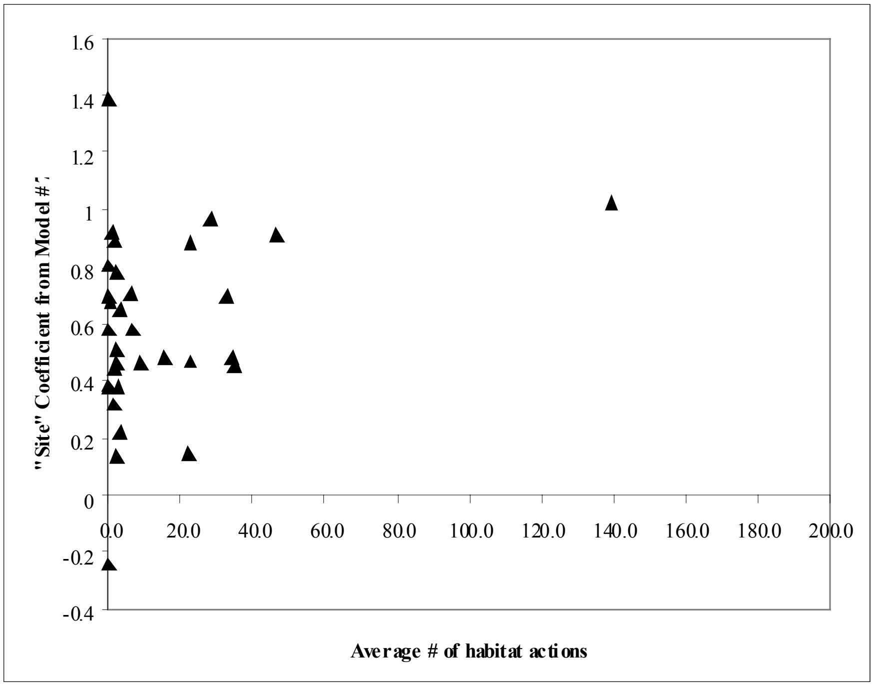


Figure 4.7. "Site" coefficient versus average number of habitat actions.

Appendix 4A - Data tables

Table 4A.1. Number tagged. Blanks denote no data.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			696				307	1146		289	305
BEARVC	1004	819	1397			427	806	820	579	1477	971
BIGC	733	706	1384				1425	1088		409	1611
CAMASC	1004	201	1412					694			900
CAPEHC	205		1177				261	414			447
CATHEC	1092	998	1984	1107	987	1261	1156	1174	1527	1464	3057
CLEARC	425	258	471			300	348	285		729	542
CROOKC	1086	1834	2973	359	542	989	2607	1197	233	1539	2581
CROOKR	450	2330	3377	524			285	244		209	
ELKC	628	949	1452			245	699	658		1514	946
GRANDR	916	1903	1854			724	919	992		344	583
HERDC	224	119	530				959	315	309		796
IMNAHR	998	2433	1756	2972	1458	4444	5001	4879	4814	4200	8150
JOHNSC	632		192				5443	5220	4167	6704	8982
LAKEC	255	227	360	133	394	672	5246	2582	2514	3119	3962
LEMHIR	643	751	1826	180	273	753	3494	1896	2150	2063	3617
LOLOC	927	1505	1648	121		624	1983	591	1128	2024	2092
LOOKGC		1946	3567	2013		1630	2837			2033	708
LOONC	261	369	855				1026	679			830
LOSTIR	995	721	1000	974	1045	998	1166	1028	1481	1550	2364
MARSHC	1000	7528	4899	275		1007	2967	2721		2558	3928
MEADOC				215			520	495	179	2004	
MINAMR	987	994	995	991	589	994	1000	996	1296	1509	1817
NEWSOC			936				1982	1973		1751	1825
PAHSIR		561	2929	377	101	245	940	786	1494	340	2607
PAPOOC			290				833	388		679	930
REDR	552	1002	2049	633		1394	1280	1247	365	403	683
SALR	2659	810	2304	993		116	352	1017	903	2275	3221
SALREF	843	1080	2024	108				672		288	
SALRSF	1654	5206	3728	1713	2042	3602	5570	8573	2476	2831	5319
SECESR	324	350	1444	554	260	1164	3023	2769	3662	4216	4698
SULFUC	712		685				436	729			557
VALEYC	1024	834	1522				1000	995	997	1490	2105
MIN	205	119	192	108	101	116	261	244	179	209	305
MEAN	823.4	1401.3	1678.6	791.2	769.1	1136.3	1802.3	1539.5	1681.9	1786.1	2371.1
MAX	2659	7528	4899	2972	2042	4444	5570	8573	4814	6704	8982

Table 4A.2. ln(survival).

site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			-2.30				-2.14	-1.98		-1.77	-4.11
BEARVC	-1.75	-1.47	-2.50			-1.04	-1.56	-1.61	-1.50	-1.92	-2.26
BIGC	-1.60	-1.84	-1.52				-1.50	-1.37		-1.22	-1.66
CAMASC	-1.52	-1.57	-2.23					-1.63			-2.43
CAPEHC	-1.86		-2.16				-1.44	-1.60			-1.98
CATHEC	-1.67	-1.48	-1.57	-1.19	-1.42	-1.52	-1.69	-1.66	-2.33	-1.93	-2.19
CLEARC	-2.04	-1.10	-1.49			-0.87	-1.31	-1.38		-1.38	-2.55
CROOKC	-1.26	-1.22	-1.66	-1.17	-1.35	-0.62	-1.13	-1.10	-0.75	-1.50	-2.23
CROOKR	-2.08	-1.77	-1.71	-1.95			-1.51	-1.77		-1.41	
ELKC	-2.07	-1.82	-2.27			-0.75	-1.50	-1.51		-1.99	-2.57
GRANDR	-1.16	-1.58	-1.72			-1.33	-1.62	-1.50		-1.18	-1.70
HERDC	-1.83	-1.78	-1.93				-1.68	-1.61	-1.26		-2.14
IMNAHR	-1.90	-1.48	-1.77	-1.26	-1.24	-0.74	-1.18	-1.20	-1.14	-1.37	-1.19
JOHNSC	-1.76		-2.65				-1.23	-1.29	-1.19	-1.27	-2.06
LAKEC	-1.34	-2.21	-2.19	-2.09	-1.59	-1.22	-1.39	-1.38	-1.12	-2.11	-2.51
LEMHIR	-1.27	-1.34	-1.10	-0.89	-0.70	-0.65	-0.96	-1.00	-1.30	-1.15	-1.32
LOLOC	-1.14	-1.29	-1.50	-3.00		-0.81	-1.60	-1.67	-1.54	-1.72	-2.53
LOOKGC		-1.46	-1.95	-1.40		-1.20	-1.28			-1.60	-1.10
LOONC	-1.02	-1.32	-1.62				-1.12	-1.37			-1.83
LOSTIR	-1.36	-1.41	-1.51	-1.50	-1.28	-0.93	-1.15	-1.34	-1.29	-1.45	-1.53
MARSHC	-1.95	-1.21	-1.56	-0.98		-0.55	-1.17	-1.33		-1.28	-1.85
MEADOC				-0.84			-0.71	-0.88	-0.60	-1.09	
MINAMR	-1.63	-1.21	-1.85	-1.59	-1.50	-1.47	-1.68	-1.40	-1.29	-1.91	-1.90
NEWSOC			-2.20				-1.66	-1.86		-2.09	-2.63
PAHSIR		-1.41	-1.36	-0.87	-1.15	-1.01	-0.97	-1.02	-1.38	-1.57	-1.57
PAPOOC			-2.13				-1.76	-2.03		-1.96	-2.22
REDR	-1.86	-1.21	-1.94	-1.27		-1.09	-1.79	-1.44	-1.47	-2.20	-3.38
SALR	-2.64	-1.92	-2.27	-1.29		-1.05	-1.23	-1.34	-1.40	-1.69	-2.05
SALREF	-2.52	-2.05	-1.98	-1.02				-1.99		-2.48	
SALRSF	-1.48	-1.65	-2.21	-1.83	-1.90	-1.14	-1.61	-1.47	-1.78	-2.42	-2.36
SECESR	-1.64	-1.92	-2.00	-1.99	-1.45	-1.11	-1.42	-1.31	-1.07	-1.88	-2.43
SULFUC	-2.25		-1.69				-1.96	-1.49			-2.01
VALEYC	-2.48	-1.99	-2.70				-1.65	-1.98	-1.85	-2.26	-2.78
MIN	-2.64	-2.21	-2.70	-3.00	-1.90	-1.52	-2.14	-2.03	-2.33	-2.48	-4.11
MEAN	-1.74	-1.57	-1.91	-1.45	-1.36	-1.01	-1.44	-1.49	-1.35	-1.71	-2.17
MAX	-1.02	-1.10	-1.10	-0.84	-0.70	-0.55	-0.71	-0.88	-0.60	-1.09	-1.10

Table 4A.3. CV[ln(survival)].

site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			0.06				0.11	0.06		0.39	0.10
BEARVC	0.10	0.07	0.04			0.09	0.07	0.09	0.05	0.05	0.06
BIGC	0.09	0.06	0.04				0.04	0.06		0.10	0.05
CAMASC	0.12	0.12	0.05					0.06			0.07
CAPEHC	0.11		0.04				0.12	0.17			0.11
CATHEC	0.06	0.07	0.04	0.07	0.07	0.05	0.05	0.06	0.03	0.07	0.04
CLEARC	0.10	0.13	0.08			0.11	0.10	0.12		0.08	0.06
CROOKC	0.08	0.06	0.03	0.13	0.10	0.07	0.04	0.07	0.10	0.08	0.04
CROOKR	0.09	0.04	0.03	0.10			0.13	0.12		0.35	
ELKC	0.08	0.06	0.05			0.12	0.06	0.07		0.06	0.07
GRANDR	0.12	0.05	0.04			0.06	0.05	0.07		0.28	0.09
HERDC	0.15	0.13	0.07				0.05	0.10	0.07		0.07
IMNAHR	0.07	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.05
JOHNSC	0.08		0.12				0.02	0.03	0.02	0.03	0.03
LAKEC	0.15	0.09	0.08	0.12	0.13	0.06	0.03	0.03	0.03	0.03	0.03
LEMHIR	0.06	0.06	0.04	0.14	0.19	0.09	0.03	0.04	0.03	0.09	0.05
LOLOC	0.08	0.04	0.04	0.15		0.08	0.04	0.07	0.04	0.05	0.04
LOOKGC		0.04	0.03	0.05		0.04	0.04			0.07	0.12
LOONC	0.40	0.12	0.05				0.07	0.08			0.06
LOSTIR	0.07	0.09	0.05	0.06	0.07	0.06	0.08	0.06	0.03	0.07	0.06
MARSHC	0.06	0.02	0.02	0.12		0.06	0.03	0.04		0.06	0.03
MEADOC				0.22			0.11	0.10	0.12	0.05	
MINAMR	0.07	0.07	0.06	0.06	0.08	0.05	0.05	0.07	0.04	0.05	0.05
NEWSOC			0.05				0.05	0.04		0.04	0.04
PAHSIR		0.07	0.03	0.09	0.19	0.11	0.06	0.06	0.03	0.17	0.05
PAPOOC			0.11				0.06	0.07		0.09	0.05
REDR	0.09	0.06	0.03	0.09		0.04	0.05	0.06	0.07	0.08	0.07
SALR	0.05	0.06	0.03	0.08		0.13	0.08	0.05	0.04	0.06	0.03
SALREF	0.06	0.06	0.03	0.38				0.06		0.18	
SALRSF	0.06	0.03	0.03	0.07	0.04	0.03	0.02	0.02	0.03	0.04	0.03
SECESR	0.12	0.07	0.04	0.08	0.10	0.05	0.03	0.04	0.02	0.03	0.02
SULFUC	0.13		0.06				0.08	0.08			0.10
VALEYC	0.07	0.06	0.04				0.05	0.06	0.04	0.05	0.04
MIN	0.05	0.02	0.02	0.04	0.04	0.03	0.02	0.02	0.02	0.03	0.02
MEAN	0.10	0.07	0.05	0.11	0.10	0.07	0.06	0.07	0.04	0.10	0.06
MAX	0.40	0.13	0.12	0.38	0.19	0.13	0.13	0.17	0.12	0.39	0.12

Table 4A.4. Length at tagging.

site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			64.5				68.7	80.3		72.4	67.2
BEARVC	73.8	63.5	63.6			75.0	65.0	62.2	73.5	66.0	62.8
BIGC	74.6	65.8	69.7				71.6	68.2		75.7	64.5
CAMASC	68.6	64.2	62.2					61.7			61.4
CAPEHC	67.1		62.9				61.5	60.7			61.2
CATHEC	76.8	80.5	76.5	87.3	86.9	82.8	78.8	80.2	80.1	76.6	75.7
CLEARC	77.8	87.6	81.5			90.1	80.1	94.9		79.0	74.4
CROOKC	79.2	77.0	70.1	82.8	82.0	84.2	75.7	82.1	83.0	69.0	72.2
CROOKR	74.8	73.8	68.5	61.0			77.6	85.8		77.2	
ELKC	77.6	64.7	66.7			77.2	67.6	65.0		68.5	62.5
GRANDR	75.2	67.9	70.9			80.2	78.6	76.7		78.3	81.2
HERDC	78.5	74.1	73.9				70.7	70.5	82.4		75.9
IMNAHR	72.7	82.6	71.8	83.8	88.6	89.0	86.8	86.2	85.1	79.1	80.1
JOHNSC	70.3		65.3				72.0	74.3	76.1	75.4	67.2
LAKEC	72.1	62.8	64.2	63.9	71.4	71.0	74.5	74.1	78.7	67.8	69.5
LEMHIR	112.4	110.3	106.2	114.1	109.6	111.5	103.5	106.0	97.3	92.0	88.7
LOLOC	76.0	82.0	75.0	107.3		85.8	68.2	79.2	80.8	68.5	68.0
LOOKGC		85.6	77.0	90.2		87.1	88.3			86.6	90.1
LOONC	70.0	64.4	66.1				67.0	63.4			65.3
LOSTIR	84.4	72.3	72.2	69.2	87.9	96.2	83.9	83.6	87.3	83.1	79.8
MARSHC	70.7	82.7	77.0	93.1		86.9	74.3	76.3		77.0	72.5
MEADOC				87.5			89.1	86.9	91.9	78.3	
MINAMR	81.5	76.5	68.2	80.5	91.6	76.2	74.5	70.3	80.6	66.8	72.4
NEWSOC			64.7				71.8	70.0		71.5	66.7
PAHSIR		105.3	96.4	107.7	113.1	112.5	102.6	105.7	106.6	102.7	93.4
PAPOOC			72.2				69.3	72.2		63.2	65.0
REDR	74.2	87.7	69.1	81.2		78.5	73.0	81.8	87.4	75.4	68.9
SALR	83.8	84.6	77.6	86.1		91.2	90.7	89.7	91.0	82.3	80.7
SALREF	76.1	76.6	75.7	91.4				65.4		87.9	
SALRSF	75.2	72.7	64.3	66.2	69.1	70.7	68.1	70.0	69.5	65.5	68.4
SECESR	68.6	61.9	63.6	65.6	70.0	71.5	70.6	72.0	75.7	67.0	66.6
SULFUC	70.8		62.5				62.7	61.4			64.4
VALEYC	73.5	67.4	64.4				68.8	64.4	72.2	70.5	62.6
MIN	67.1	61.9	62.2	61.0	69.1	70.7	61.5	60.7	69.5	63.2	61.2
MEAN	76.2	76.7	71.4	84.4	87.0	85.1	76.0	76.3	83.3	75.8	71.6
MAX	112.4	110.3	106.2	114.1	113.1	112.5	103.5	106.0	106.6	102.7	93.4

Table 4A.5. Redd Density.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			0.1				0.4	0.0		9.9	0.0
BEARVC	2.0	7.2	0.5			1.9	5.0	1.6	3.4	8.4	12.0
BIGC	1.2	2.4	0.2				4.7	3.1		44.0	35.5
CAMASC	1.1	4.2	0.3					0.5			0.0
CAPEHC	3.9		0.0				9.8	0.0			11.2
CATHEC	2.4	4.2	0.5	0.7	0.7	2.2	1.7	2.1	1.7	6.8	8.1
CLEARC	0.1	0.7	0.1			1.0	0.1	0.0		10.1	5.5
CROOKC	2.1	5.8	0.1	0.8	2.6	11.8	3.4	0.9	6.6	17.9	13.7
CROOKR	4.0	2.3	0.3	0.2			0.6	0.1		7.5	
ELKC	3.8	15.9	0.5			5.7	6.9	0.7		14.4	24.8
GRANDR	4.2	3.6	0.1			1.4	1.8	0.0		1.1	0.9
HERDC	0.3	4.1	0.4				0.9	0.3	0.3		14.7
IMNAHR	5.2	7.9	0.8	1.1	2.9	6.6	3.2	4.1	5.2	12.2	24.0
JOHNSC	25.9		6.8				16.4	7.9	8.5	60.4	62.8
LAKEC	8.0	6.4	1.2	2.0	5.4	9.8	7.7	1.6	24.1	40.3	34.6
LEMHIR	0.6	1.0	0.3	0.2	1.2	2.1	1.7	1.5	3.6	13.3	5.7
LOLOC	1.2	1.7	0.5	0.4		9.1	2.0	0.6	6.6	28.2	13.5
LOOKGC		14.9	3.4	0.4		2.0	0.4			6.7	1.4
LOONC	1.4	2.0	0.1				2.7	0.4			13.5
LOSTIR	2.1	4.9	0.8	0.5	1.3	2.3	1.8	3.0	3.2	6.5	10.4
MARSHC	3.9	7.2	0.3	0.0		3.7	5.4	0.0		11.8	10.6
MEADOC				0.0			0.1	0.1	0.5	4.1	
MINAMR	6.0	6.0	1.6	1.1	8.1	4.8	5.4	3.7	10.5	13.6	14.6
NEWSOC			0.0				3.4	0.0		23.6	5.5
PAHSIR		4.4	1.9	1.1	1.4	2.4	1.6	4.0	3.0	9.6	8.2
PAPOOC			0.0				3.1	1.1		52.0	22.3
REDR	6.1	5.7	1.5	0.5		11.1	3.1	0.5	9.5	13.2	7.0
SALR	2.2	3.0	0.9	0.2		1.1	2.2	1.2	6.9	16.9	26.5
SALREF	0.8	2.1	0.3	0.2				1.0		4.7	
SALRSF	15.7	21.6	5.5	2.2	3.7	12.5	11.9	6.4	13.0	15.6	13.9
SECESR	9.5	11.6	3.4	1.8	4.1	8.7	4.7	3.7	25.3	22.7	17.7
SULFUC	1.6		0.0				14.6	0.0			13.6
VALEYC	0.5	1.6	0.6				3.0	0.5	0.2	3.0	4.8
MIN	0.1	0.7	0.0	0.0	0.7	1.0	0.1	0.0	0.2	1.1	0.0
MEAN	4.3	5.9	1.0	0.7	3.1	5.3	4.2	1.6	7.3	17.1	14.6
MAX	25.9	21.6	6.8	2.2	8.1	12.5	16.4	7.9	25.3	60.4	62.8

Table 4A.6. PDSI.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			-3.5				1.4	-1.8		-3.6	-3.7
BEARVC	-3.4	-1.2	-3.5			0.6	1.4	-1.8	-2.4	-3.6	-3.7
BIGC	-3.4	-1.2	-3.5				1.4	-1.8		-3.6	-3.7
CAMASC	-3.4	-1.2	-3.5					-1.8			-3.7
CAPEHC	-3.4		-3.5				1.4	-1.8			-3.7
CATHEC	-3.6	-1.0	-2.5	1.6	1.2	-0.7	1.9	-3.0	-3.2	-5.9	-5.8
CLEARC	-3.4	-1.2	-3.5			0.6	1.4	-1.8		-3.6	-3.7
CROOKC	-3.4	-1.2	-3.5	2.4	1.6	0.6	1.4	-1.8	-2.4	-3.6	-3.7
CROOKR	-3.4	-1.2	-3.5	2.4			1.4	-1.8		-3.6	
ELKC	-3.4	-1.2	-3.5			0.6	1.4	-1.8		-3.6	-3.7
GRANDR	-3.6	-1.0	-2.5			-0.7	1.9	-3.0		-5.9	-5.8
HERDC	-0.3	-0.6	-0.5				5.1	3.1	1.6		1.1
IMNAHR	-3.6	-1.0	-2.5	1.6	1.2	-0.7	1.9	-3.0	-3.2	-5.9	-5.8
JOHNSC	-3.4		-3.5				1.4	-1.8	-2.4	-3.6	-3.7
LAKEC	-3.4	-1.2	-3.5	2.4	1.6	0.6	1.4	-1.8	-2.4	-3.6	-3.7
LEMHIR	-0.3	-0.6	-0.5	5.6	5.0	5.1	5.1	3.1	1.6	-0.4	1.1
LOLOC	-3.4	-1.2	-3.5	2.4		0.6	1.4	-1.8	-2.4	-3.6	-3.7
LOOKGC		-1.2	0.4	3.5		1.5	0.0			0.2	-1.9
LOONC	-3.4	-1.2	-3.5				1.4	-1.8			-3.7
LOSTIR	-3.6	-1.0	-2.5	1.6	1.2	-0.7	1.9	-3.0	-3.2	-5.9	-5.8
MARSHC	-3.4	-1.2	-3.5	2.4		0.6	1.4	-1.8		-3.6	-3.7
MEADOC				2.4			1.4	-1.8	-2.4	-3.6	
MINAMR	-3.6	-1.0	-2.5	1.6	1.2	-0.7	1.9	-3.0	-3.2	-5.9	-5.8
NEWSOC			-3.5				1.4	-1.8		-3.6	-3.7
PAHSIR		-0.6	-0.5	5.6	5.0	5.1	5.1	3.1	1.6	-0.4	1.1
PAPOOC			-3.5				1.4	-1.8		-3.6	-3.7
REDR	-3.4	-1.2	-3.5	2.4		0.6	1.4	-1.8	-2.4	-3.6	-3.7
SALR	-3.4	-1.2	-3.5	2.4		0.6	1.4	-1.8	-2.4	-3.6	-3.7
SALREF	-0.3	-0.6	-0.5	5.6				3.1		-0.4	
SALRSF	-3.4	-1.2	-3.5	2.4	1.6	0.6	1.4	-1.8	-2.4	-3.6	-3.7
SECESR	-3.4	-1.2	-3.5	2.4	1.6	0.6	1.4	-1.8	-2.4	-3.6	-3.7
SULFUC	-3.4		-3.5				1.4	-1.8			-3.7
VALEYC	-3.4	-1.2	-3.5				1.4	-1.8	-2.4	-3.6	-3.7
MIN	-3.6	-1.2	-3.5	1.6	1.2	-0.7	0.0	-3.0	-3.2	-5.9	-5.8
MEAN	-3.1	-1.1	-2.9	2.8	2.1	0.8	1.8	-1.4	-1.9	-3.5	-3.5
MAX	-0.3	-0.6	0.4	5.6	5.0	5.1	5.1	3.1	1.6	0.2	1.1

Table 4A.7. Total habitat actions.

Site	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
AMERR			0				0	0		0	0
BEARVC	2	2	2			2	2	2	2	3	3
BIGC	0	0	0				0	0		0	0
CAMASC	1	1	1					2			2
CAPEHC	0		0				0	0			0
CATHEC	3	5	23	33	34	39	44	48	49	49	49
CLEARC	0	0	0			0	0	0		1	1
CROOKC	1	1	1	1	1	1	1	1	1	1	1
CROOKR	9	9	9	9			9	9		9	
ELKC	2	2	2			2	3	3		4	4
GRANDR	14	16	20			40	41	43		44	44
HERDC	2	2	2				24	24	26		29
IMNAHR	9	18	31	46	50	53	56	61	62	64	64
JOHNSC	5		5				7	7	7	7	7
LAKEC	1	1	1	1	1	3	3	3	3	3	3
LEMHIR	10	29	45	90	133	174	196	202	211	219	226
LOLOC	4	4	4	4		7	7	8	9	9	9
LOOKGC		0	1	2		2	3			3	3
LOONC	0	0	0				0	0			0
LOSTIR	3	4	13	21	26	28	31	31	31	31	31
MARSHC	1	1	1	1		1	3	3		3	3
MEADOC				0			0	0	0	0	
MINAMR	0	2	3	3	3	3	3	3	4	4	4
NEWSOC			2				2	2		2	2
PAHSIR		1	4	12	26	30	35	39	45	47	47
PAPOOC			3				3	3		3	3
REDR	19	19	19	24		24	24	24	24	24	24
SALR	17	18	19	19		30	35	50	52	55	55
SALREF	6	8	8	14				44		54	
SALRSF	1	1	2	2	2	2	2	2	2	2	2
SECESR	0	0	0	0	0	0	0	0	0	0	0
SULFUC	0		0				0	0			0
VALEYC	5.0	6.0	6.0				23.0	29.0	30.0	32.0	34.0
MIN	0	0	0	0	0	0	0	0	0	0	0
MEAN	4.3	5.8	7.1	15.7	27.6	23.2	18.0	20.1	31.0	24.0	21.7
MAX	19	29	45	90	133	174	196	202	211	219	226

Table 4A.8. Average actions vs. Model 7 "Site" coefficients.

Site	Average # from A7	Model 7 coefficient (best among 'site' models)
AMERR	0.0	-0.2436
BEARVC	2.2	0.4651
BIGC	0.0	0.6987
CAMASC	1.4	0.317
CAPEHC	0.0	0.3813
CATHEC	34.2	0.4851
CLEARC	0.3	0.6792
CROOKC	1.0	0.9206
CROOKR	9.0	0.4631
ELKC	2.8	0.3799
GRANDR	32.8	0.6984
HERDC	15.6	0.4776
IMNAHR	46.7	0.9114
JOHNSC	6.4	0.7042
LAKEC	2.1	0.5117
LEMHIR	139.5	1.021
LOLOC	6.5	0.5808
LOOKGC	2.0	0.7793
LOONC	0.0	0.8026
LOSTIR	22.7	0.8802
MARSHC	1.9	0.8877
MEADOC	0.0	1.3856
MINAMR	2.9	0.649
NEWSOC	2.0	0.1363
PAHSIR	28.6	0.9693
PAPOOC	3.0	0.2149
REDR	22.5	0.4677
SALR	35.0	0.4568
SALREF	22.3	0.1449
SALRSF	1.8	0.4455
SECESR	0.0	0.5815
SULFUC	0.0	0.3846

Correlation	*Average # from A7*	
Average # from A7	1	
Model 7 coefficient (best among 'site' models)	0.288747326	1

Appendix 4B – Methods of Cataloging Habitat Projects

Our sources were primarily Federal (the Northwest Power Planning Council's (NPPC) Fish and Wildlife Program (F&WP), www.nwcouncil.org/fw/program/Default.htm; Bonneville Power Administration's (BPA) database of F&WP reports, www.efw.bpa.gov/cgi-bin/FW/publications.cgi; NPPC Subbasin Planning documents for the Clearwater, Salmon, and Grande Ronde/Imnaha basins, www.nwcouncil.org/fw/subbasinplanning/Default.htm; GRMWP and USBWP databases, and other Federal agencies such as the US Dept. of Agriculture (USDA) extension offices) and State government projects (the Oregon Watershed Enhancement Board's (OWEB) project database, www.oweb.state.or.us). Table B1 shows a summary of the habitat projects we used for the model. Projects were selected if we judged that they effected the juvenile (i.e. parr – to smolt) survival of one or more stocks in the model. These were usually projects in the watershed above the primary spawning and rearing areas for each stock. Projects that were on stream channels were almost always used, unless we judged that they did not effect juvenile salmonid survival (for example some land acquisition projects where management of the land did not change). Projects removed from stream channels were used if we judged that they altered geomorphic processes that would effect juvenile survival (for example sediment abatement projects such as road obliterations). Projects that were located downstream from the primary spawning and rearing areas were generally not used in this analysis. Future analyses may consider these projects and their effects on overwintering juveniles; however at this time we do not have good information as to where the parr of these stocks overwinter. Appendix 2 provides a brief summary of each project we found that potentially effected each stock in the model. More detailed project location information and descriptions are available from the authors upon request.

Table 4B.1. Projects, total, and affecting parr to smolt survival.

		Effect chinook or parr-smolt survival?			
Subbasin	**PIT Stocks**	**Yes/Yes (Used)**	**Yes/No**	**No/No**	**Total Projects**
Clearwater	American R.	0	0	0	0
	Clear Cr.	1	0	0	1
	Crooked Fork Cr.	1	4	0	5
	Crooked R.	9	0	0	9
	Legendary Bear Cr.	3	1	1	5
	Lolo Cr.	9	8	0	17
	Meadow Cr. (Selway)	0	0	0	0
	Newsome Cr.	2	0	0	2
	Red R.	24	0	1	25
Subbasin Total		49	13	2	64
Grande Ronde	Catherine Cr.	49	13	18	80
	Imnaha R.	64	1	19	84
	Lookingglass Cr.	3	1	4	8
	Lostine R.	31	9	8	48
	Minam R.	4	0	14	18
	Upper Grande Ronde R.	44	4	22	70
Subbasin Total		195	28	85	308
Salmon					
M Fk Salmon	Bear Valley Cr.	2	0	0	2
	Bear Valley Cr. & Elk Cr.	1	0	0	1
	Big Cr.	0	0	2	2
	Camas Cr.	2	0	0	2

		Effect chinook or parr-smolt survival?			
Subbasin	**PIT Stocks**	**Yes/Yes (Used)**	**Yes/No**	**No/No**	**Total Projects**
	Cape Horn Cr.	0	0	0	0
	Elk Cr.	3	0	0	3
	Loon Cr.	0	0	0	0
	Marsh Cr.	3	0	1	4
	Sulfur Cr.	0	0	0	0
South Fork Salmon	Johnson Cr.	7	0	5	12
	Lake Cr.	3	0	0	3
	Secesh R.	0	0	0	0
	S. Fk. Salmon R.	2	7	5	14
Upper Salmon	E. Fk. Salmon R.	33	2	2	37
	E. Fk. Salmon R. & Herd Cr.	21	0	0	21
	Herd Cr.	8	0	0	8
	Lemhi R.	226	5	0	231
	Pahsimeroi R.	47	0	0	47
	Upper Salmon R.	55	1	7	63
	Valley Cr.	34	1	16	51
Subbasin Total		447	16	38	501
Grand Total		691	57	125	873

Table 4B.2. Projects, total, and affecting parr to smolt survival.

		Effect chinook or parr-smolt survival?			
Subbasin	**PIT Stocks**	**Yes/Yes (Used)**	**Yes/No**	**No/No**	**Total Projects**
Clearwater	American R.	0	0	0	0
	Clear Cr.	1	0	0	1
	Crooked Fork Cr.	1	4	0	5
	Crooked R.	9	0	0	9
	Legendary Bear Cr.	3	1	1	5
	Lolo Cr.	9	8	0	17
	Meadow Cr. (Selway)	0	0	0	0
	Newsome Cr.	2	0	0	2
	Red R.	24	0	1	25
Subbasin Total		49	13	2	64
Grande Ronde	Catherine Cr.	49	13	18	80
	Imnaha R.	64	1	19	84
	Lookingglass Cr.	3	1	4	8
	Lostine R.	31	9	8	48
	Minam R.	4	0	14	18
	Upper Grande Ronde R.	44	4	22	70
Subbasin Total		195	28	85	308
Salmon					
M Fk Salmon	Bear Valley Cr.	2	0	0	2
	Bear Valley Cr. & Elk Cr.	1	0	0	1
	Big Cr.	0	0	2	2
	Camas Cr.	2	0	0	2
	Cape Horn Cr.	0	0	0	0
	Elk Cr.	3	0	0	3
	Loon Cr.	0	0	0	0
	Marsh Cr.	3	0	1	4
	Sulfur Cr.	0	0	0	0
South Fork Salmon	Johnson Cr.	7	0	5	12
	Lake Cr.	3	0	0	3
	Secesh R.	0	0	0	0
	S. Fk. Salmon R.	2	7	5	14
Upper Salmon	E. Fk. Salmon R.	33	2	2	37
	E. Fk. Salmon R. & Herd Cr.	21	0	0	21
	Herd Cr.	8	0	0	8
	Lemhi R.	226	5	0	231
	Pahsimeroi R.	47	0	0	47
	Upper Salmon R.	55	1	7	63
	Valley Cr.	34	1	16	51
Subbasin Total		447	16	38	501
Grand Total		691	57	125	873

Appendix 4C - Smolt-to-Adult survival rates and habitat actions

An interesting question is whether or not the results seen above for parr-to-smolt survival carry through to smolt-to-adult survival. In this appendix, we report preliminary results which suggest that in fact a similar relationship between habitat actions and survival may be present in the data: namely, that higher numbers of habitat actions are associated with higher parr-to-adult survival.

We first show how estimate smolt-to-adult survival with the tagging and detection data in hand. We next show how, for the stocks used in the model, it appears that smolt-to-adult survival rates are in similar to those for wild spring-summer chinook above LGR. We then show how models using habitat actions rank with those that do not, using smolt-to-adult survival as the dependent variable. The appendix concludes with some speculation on why habitat actions appear to be a gift that keeps on giving, increasing both parr-to-smolt and smolt do adult survival. Along the way, we note a number of reasons why one should regard the results as preliminary, aside from the fact that they are at this writing (March 14, 2004) less than three weeks old.

Given parr-to smolt survival, and detections of tagged fish as jacks or adults at the Lower Granite adult detectors (LGRA), parr-to-adult survival is simply the detected at LGRA divided by the number released. Smolt-to-adult survival, then, is just parr-to-adult survival divided by parr-to-smolt survival. So, for example, if parr-to-adults survival for a group is, say 3/300 (1%) and parr-to-smolt survival is 25%, then smolt-to-adult survival is 4% (1% divided by 25%). Note that there is an inverse relationship between smolt-to-adult and parr-to-smolt survival — the higher the short-term survival, the lower the long-term survival, if number released and number detected at LGRA do not change. Note as well that as a practical matter, many sites and years will have smolt-to-adult survival of zero, making the weighting scheme used for the previous analysis impractical.

One check on this estimate is to use wild spring-summer chinook tagged as smolts (in the year of downstream migration) vs. those tagged as parr (the year before migration, in the sites used in Chapter 4). The results of this comparison are shown in Figure 4C.1, for downstream migration years 1995–2000. Obviously, the results are very similar, giving us some confidence that the imputed SAR's are a reasonable measure of true survival rates, and not an artifact of the estimation procedure. For both groups, we used fish that were not transported, since most tagged juveniles are allowed to migrate in-river.

The next question, of course, is whether or not there is a relationship between habitat actions and smolt-to-adult survival. Table 4C.1 shows the results for six estimated models, with models 1-3 in natural (untransformed) units, and models 4-6 using the form survival = log(parameter estimates). Since the dependent variable is the same in both cases, we can use the AICc to compare all six models. As can be seen, habitat actions are significant in the three models where they appear. The majority of the AIC weigh (64%) is given to model 6, which also uses migration year dummies and land use clusters similar to those in Paulsen and Fisher (2001). Table 4C.2 shows the parameter estimates for model 6. While it is encouraging and a bit surprising that habitat actions have a positive effect on survival (for both model 6 and for Models 2 and 5), the adjusted r-squares are considerably smaller — 0.08–0.20 — than for models using parr-to-smolt survival, where top-ranked models had adjusted r-squares of about 0.60. Note as well that length-at-tagging, of considerable importance for parr-to-smolt survival, is not important in these results. Preliminary diagnostics (outliers, normality, etc.) do not reveal any problematic observations or normality assumption violations, but we have yet to do site-by-site or year-by-year diagnostics.

Why does this result occur? At one level, it is quite surprising that habitat actions to which fish were last exposed 2–4 years before their return as adults, should have any influence on survival rates. Any answer must at this point be speculative, but we venture a couple of suggestions. Random chance is certainly possible, but not very likely given the model results just described. It is at least plausible that fish from better habitat (with more actions) arrive at LGR in better condition (larger, more smoltified, etc.) than fish leaving areas with fewer actions and, by implication, worse habitat. However, this is speculative at best, since we do not have information on the condition of fish from different tagging sites when they arrive at LGR. Further analysis of presently available data, as well as possible additional sampling of tagged fish arriving at LGR, will be needed to answer these questions.

Table 4C.1. Regression results, 98 observations, downstream migration years 1997-2000, 25 sites. Models 1-3 are in natural units, while 4-6 use a log-transform of the predictors. An “x’ denotes that a variable is included, while “X” denotes that it is included and is significant at 5%. Length-at-tagging was included in all models, but was never significant.

Model	Migration Year	# Actions	Cluster	K parameters (includes sigma)	AICc	Delta	Exp (1/2 Delta)	w(i)	R-Square	Adj. R-Square
1	**X**			5	293.256	7.60	0.02	0.01	0.13	0.08
2		**X**		3	298.267	12.61	0.00	0.00	0.04	0.01
3			**x**	6	300.319	14.66	0.00	0.00	0.08	0.02
4	**X**		**X**	9	287.832	2.17	0.34	0.22	0.25	0.17
5	**X**	**X**		6	288.824	3.17	0.21	0.13	0.18	0.13
6	**X**	**X**	**X**	10	285.659	0.00	1.00	0.64	0.29	0.20
						Sum	**1.57**	1.00		

Table 4C.2. Regression results for highest-weighted model, number 6. Bolded parameter estimates are significant at 5%.

Parameter	Estimate	Pr > Chi-Square
Intercept	-0.0037	0.1599
Migration Yr. 1997	**-0.0028**	0.0076
1998	**-0.0035**	0.0001
1999	-0.0001	0.8767
2000	0	N/A
Length @tagging	0.0001	0.1624
Survival, tagging to LGR	**0.0133**	0.0025
Agricultural land	**0.0031**	0.0073
Moderate-age dry forest	**0.0022**	0.0308
Transitional area	**0.0017**	0.0425
Wilderness	0.0006	0.4924
Young, dry forest	0	N/A

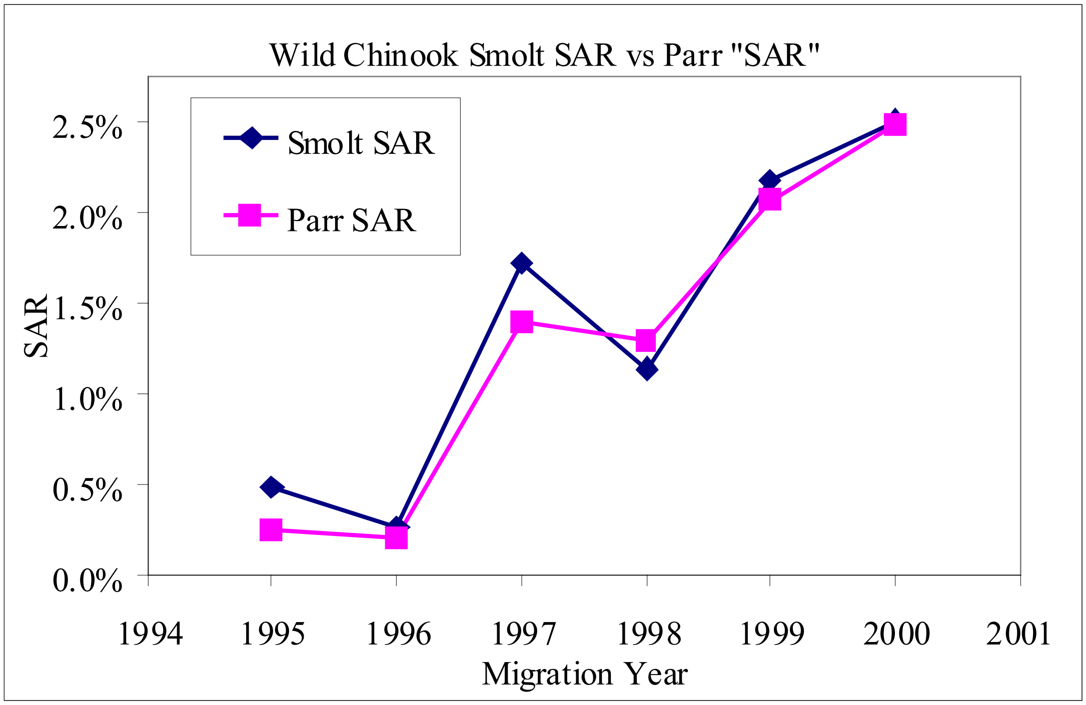


Figure 4C.1. Wild chinook smolt-to-adult (run-at-large) SAR vs. imputed SAR for fish tagged as parr.

5. Using Redd Densities to Detect the Effects of Habitat Actions

5.1 Introduction

In our analysis of the effects of habitat actions on parr-to-smolt survival (Paulsen and Fisher 2003a) we noted that, for many tagging sites, habitat actions had commenced well before survival rate estimates became possible, in 1992. In addition, the time series is relatively short — only 11 years of data — and other studies (e.g., Roni et al. 2003) have suggested that several decades of data may be needed to assess the effects of habitat actions on salmonids.

To our knowledge, the longest, site-specific time series for Snake spring-summer chinook are redd counts, estimated by different fish and wildlife agencies sine the late 1950s. We decided to use redd density (redds per km of stream surveyed) to try to detect the effects of past habitat actions, using very simple stock-recruit estimates, since return-at-age information is not readily available for most of the 26 stocks. Because of the crudeness of the spawner-recruit estimates, we also decided to use as many stocks as possible, hoping, as it were, to substitute a large number of coarse estimates for a much smaller number of more refined estimates (perhaps 7-8 of the 26 stocks have current run reconstructions).

5.2 Data and methods

Redd survey information (redds counted and stream length surveyed) was obtained from various sources for the spawning streams (P. Keniry, ODFW, 107 20th Street LaGrande OR 97850, personal communication, 2002 and 2003 [Grande Ronde and Imnaha River basins] and Hassemer 1993; Elms-Cockrum 2001, updated by S. Keifer, IDFG, 600 S Walnut St. Boise ID 83707, personal communication, 2002, and E. Brown, IDFG, 600 S Walnut St. Boise ID 83707, personal communication [Salmon River basin]).

We estimated recruitment for brood year "t" simply as the density of redds in year t+5. This choice was based on simulations using stock-recruit models developed by Paulsen and Hinrichsen (2002), where it appeared that, in the absence of stock- and year-specific age-at-return information, assuming all fish returned at age 5 yielded more powerful models for detecting effects of habitat actions (Paulsen, unpublished). Although we do not report the results further, we note that defining age-4 returns as "recruits" yielded very similar results. The subbasins, stocks, and years of recruits per spawner (R/S) estimates are shown in Table 5.1. The resulting data has 36–41 years of R/S estimates for each of the 26 stocks, for a total of 997 observations.

We also compiled data on habitat actions that we judged would effect R/S estimates for each stock. Habitat actions were those remediation, mitigation, and other actions taken with the intent of improving habitat for anadromous salmonids. These actions were carried out over a span of at least 25 years, by various Federal, State, and private entities. We used our best judgment to narrow the list of habitat actions to those which would most likely effect R/S estimates for spring/summer chinook salmon. These were generally actions targeted at improving riparian and/or instream habitat, general water quality, or juvenile and/or adult passage conditions, reducing sediment, and increasing instream flow, and which occurred near the principal spawning and rearing areas of the stocks. In calculating the number of actions, we assumed that any action, once taken, would be effective from the time it was implemented through the end of 2002.

Habitat actions were entered into the model in two ways: as a simple 0/1 dummy, encoded as "0" for sites/years where no habitat actions had occurred, and a "1" otherwise, and as a series of dummies, for zero actions, 1–4 actions and 5 or more actions. The 1–4 and 5+ cut-points were chosen to be either side of the median number of actions for sites with > 0 habitat actions.

Other independent variables, from ICBEMP (Quigley and Arbelbide 1997) were used to describe site-specific characteristics (Table 5.2).

Using R/S as the dependent variable, we employed information-theoretic methods similar to those in Paulsen and Fisher (2003a) and Paulsen and Fisher (2003b) to select the best-fitting models. Models are of the form ln (R/S) is a linear function of the independent variables. All models included spawners and common year effects (i.e., Paulsen and Hinrichsen 2002), as well as the independent variables as specified in Table 5.3. What differentiates the 27 models is what site-specific variables are used, how habitat actions are entered, and whether or not a common or shared carrying capacity (Ricker "b" term) is used.

5.3 Results and discussion

Table 5.4 shows the results — deviance, number of parameters, AICc, etc. — for each of the 27 models. The three top-weighted models — 17, 23, and 26 — either did not include habitat actions as independent variables (17 and 26), or, if they were included, the estimated coefficients did not differ significantly from zero. The habitat variables were never significant in any of the 18 models where they were used.

The most parsimonious explanation for the results, of course, is simply that the habitat actions that have been undertaken to date did not affect productivity, estimated here as R/S. Other potential explanations abound. Among other potential problems, we note:

1. The lack of age-at-return data is likely to limit the statistical power to detect effects. While we have estimates of age at return from carcass surveys for most stocks for the late 1980's to present, older estimates are apparently warehoused at ODFW and IDFG offices.
2. Paulsen and Hinrichsen (2002) showed that detecting a doubling in survival (R/S) for stocks with age data would require 3–4 years of treatment, plus five years for all progeny to return. It is possible that insufficient time has elapsed to detect what may very well be large effects on R/S.
3. Effects may in fact be present, but small. Using the same model as Paulsen and Hinrichsen (2002), Paulsen (unpublished) showed that detecting smaller effects (10-50% increase in R/S) would require 10-50 years, while large scale habitat actions have only been occurring for a decade or so.

Table 5.1. Years of recruit-per-spawner (R/S) estimates for stocks used in the models.

Subbasin	Stream	Model Stock	# yrs R/S estimates
Middle Fork Salmon	Bear Valley Creek	BEARVC	41
Middle Fork Salmon	Big Creek	BIGC	41
Middle Fork Salmon	Camas Creek	CAMASC	39
Middle Fork Salmon	Cape Horn Creek	CAPEHC	38
Middle Fork Salmon	Elk Creek	ELKC	40
Middle Fork Salmon	Loon Creek	LOONC	38
Middle Fork Salmon	Marsh Creek	MARSHC	40
Middle Fork Salmon	Sulfur Creek	SULFUC	38
NE Oregon	Catherine Creek	CATHEC	41
NE Oregon	Imnaha R.	IMNAHR	41
NE Oregon	Looking Glass Creek	LOOKGC	40
NE Oregon	Lostine R.	LOSTIR	40
NE Oregon	Minam R.	MINAMR	41
NE Oregon	Upper Grand Ronde R.	GRANDR	38
NE Oregon	Wenaha R.	WENR	36
S. Fork Salmon	Johnson Creek	JOHNSC	41
S. Fork Salmon	Lake Creek	LAKEC	40
S. Fork Salmon	Secesh R.	SECESR	41
S. Fork Salmon	South Fork Salmon R.	SALRSF	41
Upper Salmon	Alturas Lake Creek	ALTULC	39
Upper Salmon	E. Fork Salmon R.	SALREF	41
Upper Salmon	Herd Creek	HERDC	32
Upper Salmon	Lemhi R.	LEMHIR	41
Upper Salmon	Upper Salmon R.	SALR	41
Upper Salmon	Valley Creek	VALEYC	40
Upper Salmon	West Fork Yankee Fork	YANKWF	39

Table 5.2. Correlations between redd density, recruits per spawner (R/S), ln(recruits per spawner), and brood year and the potential independent variables. Correlations significant at 0.05 are bolded.

Variable	Redds / mile	R/S	Ln(R/S)	Brood Year
Redd density	1	-0.087	-0.262	-0.46
R/S	-0.087	1	0.361	0.12
Ln(R/S)	-0.262	0.361	1	0.14
Brood Year	-0.459	0.123	0.138	1
Cumulative habitat actions	-0.11	0.043	0.183	0.27
Drainage density, km/km^2	0.061	-0.008	-0.016	-0.03
# 6th field HUCs upstream	0.088	0.073	-0.009	0.01
Total 1:100K streams	0.164	0.012	-0.009	0.02
Mean elevation, ft	0.057	0.014	-0.006	-0.05
Geometric mean road density, km/km^2	-0.076	-0.02	-0.012	0.01
Annual average temp, Degrees C	-0.049	-0.025	-0.005	0.04
Prism precipitation, mm	0.049	-0.04	0.039	0.02
Solar radiation, watts/m^2	0.013	0.015	-0.01	-0.06
Private and BLM rangeland	0.009	-0.01	-0.01	0.01
FS forest and range, mod impact grazed	0.038	-0.039	-0.01	0
Private land and FS forest land	-0.083	-0.007	0.011	0.01
FS forest, hi-mod impact, no grazing	0.252	-0.005	-0.007	0
BLM rangeland	-0.042	-0.009	-0.031	-0.03
FS-managed wilderness	-0.066	0.061	0.024	0
Moist forest, under story re-initiation	-0.07	-0.01	0.031	0.01
desert shrub	-0.045	-0.006	-0.012	0
Transition	-0.042	-0.008	-0.028	-0.04
Young dry forest	-0.093	0.03	0.018	0.03
Young spruce-fir-lodge pole	-0.066	0.02	-0.021	0.03
Old spruce-fir-lodge pole	0.174	-0.019	-0.006	-0.04
Moist forest, stem exclusion	-0.076	-0.009	0.028	0.01
Total acres	-0.006	0.061	0.002	0.04

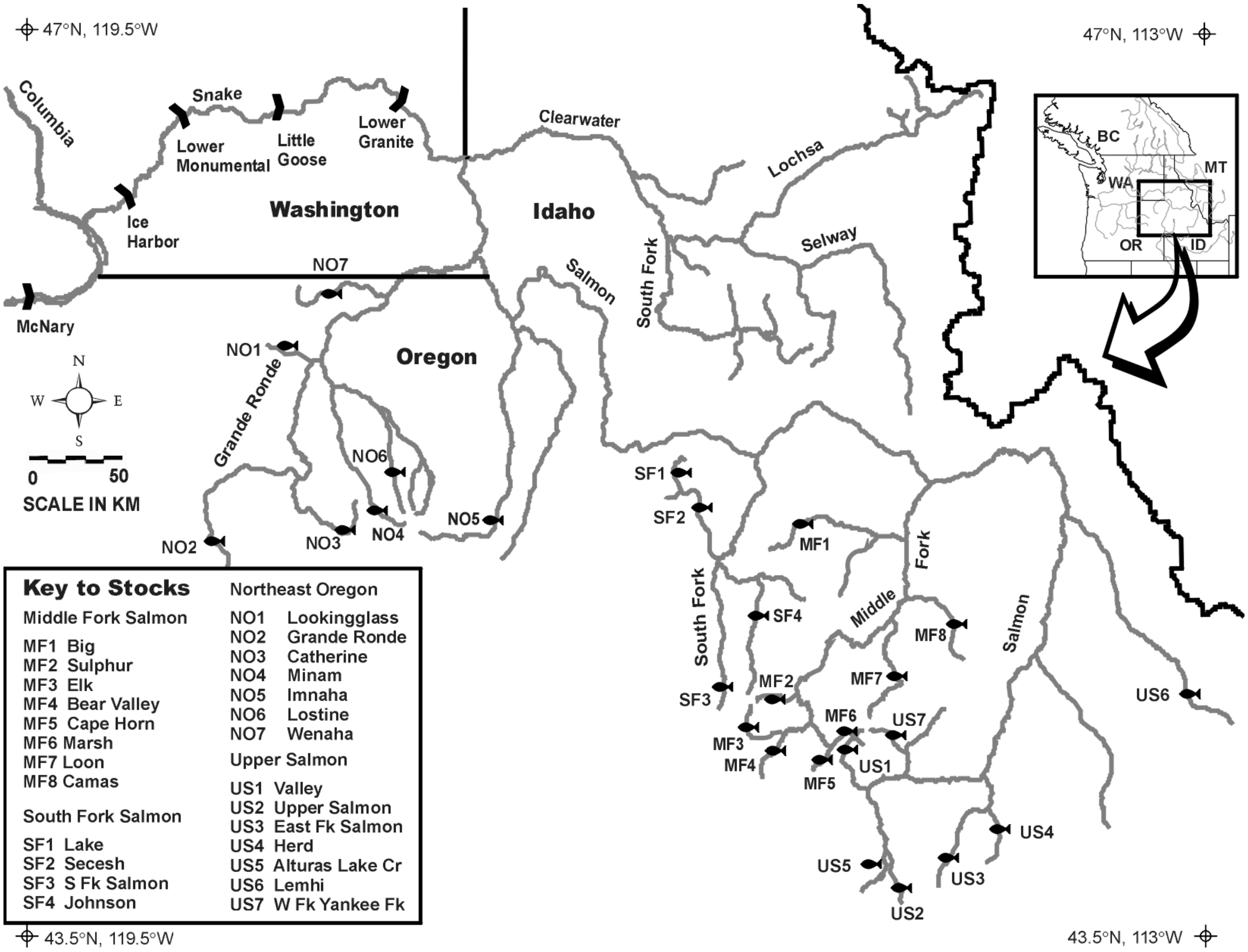
Table 5.3. 27 models estimated.

Model #	Site-specific variables	Habitat actions	Ricker B
1	Separate Ricker "a"	0, 1-4, 5+	Common to all stocks
2	Separate Ricker "a"	0, 1-4, 5+	Site-specific "b"
3	Separate Ricker "a"	0, 1-4, 5+	No "b" term
4	Separate Ricker "a"	0 or > 0	Common to all stocks
5	Separate Ricker "a"	0 or > 0	Site-specific "b"
6	Separate Ricker "a"	0 or > 0	No "b" term
7	Separate Ricker "a"	None	Common to all stocks
8	Separate Ricker "a"	None	Site-specific "b"
9	Separate Ricker "a"	None	No "b" term
10	ICBEMP land use, etc.	0, 1-4, 5+	Common to all stocks
11	ICBEMP land use, etc.	0, 1-4, 5+	Site-specific "b"
12	ICBEMP land use, etc.	0, 1-4, 5+	No "b" term
13	ICBEMP land use, etc.	0 or > 0	Common to all stocks
14	ICBEMP land use, etc.	0 or > 0	Site-specific "b"
15	ICBEMP land use, etc.	0 or > 0	No "b" term
16	ICBEMP land use, etc.	None	Common to all stocks
17	ICBEMP land use, etc.	None	Site-specific "b"
18	ICBEMP land use, etc.	None	No "b" term
19	Common Ricker "a"	0, 1-4, 5+	Common to all stocks
20	Common Ricker "a"	0, 1-4, 5+	Site-specific "b"
21	Common Ricker "a"	0, 1-4, 5+	No "b" term
22	Common Ricker "a"	0 or > 0	Common to all stocks
23	Common Ricker "a"	0 or > 0	Site-specific "b"
24	Common Ricker "a"	0 or > 0	No "b" term
25	Common Ricker "a"	None	Common to all stocks
26	Common Ricker "a"	None	Site-specific "b"
27	Common Ricker "a"	None	No "b" term

Table 5.4. AICc weights, etc. for 27 estimated models.

Model #	Log Likelihood	Deviance	# Parameters	AICc	Delta AICc	AICc weight	AICc Rank
1	-1287.82	771.04	70	2726.37	108.332	8.91E-25	15
2	-1213.2	662.37	95	2636.65	18.611	2.71E-05	9
3	-1340.18	856.51	69	2828.78	210.746	5.14E-47	27
4	-1287.84	771.14	69	2724.1	106.065	2.77E-24	13
5	-1213.15	662.38	94	2634.11	16.072	9.64E-05	8
6	-1340.17	856.54	68	2826.44	208.409	1.65E-46	26
7	-1289.25	773.38	68	2724.62	106.584	2.14E-24	14
8	-1213.18	662.48	93	2631.72	13.689	3.17E-04	7
9	-1340.45	857.1	67	2824.72	206.68	3.93E-46	25
10	-1305.08	798.91	57	2731.21	113.172	7.93E-26	18
11	-1221.79	674.74	82	2622.48	4.447	3.22E-02	6
12	-1340.92	858.51	56	2800.63	182.593	6.67E-41	24
13	-1305.11	799	56	2729	110.969	2.38E-25	17
14	-1221.75	674.74	81	2620.03	1.991	1.10E-01	4
15	-1340.94	858.6	55	2798.43	180.395	2.00E-40	23
16	-1305.95	800.4	55	2728.45	110.415	3.14E-25	16
17	-1222.05	675.2	80	2618.25	0.211	2.68E-01	2
18	-1341.32	859.31	54	2796.95	178.919	4.19E-40	22
19	-1311.64	810.01	45	2717.64	99.6	7.02E-23	12
20	-1234.75	693.18	70	2620.24	2.2	9.91E-02	5
21	-1343.2	862.98	44	2778.56	160.522	4.14E-36	21
22	-1311.62	810.01	44	2715.4	97.361	2.15E-22	11
23	-1234.81	693.31	69	2618.04	0	2.98E-01	1
24	-1343.18	862.99	43	2776.33	158.293	1.26E-35	20
25	-1312.05	810.75	43	2714.08	96.041	4.16E-22	10
26	-1236.4	695.58	68	2618.91	0.873	1.92E-01	3
27	-1343.87	864.23	42	2775.53	157.497	1.88E-35	19

Figure 5.1. Map of stock locations.



6. Review of Action Effectiveness Studies ("Blue Ribbon") of Relevance to Habitat Restoration in the Columbia Basin

(C. Pinkham and D.R. Marmorek)

It was recognized at the outset of this pilot project that we would only be able to evaluate some of the restoration actions of interest to NMFS, the USFWS, the NWPCC and other federal, state and tribal management agencies. To better allocate limited resources towards action effectiveness studies, there is an interest in identifying:

1. which actions do not have good historic data sets to evaluate their effectiveness, and therefore need new pilot studies;
2. which actions have some useful past data suitable for retrospective analyses, but merit continued monitoring to provide a more thorough effectiveness evaluation; and
3. which actions have been thoroughly evaluated, and do not need further retrospective studies, monitoring or pilot studies.

As a contribution towards the above "triage," we undertook a review of identified "blue ribbon" studies of action effectiveness of relevance to the Columbia Basin, from various parts of the Pacific Northwest, which is presented in Appendix 1. Some review papers have been included because they provide a useful synthesis of other experimental studies.

The studies summarized in Appendix 1 are examples that have relatively strong experimental designs and duration of time series for detecting the impacts of habitat restoration actions on salmon and steelhead survival. While many of these studies are outside of the Columbia Basin, they are all within the Pacific Northwest and offer both guidance to future monitoring studies as well as potentially relevant data on outcomes. The studies are organized alphabetically by author. The table below provides a list of the studies presented in Appendix 1 and the corresponding RPA actions considered.

Below Table 6.1 we present two summaries of Appendix 1:

- a bulleted list of key points raised by the authors of these studies with respect to: performance measures worth monitoring; temporal and spatial scales of response; and factors to consider in designing restoration actions; and
- a tabular summary of the outcomes of various restoration actions, in terms of monitored changes in survival, growth or abundance.

The study summaries are in alphabetical order by author in Appendix 1.

Table 6.1. Summary of studies reviewed in Appendix 1, and their relevance to actions mentioned in RP 183.

		Compliance with water quality standards			Improved riparian conditions		
Reference	**Attainment of minimum instream flows**	**Alteration of grazing practices**	**Reduction of sediment through road closures**	**Enhanced levels of marine–derived nutrients**	**Alteration of grazing practices**	**Active stream restoration**	**General Paper**
Amour and Taylor (1991) in Higgins (2001)[8]	✔						
Bayley (2002)							✔
Beechie and Bolton (1999)							✔
Bilby et al. (1998)				✔			
Cederholm et al. (1999)				✔			✔
Clayton (2002)						✔	
Giannico (2000)						✔	
Kauffman et al. (2002)		✔			✔		
Johnston et al. (1990)				✔			
McHugh (2003)						✔	
Michael Jr. (1995)							✔
Nickelson et al. (1992)						✔	
Paulsen and Fisher (2001)			✔				✔
Reeves et al. (1997)						✔	
Roni et al. (2002)						✔	✔
Roni and Quinn (2001)						✔	
Solazzi et al. (2000)						✔	
Ward et al. (2002)				✔		✔	
Watson and Hillman (1997)							✔
Wipfli et al. (2003)				✔			

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[8] There is uncertainty in instream flow assessment through the wide use of physical habitat models such as PHABSIM. There have been many technical concerns about the shortcomings of PHABSIM but it is still the most commonly applied method for instream flow assessment in the U.S. and Canada. In Amour and J.G. Taylor (1991), only 1% (n=6) of the 616 applications of PHABSIM known to the US Fish and Wildlife Service prior to 1988 had any monitoring to examine the outcome of management actions. In those where follow-up monitoring was conducted, none were sufficient to draw quantitative conclusions about the success of the application. This paper is not summarized in this document.

6.1 Summary of major lessons learned

The following list highlights the major lessons learned from the review of blue ribbon studies that are relevant to other action effectiveness studies. The points are organized thematically.

6.1.1 Performance Measures Worth Monitoring

- "Physical parameters provide an important tool for detecting initial responses to stream restoration to ensure a site is evolving in an acceptable manner, but they do not preclude the importance of monitoring biological parameters. Biological parameters may be more resilient and capable of large changes over a short period whereas physical parameters may require a longer period to exhibit large changes" (Clayton 2002). Based on findings from the study by Clayton (2002), "physical monitoring in stream restoration can complement biological monitoring to decrease the time required until responses to restoration are detectable."
- Clayton (2002) found that after five years of post-restoration monitoring, physical parameters (e.g., median particle size) would require a 19% change relative to baseline conditions to be detectable, but biological parameters (e.g., age 0 chinook densities) would require a 171% change to be detectable (one-tailed test, $\alpha=0.10$, power=80%, equal variance before and after).
- "The longer-term (years to decades) response and ultimate success of reach-scale restoration may depend upon resolution of limiting factors controlled at the watershed scale. From a physical perspective, if the channel is resilient enough to transport the supply of water and sediment it receives from the watershed while maintaining its slope, sinuosity, and dimensions, it could be considered in equilibrium. From a biological perspective, an increase in the number of redds at the project reach, not just a redistribution of redds already in the area, and an increase in the abundance and size of smolts emigrating from the watershed relative to the adjacent unrestored watersheds might be considered the true test of success" (Clayton 2002).
- The criteria for assessing the success of a restoration effort should be established at the start of a project and not be based solely on statistical differences (Reeves et al. 1997).
- Different species/age-classes may not respond in the same manner and this should be recognized when establishing objectives and expectations for restoration (Reeves et al. 1997).

6.1.2 Temporal and Spatial Scale of Response

- "Since physical and biological responses to ecological restoration are influenced by processes acting at multiple spatial and temporal scales, attributing change to habitat restoration requires separating forcing functions imposed by restoration from those occurring naturally. A framework is proposed to separate factors influencing ecological response into four levels: external physical forcing functions, restoration-induced functions, and physical and biological response variables" (Clayton 2002).
- Grazing exclosures are a simple, holistic, and effective restoration strategy. Changes in vegetation composition structure as well as geomorphic features suggest that livestock exclusion succeeds in restoring many important components of productive wildlife and fish habitats, though effects vary across both spatial and temporal scales (Kauffman et al. 2002):
  - Response of vegetation and geomorphology was greatest in the oldest exclosures suggesting the quality of fish and wildlife habitats increase with increasing exclosure age.
  - The scale of the exclosures sampled in Kauffman et al. (2002), (in terms of size and time) is too small to produce anticipated improvements in juvenile and adult coldwater fishes. Larger areas of livestock exclusion for long time periods will be necessary to restore salmonids. This suggests that more effective and efficient restoration can be accomplished by a strategic approach at the

sub-basin scale, taking into account the lengths of, and distances between, exclosures and their locations with respect to the migratory patterns of salmonids in each sub-basin.

- Many key questions about how and where to do restoration projects remain unanswered. Monitoring of effectiveness of restoration projects must be improved. Preconstruction monitoring and ten to twenty years of post-construction monitoring should be initiated in a large number of new restoration projects. Monitoring should focus on ecosystem, habitat, and fish population changes. Further monitoring and research will lead to better decisions about location, scale, and methods of restoration projects (Kauffman et al. 2002).
- Knowledge about the effectiveness of most restoration techniques is incomplete and comprehensive research and monitoring are needed. Even techniques that appear to be well studied, such as instream LWD placement, need more thorough evaluation and long-term monitoring (Roni et al. 2002).
- BACI (Solazzi et al. 2000) and stair-case (Ward et al. 2002) designs appear to be robust approaches to effectiveness evaluations, provided that a sufficiently large magnitude of action is applied to the area of interest to generate a significant improvement in fish survival rates.
- Hatchery salmon carcasses may be valuable in streams where wild spawners are lacking but they should not be considered a long-term solution to replacing the nutrient subsidy of wild salmon. To ensure effective recycling of nutrients from the ocean back to land, wild anadromous salmonids must recover from their current status. The findings in the literature review by Cederholm et al. (1999) illustrate the need for continued research and corresponding management to protect and recover native salmonid populations.

6.1.3 Factors to Consider in Designing Restoration Actions

- Beechie and Bolton (1999) recommend a 5-step strategy for designing restoration actions:
    1. Estimate natural rates of habitat-forming processes;
    2. Assess changes in rates of habitat-forming processes due to land use;
    3. Identify actions required to restore habitat-forming processes;
    4. Evaluate probable improvement in local biological indicator (for each task); and
    5. Prioritize actions based on costs and potential improvement in biological indicator.
- Opportunities for improving egg-to-smolt survival through habitat restoration are high for a few stocks but minimal for others; this disparity in improvement potential likely arises from differences in initial habitat conditions, the geomorphic and land use settings of watersheds, and the naturally high variability in egg-to-smolt survival in populations. The potential for reductions in survival due to reduced habitat quality is great for all populations (McHugh 2003).
- The model described in McHugh (2003) can be useful to managers concerned with evaluating recovery options involving freshwater spawning and rearing habitat restoration:
    - The overall survival benefit of alternative habitat restoration strategies can be evaluated by coupling egg-to-smolt survival predictions made using a model for early life history stages with a total life cycle model to compute relevant population growth parameters. Knowledge of population growth rates under different management scenarios could better enable managers in selecting the best recovery strategy.
    - Such a combined model can be used to prioritize restoration activities within watersheds - there is a need for an objective tool for identifying areas within high-priority watersheds, where localized restoration activities could provide the greatest survival benefit to stocks in question.
- The construction of full-width structures resulted in the creation of habitat suitable for rearing of juvenile coho salmon during the summer (Nickelson et al. 1992). This demonstrated that the type of habitat preferred by a species and the availability of that habitat throughout the year must be

considered when planning habitat enhancement. Creation of suitable summer habitat may not create suitable winter habitat. Imitating the natural habitat preferred by the species of interest and that is in shortest supply will likely be successful in increasing production. Nickelson et al. concluded that the development of off-channel habitat has the greatest potential to increase production of wild coho salmon smolts in Oregon coastal streams.

- Paulsen and Fisher (2001) found that increasing road density is associated with lower overwinter survival of spring-summer chinook. Their analysis suggests that road-building and associated land-use activities in the Snake River region may have a detrimental effect on the survival of juvenile chinook salmon.
- Adaptive management (evaluation of restoration concurrently with the restoration effort of creating large woody debris and off-channel ponds) allowed immediate feedback before finalizing designs (Reeves et al. 1997).
- Successful restoration is dependent on restoring in-channel and upslope conditions, particularly in steep terrain where floods can cause severe damage to stream channels (Reeves et al. 1997).
- Roni and Quinn's (2001) results provide strong evidence that artificially placed LWD leads to significantly higher densities of juvenile coho in summer and winter and higher densities of cutthroat and steelhead during winter, particularly at sites deficient in wood to begin with. There are far fewer studies for chinook. The study was not designed to determine the effectiveness of individual projects but it does provide insight into factors that make projects successful. The focus was on forested sites — urbanized and agricultural areas may be different.
- It is important to consider that high densities of woody debris in the stream channel can negatively affect juvenile coho salmon abundance just as absence can. Giannico (2000) indicates that open foraging areas interspersed with woody debris and small hydrological structures (waterfalls) characterize the summer habitat that coho prefer.
- Work by Solazzi et al. (2000) found that the key to increased coho salmon smolt abundance was increased overwinter survival. Their results are specific to the particular type of habitat created and should not be interpreted as a general justification for all types of instream habitat restoration
- The presence of salmon carcasses and eggs from spawning salmon increases the growth rates, body mass and improves condition factors of salmonids (Wipfli et al. (2003), Bilby et al. (1998)). Because biomass provided by spawning salmon appears to increase productivity of multiple trophic levels in streams, maintaining this subsidy in freshwater appears to be important for sustaining fish production. Restoring and protecting salmon stocks may have as much to do with restoring nutrients, food abundance, and nutrition through generous escapements as restoring habitat, fish passage and genetic diversity (Wipfli et al. (2003)).
- Manipulation of inorganic nutrient concentrations to increase primary production can be a useful technique to increase fish growth in nutrient deficient streams (Johnston et al. (1990)). Increases in steelhead and coho fry sizes may have important effects on smolt output due to overwinter survival increasing with fry size. Increased smolt numbers and size are likely to increase adult returns since smolt-to-adult survival increases with smolt size in steelhead (Ward and Slaney 1988) and in coho (Hagar and Noble 1976).
- Based on the relationship between pink salmon and coho salmon and the potential for interactions with other salmonid species, it is obvious that decisions regarding spawner escapement levels for one species need to consider the impacts on, and interactions with, other species. There is a need to further study the relationship between nutrient level in streams and resultant fish populations. The relationships between fish production and development in a basin needs to be evaluated so resource management and utilization decisions can be made which will integrate the entire ecosystem rather than isolate each piece with decisions made in a vacuum. (Michael 1995)

- Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed. (Roni et al. 2002)
- Bayley (2002) provides the following recommendations on how to proceed in designing a long-term monitoring program to improve understanding of the responses of salmonids to habitat changes.

> "Future monitoring surveys should take advantage of existing, comparable fish sample information, providing that the information contributes to a design that incorporates current or planned contrasts between basins with extensive habitat restoration (treatments) and those with unchanged habitat (controls). Essential components of future validation monitoring surveys are as follows:
>
> 1. Reassess existing long-term and basin-wide, short-term data sets with repeatable protocols, and identify drainage basins that have contrasts in degree of habitat restoration (with or without existing fish samples). Utilize these sources in conducting components 2 and 3.
> 2. Develop simulation models of cost-limited, alternative fish sampling designs that incorporate empirical variances and biases, to provide a quantitative template for recommendation 3.
> 3. Develop long-term (decades) monitoring programs that treat a series of basins and wild fish populations as natural experiments along a gradient of habitat restoration. The sampling design should track metapopulations or extensive populations and physical changes within and among watersheds down to reach or segment scales. Because seeding and early survival variation can change the habitat variables that are limiting, a measure of year-to-year reproduction success of key salmonids (at least down to watershed scales) should be concurrent with juvenile and adult monitoring of all fish species. Reach-scale, stratified random fish sampling effort using protocols that are bias-correctable should be divided between mid-summer and winter periods. Spatial strata should be watersheds expecting/not expecting significant human alteration, litho-geomorphological zones within watersheds, and stream sizes."

Table 6.2. Summary of responses by fish performance measure.[9]

Action	Survival	Growth	Abundance	Reference
Alteration of grazing practices (11 paired stream reaches, grazed vs. exclosed/ungrazed)			Shrub, herbaceous cover ⇑ Vegetation species richness/diversity ⇑ Wetland species composition dominance ⇑ Bare ground ⇓ Channel depth ⇑ Channel width ⇓ Pool area ⇑ Young of the year salmonids ⇑ Adult salmonids ⇔ Warm water fishes ⇓ The above benefits ⇑ through time and may not be fully realized until decades after exclusion. ⇑ vegetation is likely to positively affect other ecosystem processes such as allocthonous inputs and sediment retention, thereby affecting the aquatic biota, **water quality** and stream geomorphology.	Kauffman et al. (2002)
Reduction of sediment through road closures	Coho parr survival – marked age-0; 13% higher in pristine watersheds in wilderness areas than in dry watersheds subjected to forestry operations. Parr reared in areas of low density had significantly higher overwinter survival than in areas of high road density.			Paulsen and Fisher (2001)
Enhanced levels of marine–derived nutrients	coho smolt production per spawner ⇑ 50%	mean smolt length ⇑ 30% but only in 1 of 2 years		Ward et al. (2002)
		Condition factor of age 0^+ steelhead ⇑ in Salmon Creek; juvenile coho condition ⇑ in A400 Creek	Density of all ⇑ at A400 Creek; juvenile coho ⇔ at A400 and Wasberg creeks; age 0^+ steelhead ⇑ at A400 Creek; age1^+ 10X ⇑ at A400 Creek.	Bilby et al. (1998)

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[9] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Action	Survival	Growth	Abundance	Reference
		Growth (mass and fork length) ⇑ in carcass-enriched channels for age-0 coho in artificial stream In natural stream, Cutthroat trout growth ⇑ in fall and spring (24X from Sept. – Oct., 2.5X from Sept. – May). Growth of control fish was only 2X higher in winter (Oct – May). Dolly Varden growth ⇑ in fall 5X.		Wipfli et al. (2003)
		Juvenile coho and steelhead weights ⇑ during all treatment years except coho fry during 1983 when nutrient concentrations were below target values. Steelhead mean weight ⇑ 95% ; coho mean weight ⇑ 40%		Johnston et al. (1990)
Active stream restoration (includes instream structures)			Significant ⇑ in spring coho smolts in Porter Creek, WA due to LWD; no significant difference for spring sampled juvenile coho, steelhead or trout fry; significant ⇑ in winter juvenile coho & no significant difference in steelhead or trout fry; no significant difference for summer sampled juveniles. Significant ⇑ in spring juvenile chinook in Nechako River, BC due to LWD Significant ⇑ in spring and summer juvenile steelhead in Steamboat Creek, OR due to LWD and boulders. Significant ⇑ in summer juvenile coho in Nestucca River, OR due to LWD; no significant response from juvenile cutthroat, steelhead and trout fry. Significant ⇑ in summer juvenile coho and cutthroat in East Fork Lobster Creek, OR due to boulders and gabion; no significant response from juvenile steelhead and trout fry.	Roni et al. (2002)[10] (various studies reviewed)
	coho overwinter survival rate ⇑ by 150% in one treatment and 250% in another		⇑ coho salmon smolt abundance by 200% in both treatments.	Solazzi et al. (2000)

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[10] Sources: Ward and Slaney (1981); Moreau (1984); House and Boehne (1986); House et al. (1989); V. A. Poulin and Associates (1991); Slaney et al. (1994); Chapman (1996); House (1996); Cederholm et al. (1997)

Action	Survival	Growth	Abundance	Reference
			Rainbow & cutthroat fry and chinook parr ⇑ in 2001 compared to previous years but not statistically significant. Chinook parr densities increased gradually since 1998. Age 0 chinook density - NS diff. during and after restoration relative to control. Large variability, no strong trends in redd counts/	Clayton (2002)
			Food and the interaction between food and fine woody debris (FWD) had a strong effect on the distribution of juvenile coho salmon among pools.	Giannico (2000)
Improved riparian conditions: - Active stream restoration (includes instream structures)			Density of juvenile coho in pools with brush sig. > those without (dammed pools but not plunge pools) Addition of brush ⇑ density in constructed dammed pools in winter to a level not sig. different from natural pools.	Nickelson et al. (1992)
		Coho juveniles ⇑ 14.8% longer (significant) Coho smolts departing ⇑ 6.8% longer (not significant) Steelhead YOY ⇑ 12.5% in length (sig.) Age-1 ⇑ 4.1% (sig.)	Coho juveniles ⇓41.8% (not significant) Coho smolts departing ⇑ 12.7% (not significant) Steelhead YOY ⇓ 53.2% (sig.) age-1 ⇑ 11.7% (NS) smolts ⇑ 27.7% (NS)	Reeves et al. (1997)
		No significant difference in lengths of treatment and reference juvenile coho, cutthroat and steelhead trout and trout fry, in either summer or winter.	Juvenile coho was 1.8 and 3.2 times higher in treated reaches during summer and winter. Cutthroat and steelhead age-1+ densities were 1.70 and 1.73 higher than controls in winter (respectively) but did not differ from controls in summer.	Roni and Quinn (2001)
Other actions (e.g. not differentiated)				

7.0 Summary of Lessons Learned

7.1 General lessons from other studies regarding experimental design

A great deal of literature exists that provides valuable lessons for the design of prospective effectiveness monitoring programs and we summarize important points here:

- **Section 7.1.1** Summary of important lessons from our review of 'blue ribbon' studies (Chapter 6) for the design of habitat restoration experiment.
- **Section 7.1.2** A review of recent comprehensive literature syntheses of design principles applicable to effectiveness monitoring programs in the Columbia River basin and the Pacific Northwest.
- **Section 7.1.3** A general overview of quantitative statistical power results from studies oriented towards the prospective design of experimental or monitoring programs targeted at detecting effects on salmonid populations. We provide a tabular summary of representative results from these studies (Table 7.1).
- **Section 7.1.4** A summary 'toolbox' of techniques and methods useful for the quantitative related to the design and evaluation of effectiveness evaluation programs.

7.1.1 Factors to consider in designing restoration actions from our review of 'blue ribbon' studies (Chapter 6)

The following bullets list the major lessons learned from our review of blue ribbon studies (Chapter 6) that are relevant to the design of prospective effectiveness studies.

- Beechie and Bolton (1999) recommend a 5-step strategy for designing restoration actions:
    1. Estimate natural rates of habitat-forming processes;
    2. Assess changes in rates of habitat-forming processes due to land use;
    3. Identify actions required to restore habitat-forming processes;
    4. Evaluate probable improvement in local biological indicator (for each task); and
    5. Prioritize actions based on costs and potential improvement in biological indicator.
- Opportunities for improving egg-to-smolt survival through habitat restoration are high for a few stocks but minimal for others; this disparity in improvement potential likely arises from differences in initial habitat conditions, the geomorphic and land use settings of watersheds, and the naturally high variability in egg-to-smolt survival in populations. The potential for reductions in survival due to reduced habitat quality is great for all populations (McHugh 2003).
- The model described in McHugh (2003) can be useful to managers concerned with evaluating recovery options involving freshwater spawning and rearing habitat restoration:
    - The overall survival benefit of alternative habitat restoration strategies can be evaluated by coupling egg-to-smolt survival predictions made using a model for early life history stages with a total life cycle model to compute relevant population growth parameters.

Knowledge of population growth rates under different management scenarios could better enable managers in selecting the best recovery strategy.

  - Such a combined model can be used to prioritize restoration activities within watersheds - there is a need for an objective tool for identifying areas within high-priority watersheds, where localized restoration activities could provide the greatest survival benefit to stocks in question.

- The construction of full-width structures resulted in the creation of habitat suitable for rearing of juvenile coho salmon during the summer (Nickelson et al. 1992). This demonstrated that the type of habitat preferred by a species and the availability of that habitat throughout the year must be considered when planning habitat enhancement. Creation of suitable summer habitat may not create suitable winter habitat. Imitating the natural habitat preferred by the species of interest and that is in shortest supply will likely be successful in increasing production. Nickelson et al. concluded that the development of off-channel habitat has the greatest potential to increase production of wild coho salmon smolts in Oregon coastal streams.
- Paulsen and Fisher (2001) found that increasing road density is associated with lower overwinter survival of spring-summer chinook. Their analysis suggests that road-building and associated land-use activities in the Snake River region may have a detrimental effect on the survival of juvenile chinook salmon.
- Adaptive management (evaluation of restoration concurrently with the restoration effort of creating large woody debris and off-channel ponds) allowed immediate feedback before finalizing designs (Reeves et al. 1997).
- Successful restoration is dependent on restoring in-channel and upslope conditions, particularly in steep terrain where floods can cause severe damage to stream channels (Reeves et al. 1997).
- Roni and Quinn's (2001) results provide strong evidence that artificially placed LWD leads to significantly higher densities of juvenile coho in summer and winter and higher densities of cutthroat and steelhead during winter, particularly at sites deficient in wood to begin with. There are far fewer studies for chinook. The study was not designed to determine the effectiveness of individual projects but it does provide insight into factors that make projects successful. The focus was on forested sites — urbanized and agricultural areas may be different.
- It is important to consider that high densities of woody debris in the stream channel can negatively affect juvenile coho salmon abundance just as absence can. Giannico (2000) indicates that open foraging areas interspersed with woody debris and small hydrological structures (waterfalls) characterize the summer habitat that coho prefer.
- Work by Solazzi et al. (2000) found that the key to increased coho salmon smolt abundance was increased overwinter survival. Their results are specific to the particular type of habitat created and should not be interpreted as a general justification for all types of instream habitat restoration
- The presence of salmon carcasses and eggs from spawning salmon increases the growth rates, body mass and improves condition factors of salmonids (Wipfli et al. (2003), Bilby et al. (1998)). Because biomass provided by spawning salmon appears to increase productivity of multiple trophic levels in streams, maintaining this subsidy in freshwater appears to be important for sustaining fish production. Restoring and protecting salmon stocks may have as much to do with restoring nutrients, food abundance, and nutrition through generous escapements as restoring habitat, fish passage and genetic diversity (Wipfli et al. (2003)).
- Manipulation of inorganic nutrient concentrations to increase primary production can be a useful technique to increase fish growth in nutrient deficient streams (Johnston et al. (1990)). Increases in steelhead and coho fry sizes may have important effects on smolt output due to overwinter survival increasing with fry size. Increased smolt numbers and size are likely to increase adult

returns since smolt-to-adult survival increases with smolt size in steelhead (Ward and Slaney 1988) and in coho (Hagar and Noble 1976).

- Based on the relationship between pink salmon and coho salmon and the potential for interactions with other salmonid species, it is obvious that decisions regarding spawner escapement levels for one species need to consider the impacts on, and interactions with, other species. There is a need to further study the relationship between nutrient level in streams and resultant fish populations. The relationships between fish production and development in a basin needs to be evaluated so resource management and utilization decisions can be made which will integrate the entire ecosystem rather than isolate each piece with decisions made in a vacuum. (Michael 1995)
- Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed. (Roni et al. 2002)
- Bayley (2002) provides the following recommendations on how to proceed in designing a long-term monitoring program to improve understanding of the responses of salmonids to habitat changes.

> "Future monitoring surveys should take advantage of existing, comparable fish sample information, providing that the information contributes to a design that incorporates current or planned contrasts between basins with extensive habitat restoration (treatments) and those with unchanged habitat (controls). Essential components of future validation monitoring surveys are as follows:
>
> 1. Reassess existing long-term and basin-wide, short-term data sets with repeatable protocols, and identify drainage basins that have contrasts in degree of habitat restoration (with or without existing fish samples). Utilize these sources in conducting components 2 and 3.
> 2. Develop simulation models of cost-limited, alternative fish sampling designs that incorporate empirical variances and biases, to provide a quantitative template for recommendation 3.
> 3. Develop long-term (decades) monitoring programs that treat a series of basins and wild fish populations as natural experiments along a gradient of habitat restoration. The sampling design should track metapopulations or extensive populations and physical changes within and among watersheds down to reach or segment scales. Because seeding and early survival variation can change the habitat variables that are limiting, a measure of year-to-year reproduction success of key salmonids (at least down to watershed scales) should be concurrent with juvenile and adult monitoring of all fish species. Reach-scale, stratified random fish sampling effort using protocols that are bias-correctable should be divided between mid-summer and winter periods. Spatial strata should be watersheds expecting/not expecting significant human alteration, litho-geomorphological zones within watersheds, and stream sizes."

7.1.2 A review of recent comprehensive literature syntheses of design principles applicable to effectiveness monitoring programs in the Columbia River basin and the Pacific Northwest

Several literature syntheses have been produced concurrent with our study. Their focus is the design of prospective effectiveness monitoring of habitat actions intended to increase salmonid survival rates. They provide excellent overviews of monitoring and experimental design issues in the context of the Columbia River basin and Pacific Northwest. In this section we provide summaries and extracts to highlight important points from some of these sources to highlight interesting design considerations. We encourage the reader to pursue each in more detail.

Monitoring Strategy for the Upper Columbia Basin (Hillman 2003)

Hillman (2003) provides an excellent summary of recommended experimental designs for Effectiveness Monitoring, which we quote below:

> **“Effectiveness Monitoring**—Because effectiveness monitoring attempts to explain cause-and-effect relationships (e.g., effect of a tributary project on fish abundance), it is important to include as many elements of valid statistical design as possible. An appropriate design recommended by the Action Agencies/NOAA Fisheries (2003), ISAB (2003), and WSRFB (2003) is the Before-After-Control-Impact or BACI design (Stewart-Oaten et al. 1986, 1992; Smith et al. 1993). This type of design is also known as a Control-Treatment Paired or CTP design (Skalski and Robson 1992), or Comparative Interrupted Time Series design (Manly 1992). Although names differ, the designs are essentially the same. That is, they require data collected simultaneously at both treatment and control sites before and after treatment. These data are paired in the sense that the treatment and control sites are as similar as possible and sampled simultaneously. Replication comes from collecting such paired samples at a number of times (dates) both before and after treatment. Spatial replication is possible if the investigator selects more than one treatment and control site.[11] The pretreatment sampling serves to evaluate success of the pairings and establishes the relationship between treatment and control sites before treatment. This relationship is later compared to that observed after treatment.
>
> The success of the design depends on indicator variables at treatment and control sites “tracking” each other; that is, maintaining a constant proportionality. The design does not require exact pairing; indicators simply need to “track” each other. Such synchrony is likely to occur if similar climatic and environmental conditions equally influence sampling units. Precision of the design can be improved further if treatment and control stream reaches are paired according to a hierarchical classification approach (see Section 5). Thus, indicator variables in stream reaches with similar climate, geology, geomorphology, and channel types should track each other more closely than those in reaches with only similar climates.
>
> It is important that control and treatment sites be independent; treatment at one site cannot affect indicators in another site. The NRC (1992) recommends that control data come from another stream or from an independent reach in the same stream. After the pretreatment period, sites to be treated should be selected randomly.[12] Randomization eliminates site location as a confounding factor and removes the need to make model-dependent inferences (Skalski and Robson 1992). Hence, conclusions carry the authority of a “true” experiment and will generally be more reliable and less controversial. Post-treatment observations should be made simultaneously in both treatment and control sites.

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

[12] As noted later, in most cases treatments will not be randomly assigned to sites. Thus, the studies will be “causal-comparative,” rather than “true” experimental studies.

> Several different statistical procedures can be used to analyze BACI designs. Manly (1992) identified three methods: (1) a graphical analysis that attempts to allow subjectively for any dependence among successive observations; (2) regression analysis, which assumes that the dependence among successive observations in the regression residuals is small enough to ignore; and (3) an analysis based on a time series model that accounts for dependence among observations. Cook and Campbell (1979) recommend using autoregressive integrated moving average models and the associated techniques developed by Box and Jenkins (1976). Skalski and Robson (1992) introduced the odds-ratio test, which looks for a significant change in dependent variable proportions in control-treatment sites between pretreatment and post-treatment phases. A common approach, recommended by WSRFB (2003), includes analysis of difference scores. Differences are calculated between paired control and treatment sites. These differences are then analyzed for a before-after treatment effect with a two-sample t-test, Welch modification of the t-test, or with nonparametric tests like the randomization test, Wilcoxon rank sum test, or the Mann-Whitney test (Stewart-Oaten et al. 1992; Smith et al. 1993). Choice of test depends on the type of data collected and whether those data meet the assumptions of the tests.
>
> In some cases, the investigator will not be able to randomly assign treatments to sampling locations. Despite a lack of randomization of treatment conditions, if the treatment conditions are replicated spatially or temporally, a sound inference to effects may be possible. Although valid statistical inferences can be drawn to the sites or units, the authority of a randomized design is not there to "prove" cause-effect relationships. Skalski and Robson (1992) describe in detail how to handle BACI designs that lack randomization."

Research, Monitoring and Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion (Jordan et al. 2003)

The federal Research, Monitoring and Evaluation (RME) Plan developed by NOAA and the Action Agencies (Jordan et al. 2003; pages 91-93) notes that action effectiveness studies have the challenge that treatments are rarely randomly assigned to sites. As a result there may be hidden biases in the results due to site differences that could be erroneously inferred to be the result of the treatment. Jordan et al. propose applying the principles of observational statistics (Rosenbaum 2002) to deal with these challenges:

- generate as many alternative hypotheses as possible;
- collect all of the classification variables that might be correlated with each hypothesis; and
- carefully match treatment and control sites, checking to ensure that treatments are free from hidden bias

These principles make good sense, and we have endeavored to apply them to the extent possible in the case studies presented in chapters 2 to 5. However, it is more feasible to rigorously apply these principles at reach to moderate tributary scales than at the larger spatial scale of rivers and sub-basins. At these larger spatial scales there will likely not be enough rivers / sub-basins within the same general ecoregion to get treatment-control matches that are free from hidden bias. Thus at larger spatial scales it will not be possible to entirely eliminate site differences as factors contributing to survival differences between treatment and control sites.

The RME plan (Jordan et al. 2003, pg. 93–94) also makes some helpful recommendations for how to assign sampling sites within a watershed subjected to a variety of restoration actions (Figure 7.1).

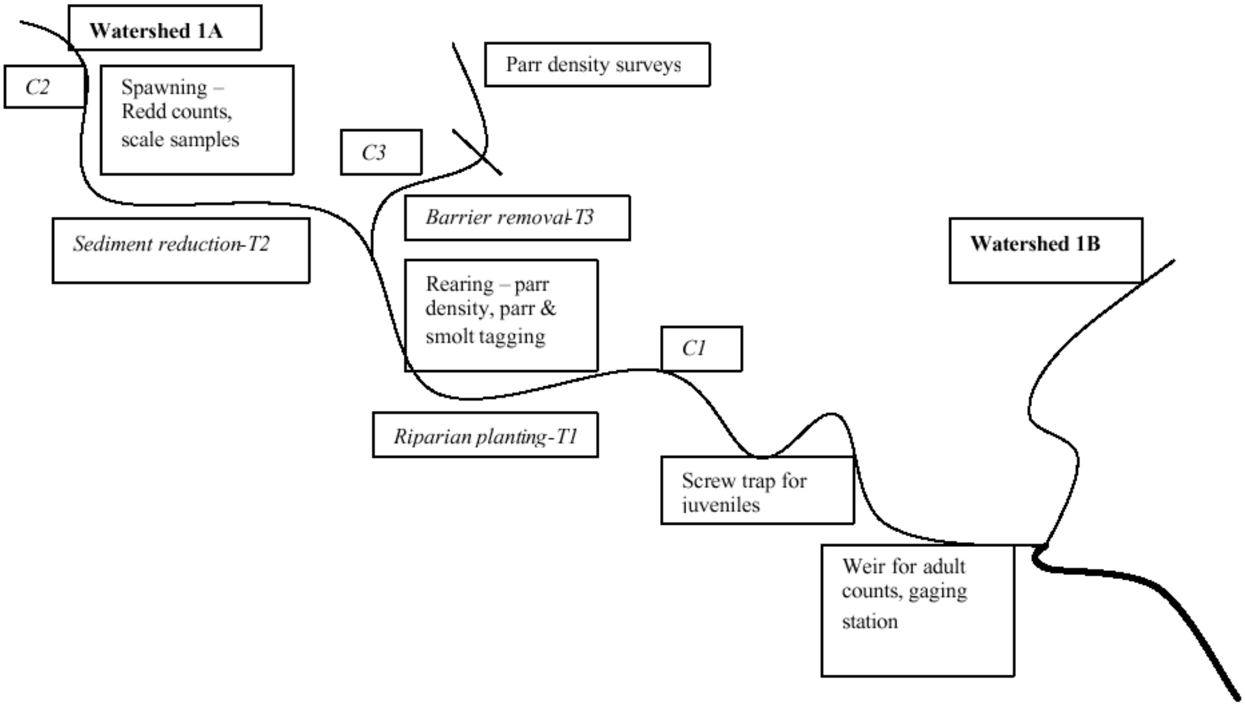

Figure 7.1. Example watershed showing layout of habitat actions and sampling sites. Monitoring sites are in regular type; action and control locations are italicized. "T(n)" denotes sites for intensive monitoring at treatment sites; "C(n)" similar monitoring sites for control sites. See text for further explanation. Source: NOAA and Action Agencies RME Plan, Jordan et al. (2003)

The example watershed has three actions: riparian planting in a juvenile rearing reach, sediment reduction in a spawning reach, and barrier removal on a small tributary. Both a treatment watershed (1A) and a control watershed (1B) would be monitored for five years prior to restoration treatments and five years afterwards, at six reaches / watershed. Sample sites would include:

- a gauging location for measuring flow, water temperature, and water chemistry is located at the bottom of the system;
- adult counts in summer/fall at a weir at the bottom of the system (lower right);
- annual redd counts and carcass surveys (for age, sex and hatchery origin) in the spawning reach near the top (upper left) of the system;
- estimates of juvenile emigrants (parr in summer, smolts in spring) at a screw trap above the weir; and
- PIT-tagging of all captured fish and re-release of some fish above the trap to estimate trap efficiency and emigrant abundance, with subsequent detection at mainstem dams to estimate parr to smolt survival.

As explained in Jordan et al. (2003), this form of design could be used to test various hypotheses across a number of spatial scales, using BACI statistical methods. These hypotheses could include:

H1: sediment in spawning gravels has decreased at the single treatment site compared to both pre-treatment conditions and the control sites in watersheds 1A and 1B;

H2: parr density has increased at the riparian treatment site compared to both pre-treatment conditions and the control sites in watersheds 1A and 1B;

H3: parr to smolt survival has increased for watershed 1A compared to pre-treatment conditions and compared to watershed 1B; and

H4: smolts per spawner has increased for watershed 1A compared to pre-treatment conditions and compared to watershed 1B.

7.1.3 Summary of quantitative estimates of statistical power for different monitoring and experimental designs for different species

It is commonly known that sample size, either in terms of the duration of monitoring programs, or the number of systems monitored, can increase statistical power (e.g., Peterman 1990), an important point which our review of blue ribbon studies emphasizes (Chapter 6). However, this is a generality and does not say specifically for how long one should monitor, or how many sites need to be monitored. While statistical power analysis can help address these important design questions, there may often not be enough information available prior to the onset of a project to do this. However, there are now many examples of power analyses available for salmonid performance measures and monitoring programs. These results may be help provide stronger bounds on the question of "how long" and "how many."

Table 7.1 summarizes results of power analyses for a variety of salmonid monitoring frameworks and performance measures in terms of the number of years or sites required to achieve high statistical power to detect specified changes for a range of experimental and monitoring designs. Several caveats are necessary. The objectives of the listed studies vary and where their focus was not to estimate statistical power we have extracted this information. Additionally, the table is meant to illustrate the range of statistical power associated with these studies and therefore in some cases we have greatly simplified the results. For example, Korman and Higgins (1997) and Parnell et al. (2003) consider statistical power over a range of estimated values for freshwater and marine process error, measurement error, covariance, effect sizes, and monitoring durations. Summaries for each study are provided below.

Another important caveat is that statistical power is not directly comparable between studies because it is has often been calculated for different types of statistical tests. For example, Paulsen and Hinrichsen (2002) and Paulsen and Fisher (2003) calculated statistical power based on a 2-tail t-test and $\alpha = 0.05$, Parnell et al. (2003) used a 2-tail t-test and $\alpha = 0.2$, and Korman and Higgins (1997) used a 1-tail t-test and $\alpha = 0.2$. Statistical power tends to be proportional to α. This suggests that for the latter two studies years would be required to detect effects with 80% probability if α=0.05 were used instead of α=0.2.

Finally, while most of these studies provided information that could be interpreted in terms of the number of years required to achieve high power, the results of Ham and Pearsons (2000) and some results from Roni et al. (2003) cannot. Ham and Pearsons (2000) expressed their results in terms of the detectable effect for a power of 0.9 after 5 years of abundance monitoring and these are the numbers in the 'magnitude of survival change' column. Roni et al. (1993) compared statistical power results for both BA/BACI and extensive post-treatment (EPT) type designs. The BA/BACI power results are provided in terms of number of years of monitoring and effect size, however the EPT designs are based on data from reaches within 30 streams measured only once. Roni et al. (1993) considered EPT designs with and without instream pairing of treatment-control reaches. The results in the 'Number of years to detect with

80% probability' column are for the number of sites that must be monitored to achieve 80% power for the effect size listed in the 'magnitude of survival change' column.

Despite the above caveats, Table 7.1 provides some interesting results.

Nevertheless, some Table 7.1 provides some interesting results:

- BACI is not always better than BA; the results depend upon the degree of covariation in the performance measures between streams (e.g., see the results from Roni et al. 1993 and Parnell et al. 2003).
- Spatial replication can greatly reduce the number of years required to detect effects for BACI type designs (Paulsen and Hinrichsen 2001, Paulsen and Fisher 2003).
- Parr-to-smolt survival rates based on PIT tagging studies allow for detection of relatively small changes (Paulsen and Fisher 2003).
- For BA/BACI designs with fewer spatial replicates and less direct measures of survival rates it will generally take a long time to detect even relatively large changes with high power.

Table 7.1. Summary of the number of years or sites required to achieve 80% statistical power to detect specified changes in various salmonid performance measures for a range of experimental and monitoring designs. ('*' Magnitude of change in performance measure for Ham and Pearsons (2000) are detectable impacts as % of baseline abundance at a power of 0.9). 'BA' = Before-After monitoring. BACI = Before-After-Control-Impact monitoring. 'EPT' = extensive post-impact monitoring. 'Trend' = trend monitoring.

Authors	Spp/# streams	Performance Measure	Magnitude of change in performance measure	Length of time series (years)	Spatial Scale of information	Design (e.g., BA, BACI, etc.)	Number of years to detect with 80% probability
Parnell et al. 2003	CM 1 stream	Fry and Spawner abundance	-25% +75%	14-31	tributary	BA	-ve: >12/12 +ve: >12/12 (2 tail, $\alpha = 0.2$)
Parnell et al. 2003	CO 1-2 streams	Smolt abundance	-75% -75%	9-26	tributary	BA/BACI	-ve: >12/12 +ve: 4/12 (2 tail, $\alpha = 0.2$)
Paulsen and Hinrichsen 2002	CH 7 streams	Recruits per spawner and Ricker productivity	A1 +300% A2 +300% A3 +100% A4 +100%	>40	tributary	BA all On BA On/Off BACI BA all On	A1: 5 A2: 10 A3: 3 A4: >20 (2 tail, $\alpha = 0.05$)
Paulsen and Fisher 2003	CH 8 streams	Parr-to-smolt survival rates	+30% +50%	10	tributary	BACI	30% : 7 50% : 3 (2 tail, $\alpha = 0.05$)
Korman and Higgins 1997	CH 1-2 streams	Spawning escapement	-200%	38	tributary	BA BACI	15-40 17-10 (1-tail, $\alpha = 0.2$)
Maxell 1999	BT 12 streams	Redd counts	-50% to +50%	16-19	tributary	Trend	6 to >15 (2 tail, $\alpha = 0.05$) 4 to >15 (1 tail, $\alpha = 0.2$)

Authors	**Spp/# streams**	**Performance Measure**	**Magnitude of change in performance measure**	**Length of time series (years)**	**Spatial Scale of information**	**Design (e.g., BA, BACI, etc.)**	**Number of years to detect with 80% probability**
Ham and Pearsons 2000	Sp CH Fall CH SH BT	abundance	-55% -79% -59% -76%	16 16 16 3	mainstem/ tributary	BA	*5 years (1-tail t-test, α = 0.1)
Clayton 2002	CH 0+ 2 control and 1 treatment reach	density	+171% change	12 (pre restoration)	reach	BACI	5 (post restoration) (1-tailed t-test, α = 0.1)
Roni et al. 1993 (their Figure 3)	CO parr CO smolt SH 1+ SH smolt 1-2 streams	abundance	-100%	8	tributary	BA, BACI	20, 10 >70, >70 12, 25 85, 50 (2-tailed t-test, a =0.05)
Roni et al. 1993 (their Figure 4)	CO parr CO presmolt SH parr SH presmolt 30 streams	abundance	+100%	30 treatment-control stream pairs sampled once	reach	EPT (paired/ unpaired)	12/50 sites 15/60 sites 8/60 sites 10/45 sites (2-tailed t-test, a =0.05)

Maxell (1999): A power analysis on the monitoring of bull trout stocks using redd counts.

Maxell conducted a prospective power analysis on a proposed monitoring program using the observed variance for trends of bull trout redd counts in tributaries of the North and South forks of the Flathead River and Swan River subbasins, Montana. He found that with standard significance levels and two-tailed testing procedures the yearly variation in redd numbers limits the power of detecting less than 50% of changes in population size per generation to less than 0.8 during the first 15 years of the monitoring program. Based on these results he recommended: 1) reducing the level of measurement error involved in redd counts; 2) using levels of statistical power that balance the risks of committing Type I and II errors; 3) using a one tailed testing procedures for identifying population declines during initial an other critical years of a monitoring program; 3) and exploring the use of other methods of monitoring.

***Paulsen and Fisher** (2003): Statistical power of experiments, used parr-to-smolt survival rate estimates*

Using 10 years of parr-to-smolt survival data from eight streams in the Columbia River basin, Paulsen and Fisher (2003) explored the statistical power of alternative BACI experimental designs to detect multiplicative increases in parr-to-smolt survival rates that ranged from 30% to 110%. They compared the power of the best and worst models selected through an information-theoretic model selection process and found that models with higher information-theoretic weights were more powerful than less plausible models. For the best model, there was a power of 0.80 to detect a multiplicative survival rate increase of 30% within 3-7 years, depending upon whether 3 or 1 treatment streams were used, respectively. They found that models using juvenile survival were substantially more powerful than models using spawner–recruit data for the same stocks (results shown in Paulsen and Hinrichsen 2002).

***Paulsen and Hinrichsen** (2002): Statistical power of management experiments, used recruit per spawner data.*

Paulsen and Hinrichsen (2002) used a retrospective-prospective modeling approach to explore, among other things, the statistical power of 4 types of design to detect increases in overall productivity resulting from management actions. The main models were parameterized using 40 years of spawner-recruit data for 7 spring-summer chinook index stocks in the Columbia River basin. There were four base experimental designs: A1 was a 'do everything possible' approach applied to all stocks. A2 was the 'do everything possible' approach, with actions turned 'On' and 'Off' in alternate years. A3 was a treatment-control approach for testing the effect of nutrient supplementation in freshwater rearing areas (e.g., carcass placement); there were four treatment and three control streams. A4 was a nutrient action like action A3, but without controls; all streams were treated. Each of the four designs was simulated over 1 to 20 years and statistical power was calculated at the end of each period (2-tailed tests, $\alpha = 0.05$). The simulated effect sizes were derived in two ways. For A1 and A2, the effect size was derived from estimates of common year effects during the period 1957-1966, believed to be a good period (good ocean conditions, fewer dams). For A3 and A4, which focus on freshwater effects, the effect size is based on parr-to-smolt survival and spawner-to-smolt survival analyses. The assumed effect sizes were quadruple and double base conditions for A1/A2 and A3/A4 respectively. 'Before' information is used for all designs, but only A3 is a BACI type design.

***Parnell et al.** (2003)*

Quantitative evaluation of the statistical and cost performance of alternative salmonid monitoring design options in support of the Cheakamus River Water Use Plan, British Columbia, Canada. Stakeholder consultations for British Columbia Hydro's Cheakamus River Water Use Plan identified the need to monitoring fish populations to reduce uncertainty about the impact of changes in the flow regime on salmonid populations. A two-stage life cycle model was used to evaluate the statistical performance of several monitoring designs for detecting changes of interest to stakeholders that represented either a -25% or a +75% change in survival related to habitat conditions (H index) for chum and coho salmon. Model parameterization was based on a meta-analysis of multiple spawner-recruit and fry or smolt per spawner data sets for both species. The parameters estimated included freshwater and marine process error, productivity and density dependence and the degree of covariance amongst stocks. The results were used to specify the range of parameters used in modeling. Each monitoring design consisted of a particular duration and pattern of Before and After monitoring, either status quo or enhanced sampling methods, with or without a control stream (BA or BACI), for three performance measures: mean smolt (or fry) abundance, mean spawner abundance, or residuals from fits of smolt (or fry) per spawner relationships. Bootstrap analysis was used to estimate the statistical performance of each design in terms of average observed H, the 10th to 90th percentiles of H, bias (observed-actual H), and statistical power to detect H at $\alpha = 0.05$. Example results are shown in Figure 7.2.

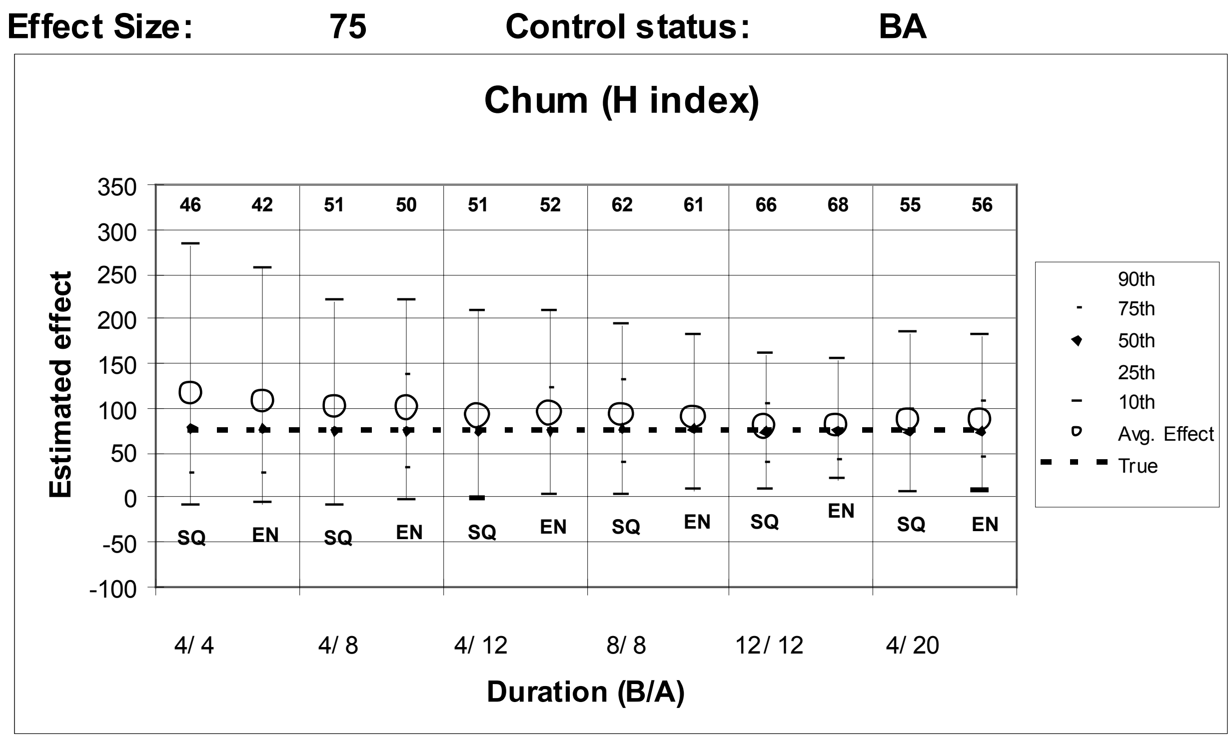

Figure 7.2. Chum spawner-fry H index results for the +75% effect size. The y-axis is the estimated effect size. The x-axis is the total duration and pattern of before/after monitoring in years – sum the two numbers for total duration (e.g., 4/4 = 8 years total duration). The vertical lines that span the figure separate the two results for each duration; SQ is status quo monitoring method, EN is enhanced monitoring method. "Control status:" at the top right of the figure indicates whether the simulation included monitoring a control (BACI) or did not monitor a control (BA) system. The short vertical lines show the distribution of 1500 estimated effects in terms of the 10th, 25th, 50th, 75th, and 90th percentiles of. Each short line represents a single monitoring design. The number above each vertical distribution line is the statistical power for that particular design to detect the stated effect size. The dashed horizontal line is the true effect that is simulated and tested for statistically. This value differs between the H and Smolt or Spawner indices. For the H index the true effect is equal to the simulated effect size shown at the top of the graph (e.g. -25% as shown here). However, for smolt and spawner indices, the true effect is converted and expressed in terms of a smolt or spawner equilibrium value. Appendix C.3 provides a detailed explanation of these differences. The hollow circle on each distribution line shows the average estimated effect over the 1500 simulations. (Source: Parnell and Marmorek 2003).

***Korman and Higgins** (1997). Utility of spawner escapement.*

"We provide a quantitative examination of the utility of escapement data for monitoring changes in salmonid populations caused by habitat alterations. We used Monte Carlo simulations to determine the precision, duration of monitoring, and the effect size required to achieve acceptable statistical inferences based on before-after (BA) and before-after-control-impact (BACI) comparisons. There was generally less than a 50% chance of detecting a population response unless the population change was large (more than a twofold increase) or the post-treatment monitoring period long (>10 years). Statistical power was improved by increasing the precision of escapement estimates, but the extent of improvement was dependent on the magnitude of population response to treatment, the duration of monitoring, and the extent of natural variability in abundance. BACI comparisons generally had a 10–15% lower probability of detecting a population change than BA comparisons unless the degree of covariation in survival rates between control and treatment stocks was very strong. Autocorrelation in error, simulating patterns of high and low survival rates over time, generally reduced power by 5–15%. Our results identify the conditions where escapement information can be used to make reliable inferences on salmonid population changes and provides a means for evaluating alternative monitoring designs."

Ham and Pearsons *(2000). Can reduced salmonid population abundance be detected in time to limit management impacts?*

"We evaluated eight populations of native salmonids to determine if rapid, sensitive detection of a reduction in abundance is possible in the Yakima River basin, Washington, where a large-scale test of hatchery supplementation is being conducted. Prospective power to detect impacts to abundance was estimated from 3–16 annual baseline surveys conducted by electrofishing, trapping, or snorkeling. High interannual variation in abundance estimates (CV = 26–94%) prevented detection of small impacts for most taxa. For three taxa, models of environmental and biological influences accounted for between 42 and 49% of temporal variation, increasing our ability to detect impacts of other influences. Detectable impacts for a t test with $\alpha = 0.1$ and $\beta = 0.1$ were >18% for all eight taxa and >54% for four of eight taxa. We suggest that population abundance monitoring may not provide feedback sufficiently sensitive or rapid enough to implement corrective actions that prevent impacts from causing harm or exceeding an acceptable level, especially for rare or highly valued taxa with small acceptable impacts."

Clayton *(2002). Quantitative evaluation of physical and biological responses to stream restoration.*

As part of the Lower Red River Meadow Stream Restoration project in north-central Idaho, a Before-After-Control-Impact monitoring design was implemented to monitor important physical and biological variables (density of age 0 chinook salmon). No statistical difference was found for age 0 chinook density; given the variability in the index, it would have had increase by 171% within 5-years of post restoration monitoring to be detectable with a power of 0.8.

Roni et al. *(2003). Monitoring and evaluating fish response to instream restoration.*

This paper reviews literature on the effectiveness of instream restoration projects for increasing salmonid performance measures and uses data from two recent studies to quantitatively explore the relationship between statistical power and sample size requirements over a range of effect sizes. Using the data of Solazzi et al. (2000) they present charts showing how statistical power varies with duration of monitoring (years) over a 1 to 3 fold increase in abundance for juvenile coho and steelhead for Before-After (BA) and Before-After-Control-Impact designs (BACI). These designs replicate sampling over time. Using the data of Roni and Quinn (2001) they present charts showing how statistical power varies with the number of reaches sampled for an extensive post-treatment design (EPT, replicates in space), with or without treatment-control reaches measured in the same stream, for juvenile coho and steelhead abundance. BA/BACI type designs required 10 to more than 50 years of monitoring to detect a doubling of juvenile salmonid abundance. EPT designs required sampling 20-30 sites to detect a doubling in juvenile coho and steelhead abundance

7.1.4 A toolbox of monitoring designs and analytical methods

Much work has been done in recent years to develop more rigorous monitoring and experimental designs for application in natural systems and to develop the analytical tools, which may be used to draw inferences when there is no formal experimental design. Some of this literature is referenced earlier in Section 7.1. In table 7.1 we present a concise summary of design 'type,' the common name applied to that design type in the monitoring and evaluation literature, the benefit of applying that method, and some applied examples.

Table 7.2. An toolbox of monitoring designs and analytical methods for testing and evaluation of habitat restoration hypotheses.

Type of data/design	Analytical "Toolbox"	Benefit of method	Example references
1. Same metric, measured in control and treatment sites before and after treatment.	"Before-After-Control-Impact" design (BACI).	Reduce confounding, improve inferences about treatment effect.	Bowles and Leitzinger 1991: experimental design and statistical power analysis for salmon supplementation in Idaho streams (multi-agency project), involves monitoring standardized set of response variables using consistent methods in multiple watersheds in Idaho, allowing comparisons among watersheds.
	"Before-After-Control-Impact-Paired series" design (BACIP), Repeated measures (BACIR)	like BACI, plus remove variance due to common environmental effects	Stewart-Oaten et al. 1986: describes basic assumptions of the BACIP model. Osenberg et al. 1994: assessed impact of a nuclear power plant's cooling water release on kelp forests along the Southern California coastline. Green 1993: explores application of repeated measures models to environmental questions.
	Modified BACI	Incorporate multiple controls	Underwood 1994a
	"Staircase" type designs	Detect "transient" effects by initiating treatments at more than one time.	Walters et al. 1988, 1989: estimates "transient" response to management actions (a "time-treatment" interaction); includes treatment and control systems, with treatments initiated at more than one starting time. Method developed to address logical weaknesses of other "single-site" type designs such as the BACIP; works well for watershed restoration situations (Mellina and Hinch 1995). Peters and Marmorek 2000: explored experimental designs for applying carcass fertilization treatments and control (no actions) to 16 streams, including staircase designs. Ward et al. 2001 applied a staircase design to evaluate the benefits of fertilization and/or in-stream structures for steelhead.
2. Same metric measured Before-After treatment, no controls	Intervention analysis	Can detect before / after differences by examining time series; need many data points	Carpenter et al. 1989
3. Same metric measured After treatment only, multiple treatment and controls	Multiple paired treatment-control watersheds	Can detect effects of treatment despite having no before-treatment measures	Keeley and Walters 1994: developed experimental design for BC Watershed Restoration Program, exploring statistical power and expected value of different multiple-watershed designs (varied number of Treatment-Control watershed pairs and the duration of experiment).
4. Same metric, after only, no control	Spatial analyses	Similar systems can serve as "pseudocontrols"	Bradford 1994: Effects of Nechako water diversion on chinook salmon, using escapement data for multiple stocks. Schaller et al. 1999; Deriso et al. 2001: Effects of Snake and Columbia river dams on Snake river chinook salmon.
5. Different, but comparable metrics, still amenable to statistical analysis	Spatial regression models	Use existing spatial information to test hypotheses about the relationship between watershed conditions and response variable of interest.	Sharma and Hilborn 2001: explored coho production in relation to stream and watershed characteristics. Thompson and Lee 2000: explored relationship between landscape level variables and chinook salmon and steelhead parr densities.
	Spatial covariation analyses	Use existing spatial information to evaluate covariation between systems; use to select treatment and control sites.	Botsford and Paulsen 2000: estimated covariation in survival indices for a suite of chinook salmon index stocks in the Columbia River basin. Bradford and Irvine 2000: evaluated the effects of land use, fishing and climate change on coho recruitment.

Type of data/design	Analytical "Toolbox"	Benefit of method	Example references
	Formal Meta-analysis	Combine results of multiple, unrelated, but similar studies to estimate the size of treatment effects.	Osenberg et al. 1999; Fukushima 2001
6. Different metrics only comparable on a qualitative basis	Qualitative assessment of proportion of cases with evidence for/against hypotheses	Provides an indication of consistency of treatment effects.	- used frequently in literature reviews of diverse studies (e.g. Marmorek and Korman 1993)

7.2 Lessons from retrospective and power analyses

This project involved three phases of work (ESSA 2002):

1. Work with a Core Group of habitat experts and managers to scope out a set of testable habitat restoration hypotheses, candidate watersheds and key participants for a workshop.
2. Identify pilot watersheds with good potential for testing these hypotheses retrospectively, using historical data. Begin gathering relevant data for these watersheds at a workshop with 20-25 habitat experts and managers. Continue data assembly after the workshop and compile these data into a database.
3. Explore statistical approaches towards analyzing the effects of restoration 'treatments' at nested spatial scales across multiple watersheds. Identify existing constraints to testing hypotheses and opportunities to overcome these constraints through improved experimental designs, monitoring protocols and project selection strategies.

At each phase we have learned some useful lessons, which are outlined below.

7.2.1 We need better information on past and current habitat restoration projects

As stated in Chapter 1, we quickly recognized at our first scoping meeting that the biological data would be the most limiting factor. We therefore focused first on the areas with the best biological data, and then looked upstream for habitat projects and potential treatment/control contrasts. We developed information on past restoration projects from a number of sources (Table 7.3).

Table 7.3. Sources of information on past habitat projects.

Data Sources	Web URL
State and tribal fish agency contacts (Appendix 2)	
Northwest Power Planning Council's (NPPC) Fish and Wildlife Program (F&WP)	www.nwcouncil.org/fw/program/Default.htm
Bonneville Power Administration's (BPA) database of F&WP reports	www.efw.bpa.gov/cgi-bin/FW/publications.cgi
NPPC Subbasin Planning documents for the Clearwater, Salmon, and Grande Ronde/Imnaha basins	www.nwcouncil.org/fw/subbasinplanning/Default.htm
GRMWP and USBWP databases	
US Dept. of Agriculture (USDA) extension offices	
Oregon Watershed Enhancement Board's (OWEB) project database	www.oweb.state.or.us

While there are plans to improve these databases, in their present form it was difficult to answer some very basic questions:

Where are all the projects which implemented a specific type of restoration action?

Knowing this would greatly facilitate effectiveness evaluations, as one could group together similar projects within similar ecoregions. The OWEB database appears to have the capability of sorting projects in this fashion.

Where exactly were the project activities located?

Location information is critical to decide if a project is upstream or downstream of spawning and rearing areas, and therefore could / could not affect survival rates of various life history stages. Second, retrospective analyses often combine information on project locations with biological monitoring data collected for a different purpose. Therefore it's critical to know if the restoration sites were upstream or downstream of juvenile fish monitoring locations (if the latter, they couldn't possibly affect monitored performance measures). Finally, location information is required to help select environmental covariates (ecoregion type, flow and temperature data) appropriate to each site.

Location information is generally not available for the databases on BPA-funded projects. NOAA is beginning to fill in such information for some sub-basins from a variety of sources in the form a habitat project database, but this itself is acknowledged as being quite incomplete for most sub-basins (Steve Katz and Katie Barnass, pers. comm.)

Were restoration actions actually implemented (implementation monitoring)?

Project funding does not ensure actual implementation of project activities. We were very fortunate that in the case of the Yakima fish screens, reports existed with both detailed *implementation monitoring* at all sites and *effectiveness monitoring* at the project scale. This was not the case for most other projects.

Over what period of time was the project implemented?

This is important because the 'survival signal' of a project, if it exists, will be affected by how soon the project begins to change the quantity or quality of fish habitat. Irrigation screening presumably

> has an effect immediately, whereas restoration of streamside vegetation, even if successful, may take several years before it begins to affect stream temperatures and bank erosion. In the absence of this information we implicitly assumed (Chapters 3, 4 and 5) that the survival signal of projects should begin in their first year of implementation (i.e. an off/on signal). Errors in timing could affect the degree to which habitat projects correlate with survival trends.
>
> *Where can one find the habitat or biological data collected for this project, or coincidentally in the same vicinity and time frame as this project?*
>
> Project proponents should be well informed of the data available for the area of their proposed project. A synthesis of such data is a logical first step in an assessment of the factors limiting fish survival or abundance. It would be valuable to use this local knowledge to include contact information, or web references to data sets when submitting restoration proposals.
>
> *What watershed area or length of stream was restored?*
>
> Knowing the scale of the project (e.g. watershed area, length of stream) can help to assess its potential impact, and provide a means of weighting smaller and larger projects in BACI analyses of changes in habitat or biological performance measures.
>
> *What were the intended benefits of the project for fish habitat and populations?*
>
> Project descriptions often state their objectives in quite general terms. Explicit statements of the expected benefits (e.g. 20% improvement in parr to smolt survival) would serve as testable predictions.

A large amount of work is required to overcome the weaknesses of existing habitat project databases. For example, it took 4 person months to compile a reasonably complete inventory of habitat projects in the Clearwater Subbasin (Tim Fisher, pers. comm.). It probably isn't worth doing this work for past projects unless there are habitat data for the restoration sites and/or biological data downstream with which one could assess project effectiveness.

7.2.2 Very few restoration projects have explicitly stated hypotheses and structured monitoring to test them

At our scoping meeting (Feb 2003) and experts workshop (March 2003) we indicated what we were seeking: well-designed adaptive management experiments to test the effects of specific watershed restoration actions on the survival of chinook, steelhead or bull trout in the Columbia Basin. We presented as an example the staircase design implemented by Ward et al. (2002) to test the single and joint effects of fertilization and in-stream structures on steelhead and coho parr abundance and smolt/spawner production on Vancouver Island (Table 7.4).

Table 7.4. Staircase design utilized by Ward et al. (2002), with both spatial and temporal contrasts in treatments of different reaches. There were six treatment reaches and a control watershed (bottom row of figure). Data were analyzed for changes in parr abundance as well as smolt length and survival. As discussed in Section 7.1, the staircase design helps to control for transient year effects due to climate or ocean factors which may confound treatment effects (Walters et al. 1988). Source: adapted from unpublished figure provided by Bruce Ward.

Site	**Year**				
	1	**2**	**3**	**4**	**5**
1. Z2	C	S	S	FS	FS
2. Y2	C	S	FS	FS	FS
3. X	C	F	FS	FS	FS
4. W	C	F	F	FS	FS
5. Y	C	C	FS	FS	FS
6. Z1	C	C	C	FS	FS
7. Waukwass	C	C	C	C	C

Treatments	Control (no treatment)	Structures	Fertilization	Fertilization & Structures
	C	S	F	FS

Unfortunately, there were very few adaptive management experiments looking at the impact of restoration actions on chinook salmon or steelhead within the Columbia River Basin. Only 3 of the 19 blue ribbon studies we examined were adaptive management experiments within the Columbia Basin (Clayton 2002, Kaufmann et al. 2002, Reeves et al. 1997; see Appendix 1 of this report, summarized in Chapter 6). When we widen the net to any studies within the Pacific Northwest,[13] Table 6.1 shows that most of the 'blue ribbon' studies examining action effectiveness pertain to active stream restoration and fertilization, and the majority of these studies apply to coho and steelhead, not chinook or bull trout. Thus for most of the actions of interest under RPA 183, we do not have reliable past information on their effectiveness for chinook or bull trout.

Given the absence of past experimental studies from which to draw inferences, we were forced to use a different approach. We needed to first find biological data (generally collected for other purposes such as status monitoring), then look upstream for potential BACI contrasts in restoration actions, and finally formulate reasonable hypotheses which could be tested with the available data. In this respect we were operating a bit more like historians or archaeologists than good biologists. We were forced to apply the procedures of adaptive management and experimental design in reverse.

7.2.3 It takes a lot of effort to find the project, habitat and biological data required to test restoration hypotheses retrospectively

We were warned at the outset of this project that it would be difficult to find the data we needed. So this lesson is not a surprise. As expected, data collection in this project involved dedicated pursuit of a long chain of contacts, and many phone calls and emails. Occasionally, after much effort by many people (and some good luck) a goldmine spreadsheet would appear with the data that we really needed. From this point on, there was further effort required to determine the sampling methods, which we generally learned

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[13] or Pacific Southwest as viewed from Canada

via unpublished reports or contacts with state and tribal biologists. We checked whether there were any years in which unusual events occurred which might cast suspicion on some of the numbers.

The biologists who had the best knowledge of such information were generally overloaded with many other high priority tasks, and it took extra effort on their part to fulfill our data requests. It was gratifying to be the beneficiaries of their extra efforts, and to hear the genuine interest by many scientists and managers in this study (e.g. "What an awful job — but I'm glad that you're doing it."; "This should have been done a long time ago."). Without the efforts of these contacts we would have nothing to say in this report! The extent of effort required is really a function of the fact that past restoration projects were not treated or designed as management experiments. This paradigm is slowly changing, with the efforts of the ISRP and many others to stress the importance of monitoring and evaluation, and a recognition that past practices missed many learning opportunities. Even with a recognition of the importance of organizing data and metadata into a structure amenable to the kinds of analyses presented herein, few agencies have sufficient staff time to do this job.

Dealing with this problem is an enormous challenge. It is important to proceed strategically, and to 'mine' those regions of the Basin which are most likely to yield data of reasonable quality for the specific questions of interest. Recently, there have been many interesting proposals for improving accessibility to data (e.g. ISRP 2000, Schmidt 2002). However, retrospective studies of action effectiveness involve an atypical synthesis of three types of historical data: descriptions of past restoration projects; measurements of habitat quality; and estimates of the abundance of spawners, parr and smolts at various locations. These three types of data have generally gathered by different agencies for various purposes (e.g. auditing program expenditures, assessing general habitat and fish status), but generally not for evaluating the effectiveness of past restoration actions. Thus the habitat and fish data may not be collected in the locations ideal from a project evaluation perspective, and also may have been collected using different sampling protocols in different watersheds which reduces the number of treatment-control pairs. While habitat data is not essential to assessing whether restoration actions improved survival, it helps to confirm that the intended habitat improvements actually occurred.

Work by various entities is beginning to chip away at the challenge of inventorying past data and metadata. The NOAA / Action Agency RME Group has made progress in compiling information on past restoration projects into a database (Katie Barnass, pers. comm.). They are also examining a random sample of such projects to determine if they were in fact implemented (Steve Katz, NOAA, pers. comm.). The CBFWA Collaborative Systemwide Monitoring and Evaluation Project (CSMEP; www.cbfwa.org/rme.htm) has been working with StreamNet to inventory existing fish and habitat information for a subset of subbasins. Significant progress on these challenges will not be made without a substantial allocation of staffing resources over several years.

7.2.4 Drawing inferences across multiple scales requires much more planning than has occurred historically

In a Validation Monitoring report, Botkin et al. (2000, pp. ii) noted:

> "A monitoring design that examines a series of related questions at nested hierarchical spatial scales can provide information on the response of salmon populations to a suite of management actions, as well as generate information on population response to conservation plans."

We agree with this laudable intent. However, it is very rare to find historical data which allow analysts to draw and compare inferences at multiple scales (i.e. projects, reaches, tributaries, independent populations, major population groupings, sub-basins, ESUs). Such multi-scale assessments need to be deliberately planned. We were fortunate in the Yakima sub-basin to have indices of smolt survival at the project scale (survival past irrigation diversions), tributary scale (recruits / spawner) and sub-basin scale (smolts / spawner). These different indices yielded quite different inferences about the effectiveness of screened diversions: survival improvements at the project level, but either negligible or negative correlations at the tributary and subbasin scale. The full suite of measures gives a much better picture of the context within which a given restoration action occurs. Similarly, our multi-watershed analyses in the Salmon and Clearwater basins yielded inferences on the effects of habitat actions on three different indices: parr/redd; parr to smolt survival; and recruits/spawner. The first two indices showed a positive association between the number of habitat projects and the fish survival; the third showed no effect.

These results illustrate how the effects of any set of habitat actions can be expected to become diluted as the spatial scale expands, with the effects of downstream and upstream passage through the hydrosystem, and variations in estuary and ocean conditions. The noise introduced by these other factors can be filtered out to some degree with the use of covariates (as demonstrated in our case studies) but signals generally become weaker at larger scales due to greater confounding of treatment-control pairs and greater difficulties in removing hidden bias. With PIT-tagging technology and larger returns in recent years, it may become possible to bridge across multiple spatial scales, and explore whether patterns in parr-to-smolt survival rates (e.g. treatment vs. control groups) persist through to SARs (smolt to adult returns). Designing such experiments will require an unprecedented level of subbasin planning and inter-basin coordination.

To analyze effects at different scales, there is a need to develop common and scalable indices of habitat restoration actions. This will involve organizing actions according to which life history stages are likely to be affected, what responses can be expected (e.g. changes in spawner distribution from barrier removal, increased growth and survival of parr from fertilization), and what proportion of the population would be affected by the habitat change. Without careful planning of actions and monitoring it is hard to link habitat actions and biological and physical data at the appropriate scale, which leads to weaker inferences about effects.

7.2.5 More attention needs to be paid to where restoration projects and reference areas are located

The previous section leads to the obvious point that careful planning of where projects are located can yield a much greater ability to elucidate their benefits. In general, the sites where most habitat actions have taken place historically are also sites where habitat conditions were judged to be bad. Otherwise, why do the projects? No systematic attempt has been made to reserve low quality, but untreated control sites, where habitat conditions were poor, but no habitat actions took place. The only areas with few to no actions tend to be in wilderness areas (where human actions of any kind were prohibited), or in areas where habitat quality was thought to be good. This leads to a severe confounding: the only sites with lots of actions are also sites with poorer habitat quality; and few if any poor-quality sites have no habitat actions. So, even if restoration actions have increased fish survival, it will be much more difficult to detect the effects on survival indices. More precise monitoring will not reduce this confounding.

The obvious solution is to develop a more rigorous multi-watershed experimental outlook in deciding where restoration actions should be located. This may be perceived by local watershed groups as a top-down view of watershed planning. Groups may object to having their local stream designated as a “degraded control” rather than a “treatment” site. It is however analogous to a National Health Institute working with local hospitals to rigorously apply certain procedures, with patients randomly assigned placebos or new drugs, so that a national scale health study will yield reliable results. Those agencies supplying the funding (e.g. BPA) have both the right and the fiscal responsibility to ensure that the full suite of habitat restoration proposals fulfil both restoration and learning objectives. These issues are discussed further in Chapter 8.

7.2.6 More attention needs to be paid to the timing of restoration projects

It was bad luck that the pre-treatment years for the Yakima Phase 1 screens had abnormally high smolts/spawner indices, which made it much harder to detect a survival benefit of these actions. The only way to have avoided this problem would have been to have had a greater within basin contrast in the timing of implementation of actions, or a formal staircase design like that shown in Table 7.4 and described in more detail by Walters et al. 1988. Such designs were developed to deal with the commonly observed problem that apparent responses to treatment depend strongly on when the treatment is applied. Walters et al. suggest that a staircase experimental design should involve at least six experimental units, two of which remain untreated over the whole study period.

It is doubtful that a staircase design could have been implemented purely within the Yakima subbasin and assessed in terms of changes in smolts/spawner, as only two tributaries (the Naches/American and Upper Yakima) are considered to be independent populations. This means that several sub-basin planning groups would have needed to jointly co-ordinate a multi-basin assessment of the benefits of irrigation screens, with actions implemented at different times. Implementation at different times reduces the risk that all sites are affected by transient year effects just as the treatment is implemented, since within the Columbia Basin, quite large regions can show significant common year effects (Deriso et al. 2001). As the scale of a multi-watershed experiment enlarges, however, there are likely to be larger site-to-site differences, which may confound the benefits. Walters et al. comment:

> “Where good experiments cannot be justified, the key question should be which of several bad assumptions to make in defining an acceptable design.
>
> A minimum staircase design (with three experimental units) is one possibility, where it would have to be assumed that there are no locally unique population trends (or other more complex behaviors) not shared among the units. Compromise to less than three experimental units makes it impossible even in principle to distinguish transient effects from environmental effects, so when less than three units are feasible we may just as well stay with only one and just make (foolish) pre- versus post-treatment comparisons.”

Over the last several decades, various restoration techniques have risen and fallen in popularity. There is therefore a risk that each time a new method of restoration is developed (e.g. LWD, carcass fertilization), managers in many regions all implement the action at the same time. This may be occurring currently with carcass fertilization, as hatchery managers attempt to dispose of very large returns by adding carcasses to many streams, <u>all at the same time</u>.

7.2.7 Strengths and weaknesses of a multi-watershed approach

In applying a multi-watershed approach retrospectively, we learned several statistical strengths to this approach:

- There are enough data for enough streams to estimate common year effects in juvenile survival indices.
- Accounting for these common year effects removes common sources of variation from treatment and control streams (e.g., effects of drought years), increasing both the precision of estimated habitat effects and the statistical power of hypothesis tests.

- This results suggest that there could be some benefits (in terms of precision and power) from expanding the prospective monitoring of survival rate indices to multiple treatment and control streams on an extensive scale, provided that the location and timing of restoration projects are implemented thoughtfully, as discussed above.

There are of course some statistical weaknesses when applying a multi-watershed approach to historical data:

- The application of habitat actions has not been random: we don't have a random sample of "treatment" and "control" systems.
- The time series of data are too short for many of the actions to exert their full effect, or to have sufficient pre and post years of monitoring for reasonable statistical power.
- There are unbalanced designs (varying years of monitoring before/after impact).
- There are occasionally missing data points in the time series.
- Monitoring methods may differ between streams, providing different levels of bias.
- We used data for a purpose other than that for which it was collected (e.g., parr density index)

8.0 Recommendations for Further Work and Future Action Effectiveness Studies

There are two fundamental approaches to action effectiveness studies:

1. **Intensive Before-After-Control-Impact tests** of habitat action effectiveness, which ideally build on places where there are a lot of historical data (e.g. Ward et al.) and involve detailed monitoring. There aren't many places with good historical time series of juvenile survival so these studies will not be statistically representative of the broader region. Also, the actions implemented in intensive studies will likely be more carefully planned, and therefore may be more likely to address the factors limiting the population than are restoration actions in general.
2. **Extensive correlative studies** can complement intensive studies so as to learn whether the action effectiveness patterns observed in intensive studies are also observed more generally across a broader region. As discussed in section 7.1, extensive studies often have higher statistical power than intensive studies. A health analogy would be between intensive controlled studies on a small sample of patients to understand how a heart medication affects various physiological indicators, versus broad studies of overall responses (e.g. 10-year survival, frequency of relapses) across thousands of people in the general population.

For both types of approaches, more work is required to both figure out the best designs, and resolve implementation challenges.

In their recent review of NOAA's RME Plan, the ISAB and ISAB and ISRP (2004) recognized the benefit of extensive correlative analyses in addition to intensive BACI studies:

> "Where suitable treatment-control paired watersheds with similar potential productivity cannot be located, we recommend use of statistical association analysis (correlation/regression) and modeling with time and time x treatment interaction variables."

8.1 Retrospective studies

At the end of Chapter 2, we note that the greatest data needs for the Yakima study of Phase 1 screens are for better historical data, which obviously cannot be gathered now. Since the Phase 1 screens are already in place, it would at first appear that gathering more data now will not help to improve estimates of their benefit. However, our retrospective analysis was not able to separate out two leading hypotheses for the absence of a positive correlation between the screening index S_c and fish performance measures (smolts/spawner and recruits/spawner):

H1) relatively high juvenile production in the pre-treatment period and insufficient spatial/temporal contrasts made it hard to detect a benefit; or
H2) Phase 1 screens really didn't provide an overall survival benefit.

More recent PIT-tagging efforts, which provide improved estimates of survival from rearing areas to Prosser Dam and McNary Dam, provide an opportunity to experimentally test hypothesis H2. We know that the survival at irrigation diversion projects has improved. However fish that are screened out of these diversions may be subject to greater predation rates, either at the return canal, or due to premature migration downstream during non-normative, high summer flows. Yakima Nation fish biologists noted that some irrigation diversions actually provide better rearing habitat than the mainstem river (Joel Hubble, Scott Nicolai, pers. comm). With PIT-tags one could use hatchery parr to test whether the overall parr to smolt survival rates of juvenile fish that are screened out of various irrigation diversions (by either Phase 1 or Phase 2 screens) are in fact significantly higher than those of juveniles which are deliberately allowed into these diversions and rejoin the Yakima River further downstream. Radio telemetry could be used to complement such studies and confirm how fish utilize different habitats in both the main river and irrigation diversions.

The data that we compiled for the Yakama and Salmon sub-basins (Chapters 2 and 3) provide a foundation for some additional statistical power analyses, which we outline in section 8.2.

Chapters 3, 4 and 5 all relied on fairly crude inventories of habitat projects. More detailed assessments of the location, timing, type and intensity of these projects could yield additional insights on the relative benefits of different types of restoration actions. Organizing project information into a GIS, together with the locations of biological sampling sites would allow us to filter out those restoration projects which could not have affected biological performance measures. The indices of habitat actions that we used in this study (HABACT in Chapter 3, H in Chapter 4) were quite preliminary; it is well worth doing more work to improve these indices. Other recommendations for follow-up work from Chapter 3 include:

- Conducting sensitivity analyses to explore different methods for creating parr density data used for survival index (e.g., data for C + B channels, other sites), and comparing GPM and ISS density estimates.
- Testing results by expanding the analysis to include more streams from the Salmon, Clearwater and Grande Ronde watersheds, which could be done with the current habitat index, though parr and redd data would have to be found for the Grande Ronde subbasin.
- Our results are driven by the contrast in the Johnson Creek data, so the habitat and survival rate indices for this stream should be scrutinized. It would be useful to determine how close the habitat actions are to the GPM parr sites and where redd counts are conducted.

The analyses in Chapters 3, 4 and 5 all assumed that projects remained effective indefinitely. Field checks of a stratified random sample of projects should be undertaken to determine: a) whether the projects were implemented as designed and remained in place (implementation uncertainty); and b) whether the current habitat condition is consistent with intended outcomes (effectiveness uncertainty).

In general, it is worth cataloguing past habitat projects and locating them on a GIS where there are good biological data downstream and/or good local data on habitat quality. If there are no biological or habitat data with which to evaluate the effectiveness of past projects, then it may be pointless to compile cataloguing information; these past projects have essentially had unknown effects. It is important to catalogue current projects.

In addition to the Salmon, Clearwater, Wenatchee and Yakima subbsains, there were several other subbasins recommended in our February 2003 Scoping Meeting as having a high potential for useful retrospective analyses (i.e. good biological data, potential contrasts in intensity of habitat restoration). These subbasins include the Grande Ronde, Deschutes and Flathead subbasins. We did not pursue retrospective analyses in these subbasins due to a lack of participants at our March 2003 meeting. Actions implemented in one or more of these three sub-basins include addition of instream structures, carcass fertilization, and barrier removals. These sub-basins have relatively good data sets on spring chinook, steelhead and bull trout.

8.2 Analytical work to explore alternative designs for action effectiveness studies

ESSA's original proposal (ESSA 2002) contemplated doing some of the analytical work outlined below, but we were only able to this was not feasible due to the large amount of time required to find, obtain, organize and analyze the data for retrospective analyses presented in chapters 2 and 3. Nevertheless the retrospective work has given us both many ideas and more importantly the foundational data required for such analyses.

8.2.1 Statistical power analyses

We recommend that rigorous bootstrapping analyses be applied to the Yakima and Salmon/Clearwater case studies to further explore the consequences of the variability in those data sets for the detection of important effects and to explore how different designs may have increased the probability of detecting effects.

Bootstrapping and Monte Carlo methods are powerful techniques for exploring the statistical power of alternative experimental designs for testing habitat restoration hypotheses (e.g., habitat actions increase egg-to-parr survival rates). Bootstrapping (Efron and Tibshirani 1993) consists of resampling from a data set (nonparametric bootstrapping) a large number of time or from probability distributions defined by a data set (parameteric bootstrapping) to explore bias and variability in the estimated parameters of a model. Monte Carlo analysis is similar to bootstrapping, but usually includes multiple runs of a more explicit simulation model, drawing from an underlying data set, defined probability distributions, or both. For example, Monte Carlo analysis can be used to simulate the entire salmon life cycle to explore the effect of natural feedback mechanisms (e.g., density dependent freshwater survival) on measured performance measures.

We could use these techniques with our existing data sets to explore alternative experimental designs that vary in their duration and pattern of Before and After monitoring, whether or not they include a control system or systems, their spatial scale (e.g., reach, tributary, or basin), species of interest, performance measure, sampling methods, and the criteria for determining whether the results were important (e.g., 2 tail t-test, $\alpha = 0.05$). Important input such as the variance of performance measures and other parameters could be estimated from the data sets we have used in our previous analyses (Chapters 2-5), or from other studies (e.g., some of those included in Table 7.5).

Bootstrap and Monte Carlo type analyses have already been conducted for designs using parr-to-smolt survival rates (Paulsen and Fisher 2003) and recruits per spawner (Paulsen and Hinrichsen 2002) as performance measures. The techniques for these analyses can be adapted to incorporate new information and explore different designs and also applied to new performance measures (e.g., parr per redd). In particular, proper bootstrapping analyses of Yakima and Salmon/Clearwater case studies would rigorously assess the benefits of:

- Increasing the number of years of data (artificially), the numbers of stocks, and the effect size. (e.g., given the observed variation prior to the onset of some habitat actions, how large would an effect have to be to achieve a specified level of statistical power?)
- Varying the pattern of Before and After years of data (e.g., 10/10. 5/10, 10/5, etc.)
- Varying the magnitude of observation error in accordance with that expected from different measurement methods (e.g., rotary screw trap estimates of juvenile abundance vs. snorkel based abundance estimates).

- Changing the selection of treatment control pairings (e.g., covariation of stock indices) or having multiple treatment-control pairs.

These analyses would provide valuable information on the magnitude of the effects likely to be detected with acceptably high probability (e.g., a statistical power of 0.8) for different experimental designs. Summary charts (e.g., nomagrams) would be used to show how statistical power varies with monitoring duration and sampling method relative to freshwater and marine process error, measurement error, the degree of covariation in survival rates between systems, and magnitude of effect size (e.g., Parnell et al. 2003 (see Figure 7.1 this report), Figures 2 and 3 of Korman and Higgins 1997). Using this information, managers and scientists could work together to determine which designs have the best chance of detecting biologically important effects, should they occur.

8.2.2 Exploration of alternative multi-watershed designs

Instead of taking some actions in every problematic watershed within a subbasin, it may be better to take lots of actions in a subset of watersheds and leave the remainder alone as controls to facilitate detection of survival effects. This idea could be explored with experimental analyses, using the large-scale datasets that we utilized in the Salmon and Clearwater subbasins. It might also be valuable to use the EMAP data for coastal coho to explore the ability to do matching of watersheds or tributaries (treatment-control pairs), using the large number of measured habitat variables. Regardless of which area is explored, it would be valuable to simulate multi-watershed, staircase designs under two sets of assumptions:

1. Assume the world is run by research scientists, and that some control areas with poor-quality habitat are left untreated, while other similar areas are treated intensively with many beneficial actions.
2. Assume the status quo, in which all poor quality areas receive the same level of treatment, and the only areas that can serve as controls are those that presently have high-quality habitat.

Even if such designs show an improved ability to detect effects of actions, there still remains the hurdle of implementing such designs in the real world. Approaches to these challenges are outlined in section 8.3 below.

8.2.3 Tradeoff analyses

While we recommend the application of bootstrap and Monte Carlo analyses to help identify experimental designs that are optimal in terms of statistical power (Section 8.2.1), such designs may not optimal in terms of monitoring costs and other constraints (e.g., regulatory restrictions) and therefore they may not be implemented. Thus we recommend that the experimental design process explicitly consider tradeoffs between scientific (e.g., high statistical power) and management objectives (e.g., work within budgets, achieve environmental improvements quickly).

Decision analysis (Peterman and Anderson 1999, Clemen 1996,) can be used to explicitly evaluate these tradeoffs (e.g., statistical power vs. cost of monitoring). The decision analysis framework can be modified to fit the nature of the problem. Some decision problems have a relatively narrow set of objectives that can be addressed within the context of a unified and quantitative modeling framework (e.g., MacGregor et al. 2002, Peters and Marmorek 2001). Other decision problems must consider a broader set of objectives that are addressed by unrelated criteria measured on different scales, or even subjectively (e.g., Marmorek and Parnell 2002, Parnell et al. 2003). Such multi-attribute decision problems are most likely to be the case for evaluating tradeoffs in the design of large-scale experimental evaluation of habitat restoration programs.

Decision analysis has been shown to be a powerful tool for the design of large-scale monitoring and experimental programs (e.g., Parnell 2002, MacGregor et al. 2002, Walters and Green 1997, Keeley and Walters 1994, Peterman and Antcliffe 1993, Antcliffe 1992, McAllister and Peterman 1992a, b). These studies often show that the optimal design, when all objectives are considered, is not necessarily the design with the highest statistical power. Three examples of particular relevance to the design of habitat restoration actions and experiments are:

1. **Keeley and Walters (1994)** developed an experimental design for the British Columbia Watershed Restoration Program to evaluate the effectiveness of restoration actions using smolt abundance as the performance measure. They explored the statistical power and expected value of different 'after only' multi-watershed designs, which varied in the number of replicates (Treatment-Control watershed pairs) and the duration of experiment. They found that the optimal experimental design was not the design with highest statistical power.
2. **MacGregor et al. (2002)** developed a quantitative decision analysis framework to determine whether the expected value of the information obtained through monitoring exceeds the costs of obtaining it. The framework was applied to a hypothetical problem where managers had a fixed budget for constructing groundwater fed channels for chum salmon and had to choose how much, if any, of that budget to allocate to monitoring. Economically optimal experimental designs for monitoring programs generally had low statistical power, partly as a result of the high cost of monitoring.
3. **Parnell (2002)** developed a Before-After-Control-Impact paired series design framework for a paired-watershed experiment testing the effectiveness of a habitat restoration action. Decision analysis was used to select an optimal design that took into account uncertainty in a biological index of spring chinook egg-to-parr survival rate, the costs associated with monitoring, and the costs associated with errors in inference (i.e. Type I and II errors). The management variables included the number of years of after monitoring and the method used to estimate the egg-to-parr survival rate. For this example, the design with the highest statistical power was optimal.

Tradeoff analyses such as these would be valuable to organizations like BPA, which are faced with the challenge of balancing competing demands for better effectiveness evaluations (learning), habitat improvements to recover endangered species (conservation), and cost-effective application of limited budgets.

8.3 Columbia Basin coordination efforts

How can the insights gained from our study and others that we've reviewed be incorporated into Columbia Basin management? Below we outline in point form a series of recommendations.

Regional planning of restoration projects

We believe there would be a benefit of having a core team of scientists with expertise in experimental design, fisheries and habitat restoration work with managers to develop both *extensive* approaches and *intensive* approaches to evaluating effectiveness of actions. Specific steps would include:

1. Complete analyses that explore statistical power (Section 8.2.1), alternative experimental designs (Section 8.2.2), and decision analyses of the learning-cost tradeoffs of different designs (Section 8.2.3).
2. Initiate a series of meetings with fish and wildlife managers to present the results of this work in simple language – i.e. demonstrate the opportunities that exist to improve rates of learning and save money through better intra and inter-subbasin planning of restoration projects.
3. Explore with the managers what cost and benefit sharing mechanisms could be instituted to ensure equitable fish and wildlife benefits, and acceptbility to private landowners.
4. Use the sub-basin planning process more specifically to co-ordinate when and where projects are implemented to increase learning from broader-scale monitoring both within and across sub-basins.
5. For individual projects focus on the proper design of reach scale analyses, but recognize that some indices and methods used to measure them should be scalable to allow broader scale comparisons (e.g., collect reach specific information in a way that could be expanded to tributary and sub-basin scale).

Database of projects

- Develop a single centralized database of new habitat projects (and the subset of past projects for which effectiveness evaluations are worthwhile) which includes geo-referenced information on project locations, activities, timing, intensity, etc. as discussed in Section 7.2. This should include all project activities regardless of who sponsored them. At present there are multiple databases maintained by different sponsoring agencies, using different project classification methods and often with different project location coordinates for the same project (Tim Fisher, pers.comm.).
- The database should include the expected magnitude and timing of responses in key performance measures (habitat indicators; salmonid abundance, survival and/or distribution). These will form pre-project hypotheses which can be tested in a subset of cases
- Where appropriate, organize a GIS database to improve the efficiency of associating independent data sets (biological and habitat monitoring) with ongoing or future habitat actions. While recent projects generally have GPS coodinates, this is not the case for older projects, whose locations must be inferred from topographic maps and general project descriptions.

Implementation monitoring

- Post-project implementation monitoring should be a pre-requisite for funding. For longer duration actions (e.g. riparian restoration, erosion control) this will involve revisiting the site 5 or 10 years after implementation.

Monitoring protocols

- Develop *action indicators* that can incorporate estimates of the scale, intensity and magnitude of an action, for use in extensive analyses of action effectiveness (i.e. a 100m revegetation project is less likely to have an effect than a 1 km integrated erosion control, revegetation and instream channel project).
- Develop a common set of habitat and biological *response indicators* that are measured in all *intensive* projects to facilitate multi-project, multi-tributary and multi-basin comparisons. Efforts are being made to move in this direction through:

  - guidelines for action effectiveness studies (Paulsen et al. 2002);
  - consistent monitoring protocols (Johnson et al. 2001);
  - collaborative monitoring and evaluation approaches within the Columbia Basin and beyond (CSMEP, PNAMP);
  - effectiveness evaluations using habitat and fish monitoring protocols applied to randomly selected sets of reaches (Washington's Salmon Recovery Funding Board, www.iac.wa.gov/srfb/docs.htm);
  - pilot projects in the John Day, Wenatchee and Salmon (originally Grande Ronde) subbasins (NMFS 2003).
- Have a smaller set of response indicators that are measured in all projects used for *extensive* studies. Smolts/spawner is probably the best integrative measure of cumulative benefit of freshwater restoration actions. It eliminates the noise contributed by other parts of life cycle. However, it must be measured well to be worthwhile (e.g. frequent measures of Rotary Screw Trap efficiency), and must have sufficient pre-treatment data to detect a response. It is worth comparing the variation in ln(smolts/spawner) with the variation in ln(recruits/spawner) for different species and locations. For our Yakima analyses of spring chinook, ln(smolts/spawner) had a CV of only 18% vs. 360% for ln(recruits/spawner); clearly smolts/spawner is the better performance measure. However, the larger number of sites with recruit/spawner measurements may make it preferable for extensive studies, especially as it is has been measured over a much longer period of time. Recruit/spawner indices also integrate over the entire life cycle, and therefore indicate the cumulative effect of all restoration effects. The best approach is therefore to use both measures.
- Determine a reasonable set of core habitat measurements that can be used for matching treatment-control pairs. The cost of measuring many habitat parameters (and doing better matching) must be weighed against other components of the experimental design (sample size, precision of biological measurements, etc.).

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Appendix 1
Summary of Blue Ribbon Studies on Habitat Action Effectiveness

Introduction

The studies summarized in Appendix 1 are examples that have relatively strong experimental designs and duration of time series for detecting the impacts of habitat restoration actions on salmon and steelhead survival. While many of these studies are outside of the Columbia Basin, they are all within the Pacific Northwest and offer both guidance to future monitoring studies as well as potentially relevant data on outcomes. The studies are organized alphabetically by author. The table below provides a list of the studies presented in Appendix 1 and the corresponding RPA actions considered.

Table A1.1. Summary of studies reviewed in Appendix 1, and their relevance to actions mentioned in RP 183.

Reference	Attainment of minimum instream flows	Compliance with water quality standards		Enhanced levels of marine–derived nutrients	Improved riparian conditions		General Paper
		Alteration of grazing practices	Reduction of sediment through road closures		Alteration of grazing practices	Active stream restoration	
Amour and Taylor (1991) in Higgins (2001)[14]	✔						
Bayley (2002)							✔
Beechie and Bolton (1999)							✔
Bilby et al. (1998)				✔			
Cederholm et al. (1999)				✔			✔
Clayton (2002)						✔	
Giannico (2000)						✔	
Kauffman et al. (2002)		✔			✔		
Johnston et al. (1990)				✔			
McHugh (2003)						✔	
Michael Jr. (1995)							✔
Nickelson et al. (1992)						✔	
Paulsen and Fisher (2001)			✔				✔
Reeves et al. (1997)						✔	
Roni et al. (2002)						✔	✔

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[14] There is uncertainty in instream flow assessment through the wide use of physical habitat models such as PHABSIM. There have been many technical concerns about the shortcomings of PHABSIM but it is still the most commonly applied method for instream flow assessment in the U.S. and Canada. In Amour and J.G. Taylor (1991), only 1% (n=6) of the 616 applications of PHABSIM known to the US Fish and Wildlife Service prior to 1988 had any monitoring to examine the outcome of management actions. In those where follow-up monitoring was conducted, none were sufficient to draw quantitative conclusions about the success of the application. This paper is not summarized in this document.

Reference	Attainment of minimum instream flows	Compliance with water quality standards		Enhanced levels of marine–derived nutrients	Improved riparian conditions		General Paper
		Alteration of grazing practices	Reduction of sediment through road closures		Alteration of grazing practices	Active stream restoration	
Roni and Quinn (2001)						✔	
Solazzi et al. (2000)						✔	
Ward et al. (2002)				✔		✔	
Watson and Hillman (1997)							✔
Wipfli et al. (2003)				✔			

A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest

Reference:

Bayley, P.B. 2002. A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest. Prepared for the Washington State Independent Science Panel. 29 pp.

Not a peer reviewed publication. The most relevant studies from this review are summarized below.

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Abstract:

An inspection of abstracts from 2,350 references produced a first-cut set of 441 studies and reviews that were subsequently classified and reviewed with respect to their potential to document responses of salmonids to habitat changes, and to guide future monitoring of salmonid watersheds. Although the literature on habitat requirements is vast, it was necessary to distinguish between studies that relied on correlations based on observational designs and those which attempted experimental designs to test cause-and-effect mechanisms.

Our understanding about environmental effects on fish is largely based on weak inferences from observational studies, which has a direct bearing on monitoring strategies. Such studies are useful in generating hypotheses on cause-and-effect, but such hypotheses need to be tested through appropriate experimental designs in the context of a validation monitoring approach. Findings from seven reviews (1988–2002) were assessed jointly with specific studies. Articles from 30 studies were reviewed, drawing from single or multiple streams, and purely observational or 'natural experiment' designs, in order to assess what improvements are needed in future programs.

Relatively few studies were long term or from multiple watersheds; most studies were of one year or spanned a single generation. Although large-spatial scale, short-term studies have increased and provided insight into clustering of populations and dependency on environmental indicators at broader scales, there is no indication of the extent to which space can be traded for time when making inferences. The main technical deficiencies were the lack of concern about unbiased density estimates and poor statistical design, analyses and reporting. Analyses that simulate alternative sampling processes and expected biases in stream networks over time and space would help resolve some of these deficiencies.

Overall, I concluded that current freshwater-based monitoring programs will either: (1) fail to indicate an improvement associated with stream habitat restoration in terms of smolt recruitment, returning adults, or population size increase at the watershed scale, or (2) indicate an improvement but fail to demonstrate which and how habitat changes were responsible so that subsequent restoration policy could be made

more cost-effective. Recommendations for approaches to a large-scale monitoring design, based partly on this review are presented. The first-cut list of references, with abstracts and classification codes, is available electronically from the author.

Overall Conclusion on Restoration Action Effectiveness

Strong inferences of increases in population abundance of juveniles in streams have been documented, however "relating this to smolt recruitment and returning numbers of adults at appropriately large scales has been neglected. Therefore, studies have not so far addressed empirically the estimation of change in total population size as a result of restoration efforts."

"Proof of dominant cause-and effect relationships operational at scales appropriate for the population will always be elusive, even with the best designed field experiments. However, validation monitoring approaches that aim for strong inference based on multi-stream studies over time are feasible, but no good examples were found."

He provides the following recommendations on how to proceed in designing a long-term monitoring program to improve understanding of the responses of salmonids to habitat changes.

> "Future monitoring surveys should take advantage of existing, comparable fish sample information, providing that the information contributes to a design that incorporates current or planned contrasts between basins with extensive habitat restoration (treatments) and those with unchanged habitat (controls). Essential components of future validation monitoring surveys are as follows:
>
> 1. Reassess existing long-term and basin-wide, short-term data sets with repeatable protocols, and identify drainage basins that have contrasts in degree of habitat restoration (with or without existing fish samples). Utilize these sources in conducting components 2 and 3.
> 2. Develop simulation models of cost-limited, alternative fish sampling designs that incorporate empirical variances and biases, to provide a quantitative template for recommendation 3.
> 3. Develop long-term (decades) monitoring programs that treat a series of basins and wild fish populations as natural experiments along a gradient of habitat restoration. The sampling design should track metapopulations or extensive populations and physical changes within and among watersheds down to reach or segment scales. Because seeding and early survival variation can change the habitat variables that are limiting, a measure of year-to-year reproduction success of key salmonids (at least down to watershed scales) should be concurrent with juvenile and adult monitoring of all fish species. Reach-scale, stratified random fish sampling effort using protocols that are bias-correctable should be divided between mid-summer and winter periods. Spatial strata should be watersheds expecting/not expecting significant human alteration, litho-geomorphological zones within watersheds, and stream sizes."

An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds

Reference:

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries. 24(4): 6-15.

Peer reviewed publication

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Abstract:

We present an approach to diagnosing habitat degradation and restoring habitat-forming processes that is focused on causes of habitat degradation rather than on effects of degradation. The approach is based on the understanding that salmonid stocks are adapted to local freshwater conditions and that their environments are naturally temporally dynamic. In this context, we define a goal of restoring the natural rates and magnitudes of habitat-forming processes, and we allow for locally defined restoration priorities. The goal requires that historical reconstruction focus on diagnosing disruptions to processes rather than conditions. Historical reconstruction defines the suite of restoration tasks, which then may be prioritized based on local biological objectives. We illustrate the use of this approach for two habitat-forming processes: sediment supply and stream shading. We also briefly contrast this approach to several others that may be used as components of a restoration strategy.

Their Approach

Their process-based restoration strategy focuses on understanding changes to habitat-forming processes and identifies locations where specific restoration actions are needed to restore such processes. It fills an information gap between in-stream diagnostics of habitat degradation and large-scale assessments of disturbance patterns on a landscape. It focuses analyses on causes of habitat degradation rather than on habitats or biota. The approach requires analysis of habitat-forming processes at the scale of watersheds in order to identify which processes are disrupted as well as locations and timing of land use effects on those processes. Restoration actions can then be identified directly from the results of the analysis. Thus, this approach complements in-stream diagnostics that assess either habitat characteristics or biotic responses to habitat change.

The strategy takes a two-tiered approach, first identifying restoration actions through diagnosis of altered habitat-forming processes and then prioritizing restoration actions. The objectives are to:

1. Restore habitat for all salmonid species while simultaneously allowing local managers to sequence restoration activities in a way that favors recovery of a selected species.
2. Help managers avoid failures associated with attempting to engineer habitats that are static in space and time.
3. Allow managers to evaluate the cost-effectiveness of different restoration options.

Application of the strategy involves five steps:

1. Estimate natural rates of habitat-forming processes;
2. Assess changes in rates of habitat-forming processes due to land use;
3. Identify actions required to restore habitat-forming processes;
4. Evaluate probable improvement in local biological indicator (for each task); and
5. Prioritize actions based on costs and potential improvement in biological indicator.

Relevance to Columbia Basin:

This approach should be applied *prior* to developing a restoration project plan, or set of restoration projects with spatial and temporal contrasts across multiple sites.

Response of juvenile coho salmon and steelhead to the addition of salmon carcasses to two streams in southwestern Washington, U.S.A.

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients

Reference:

Bilby, R. E., B.R. Fransen, P.A. Bisson, and J.K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, U.S.A. Can. J. Fish. Aquat. Sci. 55: 1909-1918.

Peer reviewed publication

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Abstract:

Availability of organic matter and nutrients transported from the marine environment to streams by spawning salmon was increased in two small streams in southwestern Washington, U.S.A., by adding salmon carcasses from a nearby hatchery. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) rearing at these sites was compared with nearby streams where few salmon spawned. Densities of age 0+ coho salmon and age 0+ and age 1+ steelhead increased following carcass additions to the treated streams. A similar increase in density was not observed at the reference sites. Condition factors in treated streams increased following carcass addition and remained at high levels while carcasses were present whereas no similar pattern was observed at the reference sites. Stomach contents of fish in streams to which carcasses had been added consisted primarily of salmon eggs and carcass flesh when carcasses were present in the stream. Stable isotope analysis indicated that the proportion of marine-derived nitrogen in the muscle tissue of juvenile salmonids increased as much as 39% following carcass placement. Results suggest that eggs and carcasses of adult salmon provide a very important resource during a period when other food items are often scarce.

Watershed Name & Location:

Salmon Creek (treatment) and Big Creek (control), third order tributaries of the Chehalis River watershed and A400 Creek (treatment) and Wasberg Creek (control) of the Willapa River watershed in the Willapa Hills of southwestern Washington.

Type of Habitat Restoration Actions and When Undertaken:

Coho salmon carcasses were placed in Salmon Creek on November 22 and 23, 1994 and in A400 Creek on November 18, 1995. The studies took place in:

- Salmon and Big creeks during the autumn and winter of 1994-1995
- A400 and Wasberg creeks during the autumn and winter of 1995-1996

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Objectives were to:

- examine the extent to which juvenile coho and steelhead utilized salmon carcasses as a food source, and
- determine whether increased availability of this material had any impact on growth, population density or condition factor.

Response Measures Monitored (fish habitat[15], fish population[16]):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)[17]
# of naturally spawning fish	All sites	Biweekly during the study period	Counted carcasses	
Fish population densities, condition factor and size	Lower 100m of each site – isolated with blocking nets.	Salmon and Big creeks during October (pre-treatment) and March. A400 and Wasberg creeks monthly from October 1995 – March 1996.	Electrofishing - three passes made through each reach. Densities estimated for each species and age-class using a removal-summation calculation modified for small population size.	Density of all ⇑ at A400 Creek; juvenile coho ⇔ at A400 and Wasberg creeks; age 0^+ steelhead ⇑ at A400 Creek; age1^+ 10X ⇑ at A400 Creek. Condition factor of age 0^+ steelhead ⇑ in Salmon Creek; juvenile coho ⇑ in A400 Creek See figures in key results.
Stomach contents	“	“	Electrofishing Stomach contents collected by gastric lavage and stored in 70% ethanol	No statistically significant differences. See figure in key results.

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[15] Fish habitat measures include temperature, turbidity, contaminants/nutrients, barriers, substrate, large wood, pools, off-channel habitat, channel condition, streamflows, watershed land use

[16] Fish population response measurements include redd / weir counts of spawners, age class of spawners, parr density / size, juvenile PIT tagging, juvenile emigrant abundance / size

[17] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

What was measured?	**Where were measurements taken? (include intended or possible control sites)**	**Frequency and Duration of Measurements (before and after treatment)**	**How (Sampling Method, Monitoring Protocol)**	**Measured Effect of Restoration Action (% Δ ± SE)[17]**
Stable isotope analysis	“ Cutthroat trout collected above a barrier to passage in each watershed. Values reflect isotope ratio of N and C from nonmarine sources.	“	Electrofishing Samples dried, ground to powder and combusted to generate CO_2 and N_2 gas – isotope rations in gases measures with a mass spectrometer	$\delta^{15}N$ for age 0^+ and age1^+ steelhead ⇑ and $\delta^{13}C$ for age 0^+ steelhead ⇑ in Salmon Creek; $\delta^{15}N$ ⇑ for coho in A400 Creek; $\delta^{15}N$ and $\delta^{13}C$ for age1^+ steelhead ⇑ in A400 Creek Proportion of marine derived N increased in muscle tissue of juvenile fish - see table in key results for details.

Key Results:

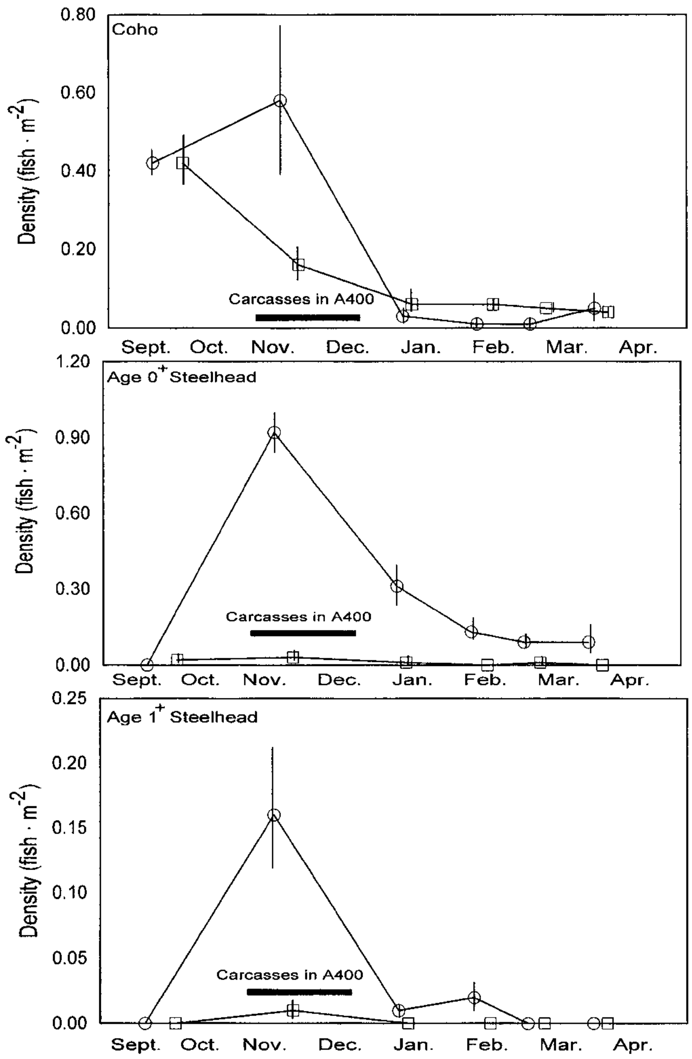

Figure. A1.1. Density of juvenile salmonids at the A400 Creek (circles) and Wasberg Creek (squares) study sites. Salmon carcasses were added to the A400 Creek site. Vertical lines associated with each data point represent ±1 SE. Values without error bars indicate that no fish were captured on that date. The heavy horizontal bar indicates the period during which carcasses were present at the treated site.

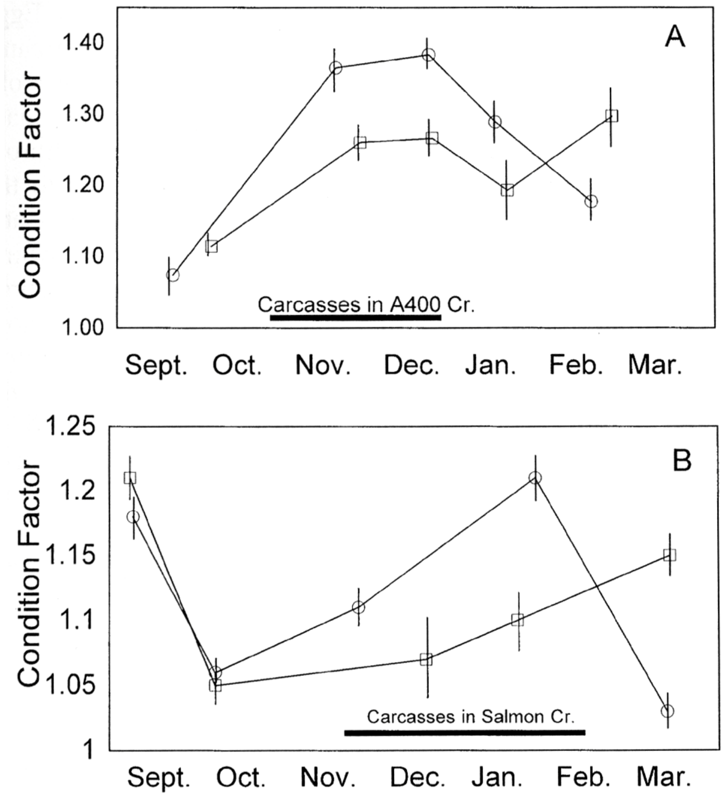

Figure A1.2. (A) Condition factor of juvenile coho salmon at the A400 Creek (circles) and Wasberg Creek (squares) study sites. Salmon carcasses were added to the A400 Creek site. Values are shown ±1 SE. Insufficient numbers of steelhead were captured at the Wasberg Creek site to enable calculation of condition factor (less than five fish). (B) Condition factor of age 0' steelhead at the Salmon Creek (circles) and Big Creek (squares) study sites. Salmon carcasses were added to the Salmon Creek site. Values are shown ±1 SE. Insufficient numbers of age 1+ steelhead were captured at the Big Creek site after October for condition factor to be determined (less than five fish). The heavy horizontal bar indicates the period during which carcasses were present at the treated sites.

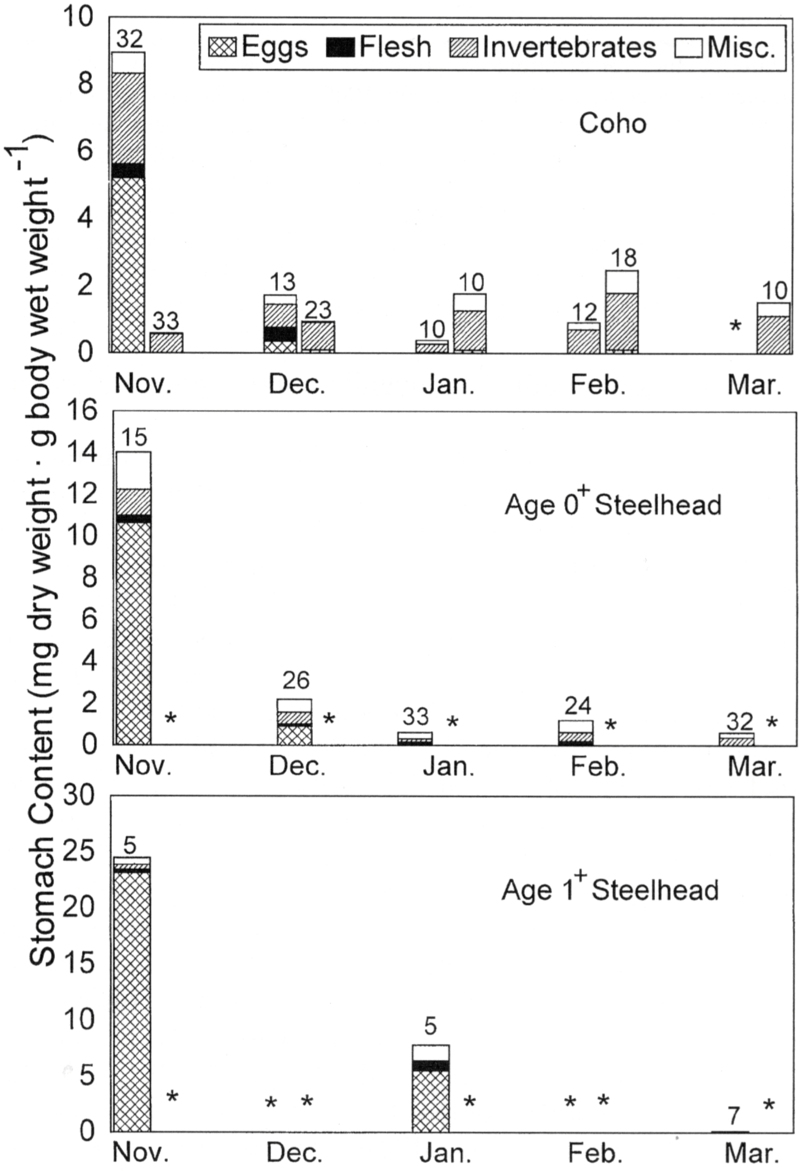

Figure A1.3. Amount and type of material removed from the stomachs of juvenile coho and age 0' and age 1+ steelhead at the A400 Creek and Wasberg Creek study sites. The first bar of each pair represents A400 Creek, and the second bar represents Wasberg Creek. The number above each bar indicates the number of fish sampled. The categories are salmon eggs (Eggs), flesh from salmon carcasses (Flesh), whole invertebrates or invertebrate parts (Invertebrates), and plant parts, inorganic matter, and unidentifiable material (Misc.). Values are shown only for those dates when five or more fish were sampled. Instances when insufficient numbers of fish were captured are indicated with an asterisk. Amount of material is expressed as the dry weight of the stomach contents per unit wet body weight of the fish from which the material was collected to normalize for any differences in fish body size between the sites.

Table A1.2. Proportion of marine-derived N in juvenile salmonid fishes in the treatment and reference stream reaches

	% marine-derived N	
	Salmon and Big creeks	A400 and Wasberg creeks
Age 0+ steelhead		
Reference site	2.0	25.5
Treatment site		
Carcasses absent	2.1	33.2
Carcasses present	17.3	46.9
Age 1+ steelhead		
Reference site	1.0	36.3
Treatment site		
Carcasses absent	3.1	34.3
Carcasses present	17.5	71.9
Coho		
Reference site	-	16.6
Treatment site		
Carcasses absent	-	25.1
Carcasses present	-	44.1

Note: We have assumed that uptake of marine-derived N occurred 50% through direct consumption of salmon eggs and flesh and 50% through consumption of invertebrates containing N derived from the spawning fish. coho did not occur at the Salmon Creek and Big Creek sites.

Relevance to Columbia Basin:

An improved understanding of how material from spawning salmon is utilized by stream-dwelling fishes will enable experiments to be designed to assess the generality of these results. Some watersheds with abundant N fixing vegetation (e.g. alders) may be much less nutrient limited than other basins (Robbins Church, U.S. EPA Corvallis, pers. comm.), which will affect the benefits of such treatments.

Overall Conclusion on Restoration Action Effectiveness

Increased densities of juvenile fish, increased body weight and improved condition factor were observed in stream reaches where salmon carcasses were added. The increase in C and N stable isotope values indicates that materials from spawning salmon are readily ingested by juvenile salmonids. Larger body size can have a dramatic effect on survival of coho and steelhead — availability of eggs and carcass tissue may positively impact survival rates through the remainder of life.

Habitat restoration should consider the nutritional health of the system in addition to measures to protect and enhance the physical attributes of a stream. Their results along with other information (including Johnston et al. (1990)) make it apparent that adequate levels of spawning salmon are an important component of health stream habitat in the Pacific Northwest.

Distribution of carcasses of hatchery-spawned salmon should be viewed as a procedure to be utilized in situations where disease introduction and water quality concerns are deemed minimal and are monitored and where the abundance of spawning salmon cannot be increased significantly through restrictions on harvest rate.

Pacific Salmon Carcasses: Essential Contributions of Nutrients and Energy for Aquatic and Terrestrial Ecosystems

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients

Reference:

Cederholm, C.J., R. E., Bilby, P.A. Bisson, T.W. Bumstead, B.R. Fransen, W.J. Scarlett, and J.W. Ward. 1997. Response of juvenile coho salmon and steelhead to placement of large woody debris in a coastal Washington stream. North American Journal of Fisheries Management 17:947–963.

Peer reviewed publication

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Abstract:

Pacific salmon and other anadromous salmonids represent a major vector for transporting marine nutrients across ecosystem boundaries (i.e., from marine to freshwater and terrestrial ecosystems). Salmon carcasses provide nutrients and energy to biota within aquatic and terrestrial ecosystems through various pathways. In this paper we review and synthesize the growing number of studies documenting this process in different localities. We also discuss the implications for maintaining the nutrient feedback system. Our findings show that future management will need to view spawning salmon and their carcasses as important habitat components for sustaining the production of fish as well as other salmon-dependent species within watersheds.

Conclusions:

This paper provides a review and synthesis of the literature on studies of nutrient subsidies provided by salmonid carcasses and their effects on aquatic environments and vertebrate communities. Spawning salmon provide marine-derived nutrients to aquatic ecosystems through and contribute to biological productivity through many pathways. The pathways for use of these nutrients occur through three avenues:

1. Uptake by primary producers after mineralization to inorganic forms that then transfer the nutrients up the food chain.
2. Uptake of dissolved organic matter released by decomposing carcasses by microfauna in the streambed substrate.

3. Direct consumption of salmon eggs, fry and carcasses.

The variables for utilization of these nutrients include the differences among salmonid species including spawning densities and preferred spawning location. Other important physical variables include hydrologic discharge, the ability of a stream to retain carcasses (physical and biotic mechanisms) and riparian ecosystem conditions that influence autotrophic variability.

Hatchery salmon carcasses may be valuable in streams where wild spawners are lacking but they should not be considered a long-term solution to replacing the nutrient subsidy of wild salmon. To ensure effective recycling of nutrients from the ocean back to land, wild anadromous salmonids must recover from their current status. Their findings illustrate the need for continued research and corresponding management to protect and recover native salmonid populations.

Quantitative evaluation of physical and biological responses to stream restoration

RPA 183 Actions Identified:

- Improved riparian conditions
    - Active stream restoration (includes instream structures)

Reference:

Clayton, S.R. (Ecohydraulics Research Group). 2002. Quantitative Evaluation of Physical and Biological Responses to Stream Restoration. A Dissertation Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy. University of Idaho, Moscow, ID. 300 pp.

Dissertation

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Abstract:

Since physical and biological responses to ecological restoration are influenced by processes acting at multiple spatial and temporal scales, attributing change to habitat restoration requires separating forcing functions imposed by restoration from those occurring naturally. A framework is proposed to separate factors influencing ecological response into four levels: external physical forcing functions, restoration-induced functions, and physical and biological response variables.

The approach is illustrated through application to the Lower Red River Meadow Stream Restoration Project in north-central Idaho, USA, a soft engineered restoration project designed to improve habitat for chinook salmon (*Oncorhynchus tshawytscha*) by restoring natural, physical processes to a 4.1 km reach. Field monitoring and hydrodynamic modeling were combined to quantify the magnitude and direction of physical and biological responses.

While the direction of physical response to individual treatments was predictable in most cases, the magnitude of change and cumulative physical response, especially from treatments with potentially offsetting effects, were less predictable. Furthermore, reach-median values demonstrated overall trends, but the direction and magnitude of responses varied between types of restored channel. Even though many active stream restoration projects are funded and implemented on the premise that restoration of physical processes will result in improved biological conditions, biological responses due directly to restoration are difficult to quantify because of their inherent high variability. Power to detect response to habitat restoration is a function of effect size, variability, and sample size. From observed variability in physical and biological parameters monitored for 3-9 years at the project reach, magnitude of detectable response was estimated as a function of years of monitoring. With five years of post-restoration

monitoring, biological parameters (e.g., age 0 chinook density) would require an order of magnitude larger response than physical parameters (e.g., median particle size) to be statistically detectable. By combining the proposed framework with the Before-After, Control-Impact (BACI) sampling design, physical parameters can be used to detect initial responses to restoration and complement biological parameters in the long-term evaluation of stream restoration.

Watershed Name & Location:

Lower Red River in north-central Idaho, 6 km downstream from the confluence of Main and South Red River forks – 985 km upstream from the mouth of the Columbia River. Riparian meadow ecosystem. Control reach 1 (IDFG's Red River Stratum 1) is 27 km upstream of the project reach, and control reach 2 (American River Stratum 1) is located near the upper end of the adjacent watershed to the north.

Type of Habitat Restoration Actions and When Undertaken:

- 1996 – 2000 during each summer except 1998.
- Excavated new channel and excavated and reconnected to historic meanders to increase channel length and sinuosity to approximate pre-disturbance (1936) conditions.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Framework and Physical Response

- Developed and field tested a framework to separate factors influencing ecological response into four levels: external physical forcing functions (Level I – land management, meteorology, etc.), restoration-induced functions (Level II – manipulation of channel), and physical and biological response variables (Levels III & IV).
- Framework designed to include physical and biological responses that may be detected within several years to a decade following active stream restoration at the reach scale.
- Field monitoring and hydrodynamic modeling (MIKE 11) were combined to identify changes in physical response variables.
- Mann-Whitney U test used to test differences for a single variable across two independent groups of cases.

Biological Response

Questions to be answered:

1. Did any biological parameters show a change during and immediately following restoration?
2. What was the magnitude and direction of response?
3. What was the natural variability of the parameters prior to the restoration?
4. Based upon the observed natural variability, how long would it take to identify a change in these parameters that could be attributed to the restoration?

Statistical Analysis

- Before-After Control-Impact (BACI) approach was applied to two physical parameters, hydraulic geometry (cross section area) and thermal gain, and one biological parameter, densities of age 0 chinook, to assess change following restoration.

Response Measures Monitored (fish habitat,[18] fish population[19]):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Physical:				
Channel topography	Study reach	Annually in late summer or fall	Topographic survey (survey-grade GPS)	Used for model and to quanitfy change in channel dimensions
Surface substrate	Along project reach at pool tail outs	Annually in early August 1997 - 2001	Standard surface sampling pebble count method (Wolman 1954)	% fines declined each year but not significantly
Subsurface substrate	Point and lateral bars in project reach	2001	Percent fines, Fredle index, geometric mean	Substrate appeared very suitable for spawning and egg-to-fry survival.
Depth (m), velocity (m/s), top width (m), flow area (m^2), shear stress (Pa)	Physical measurements at multiple locations along the reach used to calibrate and validate hydrodynamic model	1994-2001	Hydrodynamic model to evaluate effects of physical changes on physical response variables. Two flows modeled – constant base flow and constant bankfull discharge. Treatment types assigned based upon specific criteria.	Baseflow – velocity (-24%), depth (+56%) & width/depth ratio (-34%) changed significantly. Bankfull – velocity (-17%), depth (+30%) & shear stress (-29%) changed significantly. width/depth ratio (+16% NS)
Hydraulic geometry – BACI				Area at 4 out of 8 example locations was significantly different due to a decrease resulting from deposition.
Thermal gain – BACI	Downstream & upstream	August 1992, 1993, 1996, 1997, 2001	Temperature gage	NS Diff.

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[18] Fish habitat measures include temperature, turbidity, contaminants/nutrients, barriers, substrate, large wood, pools, off-channel habitat, channel condition, streamflows, watershed land use.

[19] Fish population response measurements include redd / weir counts of spawners, age class of spawners, parr density / size, juvenile PIT tagging, juvenile emigrant abundance / size.

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Biological:				
Habitat types	Control and study sites	1994 1999 - 2001	Nez Perce National Forest basin wide survey methodology (in Lanigan et al. 1991) Modified Hankin-Reeves methodology (Hankin and Reeves 1988) 1994, habitat types were fit by length to the 1994 channel alignment, digitized from a fall 1994 longitudinal profile survey of water surface points. 1999-2001, field crews flagged breaks between habitat points, and these locations were later surveyed and used to divide the channel alignment, digitized from each year's water surface elevation survey, into discrete habitat types. ArcView Version 3.2 was used to calculate the surface area of each habitat type polygon from the low flow channel.	50% increase in channel length. Pool surface area at low flow remained constant at 10% Pool: riffle ration increased from 0.4:1 to 1.1:1. Runs and glides occupied 81% of the surface area.
Parr snorkeling densities – abundance and species composition.	Control and study sites	Middle to end of July from 1999 – 2001	Snorkeling counts of individuals by age class and habitat type following "well-documented methods" Used data from 1985 to 2001 from Idaho Department of Fish and Game (IDFG) General Parr Monitoring (GPM) and Idaho Supplementation Studies (ISS)	Rainbow & cutthroat fry and chinook parr experience large increases in 2001 compared to previous years however the change was not significant when compared with pre-restoration data. Chinook parr densities increased gradually since 1998.
Age 0 chinook density(BACI)				NS diff. during and after restoration relative to control.
Redd counts	Control and study sites	August to end of September annually since 1993.	Ground surveys conducted through each stratum and surveyed redd positions with GPS, noted size and adult chinook presence.	Large variability, no strong trends.

Key Results:

- "Direction and magnitude of physical response varied between different types of restored channel. Connection of the channel to its historic meanders played a major role in the changes because the lowest velocities, deepest depths, and lowest width/depth ratios occurred in this channel type while cross sections abandoned as part of the restoration had the highest width/depth ratio at baseflow.
- At baseflow, reach-median maximum depths increased 56% to 0.43 m, and velocities decreased 24% to 0.28 m/s following restoration. The changes resulted from greater pool frequency and depth, not continued incision of the channel. After restoration, depth and velocity at baseflow had shifted into a more suitable range for chinook rearing as defined by habitat suitability curves.
- At bankfull discharge, reach-median maximum depths increased 30% to 1.5 m, and velocities decreased 17% to 0.85 m/s following restoration.
- The frequency of pools increased by 50%, resulting in an even pool: riffle ratio.

- Percent fines in pool tail outs declined each year (but not significantly) despite the observation that median particle size was closely tied to peak flow from the previous spring and flows were less than bankfull since 1999.
- Although reach-median shear stress at bankfull discharge declined 29% to 15.5 Pa, median particle size did not change from 1997 to 2001, and a sufficient competence was maintained to transport fine material (< 6 mm) through most of the project reach.
- When evaluated using three different criteria (percent fines, Fredle index, and geometric mean), substrate appeared very suitable for spawning and egg-to-fry survival relative to published values in the literature.
- For the period during and after restoration (1997-2001), resident salmonid densities (rainbow and cutthroat trout combined) showed little change relative to two control reaches and 10 years of pre-restoration data.
- Densities of age 0 chinook increased gradually from 1998-2001, but, as a result of high natural variability, 10 years of post-restoration monitoring may be required to detect a doubling in chinook parr density relative to before restoration conditions.
- Low densities of the three resident salmonids and chinook parr suggest density dependence is not a problem and the project reach may be at least an order of magnitude below carrying capacity.
- The highest density of chinook parr in 2001 occurred at one of the few locations with an extensive growth of submerged aquatic vegetation.
- Year-round cover and warm temperatures during July and August continue to be limiting factors at the project reach. These conditions are expected to become less limiting as riparian vegetation establishes, but the biggest gains would likely result from addressing sediment supply and temperature at the watershed scale” (Clayton 2002).

Relevance to Columbia Basin:

This study demonstrates that restoration of stream meanders and floodplain conditions is both feasible and improves such physical variables as decreased velocity, increased depth at basefull and bankfull flow and decreased reach-median total shear stress. The results should be transferable to similar ecoregions and base conditions.

The power analysis conducted is very relevant to prospective experimental design. Further details on this analysis are provided below:

Variability of physical and biological parameters monitored was compared to that of similar parameters from other studies. Based upon observed variability, the number of years of monitoring at the project reach required to detect impacts in physical and biological parameters was estimated. For example, after five years of post-restoration monitoring, physical parameters (e.g., median particle size) would require a 19% change relative to baseline conditions to be detectable, but biological parameters (e.g., age 0 chinook densities) would require a 171% change to be detectable (one-tailed test, α=0.10, power=80%, equal variance before and after).

The Before-After, Control-Impact (BACI) approach was applied to two example physical parameters, hydraulic geometry (cross section area) and thermal gain, and one biological parameter, densities of age 0 chinook, to assess change following restoration. The results indicate physical parameters provide an important tool for detecting initial responses to stream restoration to ensure a site is evolving in an acceptable manner, but they do not preclude the importance of monitoring biological parameters.

Overall Conclusion on Restoration Action Effectiveness

"The results indicate physical parameters provide an important tool for detecting initial responses to stream restoration to ensure a site is evolving in an acceptable manner, but they do not preclude the importance of monitoring biological parameters. Biological parameters may be more resilient and capable of large changes over a short period whereas physical parameters may require a longer period to exhibit large changes. For example, fish densities might increase by 100% in a short time, especially if current densities were well below carrying capacity, but a 20% increase in median particle size might be unrealistic over the same period. Based on findings from this study, physical monitoring in stream restoration can complement biological monitoring to decrease time required until responses to restoration are detectable.

During the next several years, improving conditions at the project reach may be expressed as an increased number of redds on the project reach relative to the unrestored upstream and downstream reaches (redistribution) and increased chinook parr and resident salmonid densities relative to the two control reaches. High quality pool habitat is expected to develop following a period of wet years, or even a single occurrence of bankfull flow, and as riparian vegetation responds to the higher watertable.

The longer-term (years to decades) response and ultimate success of the reach-scale restoration may depend upon resolution of limiting factors controlled at the watershed scale. From a physical perspective, if the channel is resilient enough to transport the supply of water and sediment it receives from the watershed while maintaining its slope, sinuosity, and dimensions, it could be considered in equilibrium. From a biological perspective, an increase in the number of redds at the project reach, not just a redistribution of redds already in the area, and an increase in the abundance and size of smolt emigrating from the watershed relative to the adjacent unrestored watersheds might be considered the true test of success" (Clayton 2002).

Habitat selection by juvenile coho salmon in response to food and woody debris manipulations in suburban and rural stream sections

RPA 183 Actions Identified:

- Improved riparian conditions
    - Active stream restoration (includes instream structures)

Reference:

Giannico, G. R. 2000. Habitat selection by juvenile coho salmon in response to food and woody debris manipulations in suburban and rural stream sections. Canadian Journal of Fisheries and Aquatic Sciences. 57: 1804-1813.

Peer reviewed publication.

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Abstract:

This study explored the effects of food and woody debris manipulations on the summer distribution of juvenile coho salmon (*Oncorhynchus kisutch*) in small suburban streams. To examine fish responses to these factors, three different experiments were carried out in modified sections of two streams. The results showed that the distribution of juvenile coho salmon in a stream section was primarily controlled by the availability and distribution of food among pools and by the presence and density of woody debris. Food, however, played a dominant role because the foraging quality of a pool not only affected the density of fish in it but also the response of those fish towards instream debris. In food-rich stream sections, low proportions of juvenile coho salmon occupied pools with dense woody debris in the spring, which changed towards late summer. In contrast, in food-poor reaches, high proportions of fish were found in pools with abundant debris in the spring. Pools that combined abundant food with sparse woody debris were the most favored by the fish. It is important that salmonid habitat enhancement projects consider that open foraging areas interspersed with woody debris characterize the type of summer habitat that juvenile coho salmon prefer.

Watershed Name & Location:

Spring Creek, Chilliwack, BC and Coghlan Creek, Langley, BC.

Type of Habitat Restoration Actions and When Undertaken:

An experimental "arena" in Spring Creek had upstream and downstream limits set by two waterfalls with a net at the upstream waterfall and a trap box at the downstream. Four pools and three riffles were constructed using large gravel and cobble, and used for food manipulations. Three sites near the headwaters of Coghlan Creek were used as replicates. Each site was a glide with well-defined riffles at both ends. Three riffles of gravel and rocks were constructed within each glide to create four pools.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Objectives:

1. Investigate spatial distribution of juvenile coho in response to woody debris and food manipulations in stream habitat that has been altered by suburban residential development and farming activities
2. Determine whether such responses change over time.

Experiment 1:

H_1: Juvenile coho salmon distribution among pools is affected by woody debris availability and density.

H_2: Food abundance alters fish response to woody debris.

H_3: Fish response to woody debris changes over the summer.

A split-plot factorial was used with food (food vs. no food) as the main plot factor and woody debris (none, sparse and dense) as the subplot factor. Analysis of covariance (ANCOVA) was used.

Experiment 2:

H1: Juvenile coho salmon distribution among pools is affected by woody debris type (LWD vs. FWD)[20] and density.

H2: Fish response to woody debris changes over time.

A randomized block design (monthly replications) with two factors (debris and site) was examined using analysis of covariance (ANCOVA).

Experiment 3:

This experiment examined whether woody debris, food alone, or the combination of both factors controls the distribution of juvenile coho salmon among pools.

A randomized block design (monthly replications) with two factors (debris and cover) was examined using analysis of covariance (ANCOVA).

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[20] LWD = large woody debris; FWD = fine woody debris.

Response Measures Monitored (fish habitat, fish population):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Experiment 1				
Coho hatchery fry distribution	Spring Creek split channel section	May 24 – June 27 (early summer) August 18 – Sept. 9 (late summer)	50 fry released into each pool per trial. 10 trials / food treatment. 25 fry released into each pool per trial. 7 trials / food treatment.	The interaction between food and FWD had a significant effect. Woody debris density had a stronger effect on fish distribution in late summer than early summer. See key results below.
Experiment 2				
Wild juvenile coho distribution	Three Coghlan Creek sites.	Monthly from June – August.	Fish individually measured and returned to pools. Dover treatments randomly redistributed among pools before fish released back into pools.	Woody debris had a significant effect on pool choice.
Experiment 3				
Coho hatchery fry distribution	Spring Creek split channel section	July 22 – August 11	25 fish were released into each pool at the beginning of each trial. 11 trials were completed.	Food and the interaction between food and FWD had a strong effect on the distribution of fish among pools.

Key Results:

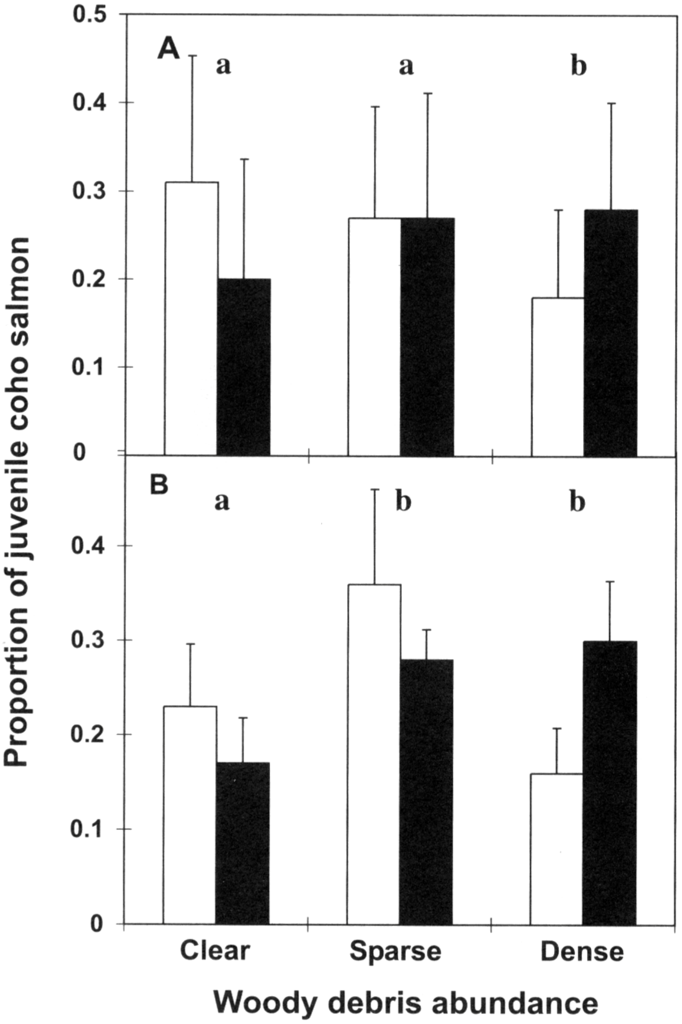

Figure 3. Experiment 1. Proportional distribution of Spring Creek coho salmon fry among channel pools receiving one of the following treatments: sparse FWD, dense FWD, or no woody debris. Channel treatments were food (open bars) or no food (solid bars) in (A) early summer and (B) late summer. Bars represent mean values and vertical lines represent 2 SE. Treatments with the same lowercase letters were classified in the same group with Tukey's test (a = 0.05).

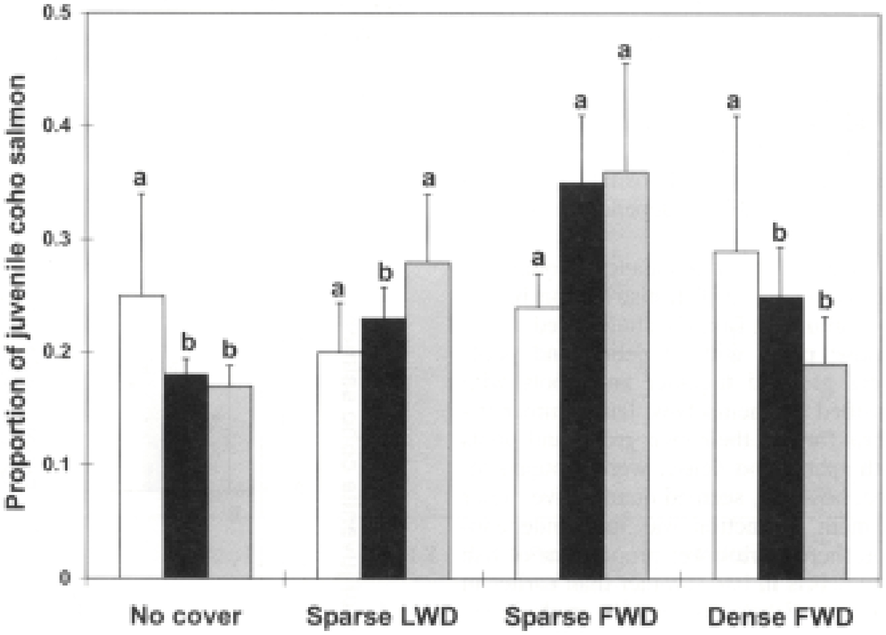

Figure 4. Experiment 2. Proportional distribution of Coghlan Creek coho salmon fry among pools that received one of the following treatments: no 1, cover, sparse LWD, sparse FWD, or dense FWD. Bars represent mean values for three different experimental sites and vertical lines,, indicate 2 SE. Open bars, June; solid bars, July; stippled bars, August. Within each month, treatments with the same lowercase letters were classified in the same group with Tukey's test (α= 0.05).

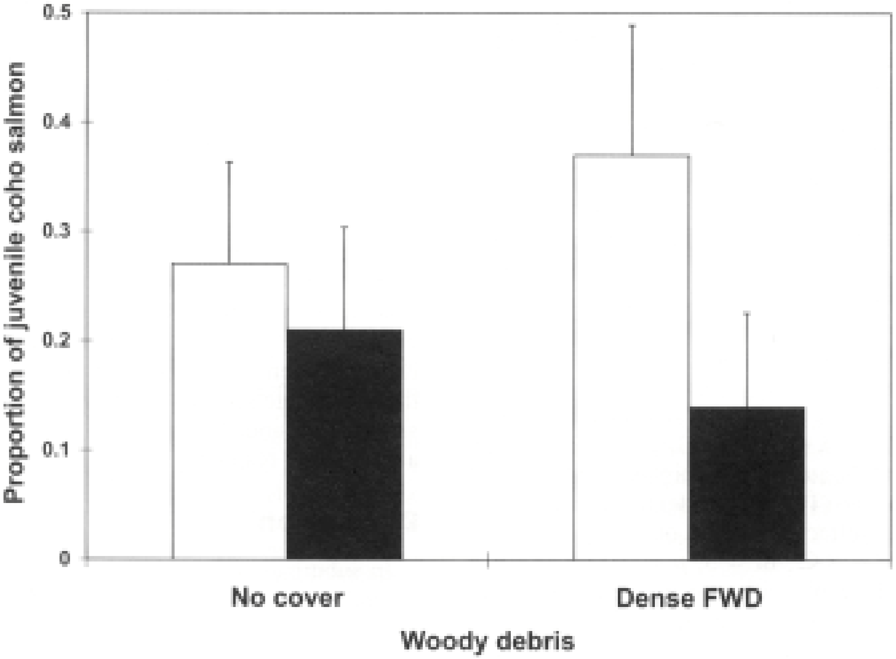

Figure 5. Experiment 3. Proportional distribution of Spring Creek coho salmon fry among pools receiving one of the following treatments: no cover food, cover and food, no cover and no food, and cover and no food. Bars represent mean values and vertical lines represent 2 SE. Open bars, food; solid bars, no food.

Relevance to Columbia Basin:

Both creeks ran through agricultural land with interspersed residential areas and are characteristic of the type of habitat that wild juvenile coho salmon find on the rural-urban fringe of the Pacific Northwest.

Overall Conclusion on Restoration Action Effectiveness

It is important to consider that high densities of woody debris in the stream channel can negatively affect juvenile coho salmon abundance just as is absence can. The results of this study indicate that open foraging areas interspersed with woody debris and small hydrological structures (waterfalls) characterize the summer habitat that coho prefer.

Increased Juvenile Salmonid Growth by Whole-River Fertilization

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients

Reference:

Johnston, N. T., C.J. Perrin, P.A. Slaney, and B.R. Ward. 1990. Increased Juvenile Salmonid Growth by Whole-River Fertilization. Canadian Journal of Fish and Aquatic Science. 47: 862-872.

Peer reviewed publication

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Abstract:

Nutrient concentrations, periphyton standing crop and size of steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) fry increased after the fertilization of a nutrient-deficient stream with inorganic phosphorus (P) and nitrogen (N). Whole-river fertilization of the Keogh River, British Columbia, during 1983–86 to increase summer average nutrient concentrations from <1 μg PL^{-1} to 10-15 μg PL^{-1} and 30-100 μg NL^{-1} resulted in five- to 10-fold increases in periphyton standing crops on artificial substrata and 1.4 to 2.0 fold increase in late-September salmonid fry weights. Diatoms and chlorophytes dominated the algal periphyton on artificial substrata at fertilized sites. Cyanophytes were unimportant despite low N:P ratios in some cases. Juvenile salmonids fed primarily on benthic insects. These results suggest that autochthonous primary production can be an important energy source in forested, middle-order streams, and indicate that the manipulation of autochthonous primary production can be a useful management tool to increase salmonid growth in nutrient-poor coastal streams.

Watershed Name & Location:

The Keogh River at the northeastern end of Vancouver Island, British Columbia.

Type of Habitat Restoration Actions and When Undertaken:

The lowermost 29 km of the river were continuously fertilized with N and P throughout the summer growing season from 1983–1986. The upper 3 km remained as an untreated control reach. The study occurred from 1976–1988.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

- BACI experimental design to assess the effects of inorganic fertilization on the weights of age 0+ coho salmon and steelhead trout fry. They compared the difference between paired measurements in control and fertilized reaches during treated and nontreated time periods.
- Analyses were done on log-transformed data. The additivity and independence assumptions were tested using the single degree of freedom test for nonadditivity and von Neumann's ration test.

Response Measures Monitored (fish habitat[21], fish population[22]):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)[23]
age 0+ coho salmon and steelhead trout fry wet weights and fork lengths	A series of locations within each treatment and control reach.	mid-summer (late July to early August) from 1976 – 1988 "end-of-growing-season" (late September to early October) 1983 - 1988	Censused fish populations in several adjacent habitats (each 10-15 m long) sealed with stop nets. Fish numbers were estimated based on 3 or 4 electrofishing circuits at each site.	Weights ⇑ during all years except coho fry during 1983 when nutrient concentrations were below target values. Fall coho fry weights were generally greater in treatment reach but there was no significant difference. Steelhead mean weight ⇑ 95% ; coho mean weight ⇑ 40%
Nutrient concentrations	Water samples in treatment riffles several km downstream of fertilizer dispensers.	Throughout the summer from 1975 – 1988.	Not described.	Target concentrations of 10 µg P·L^{-1} and 100 µg N·L^{-1} were met with the exception of P in 1983.
Periphyton standing crop - chlorophyll *a*	Control and several treatment sites	Several time series during each fertilization year.	Not described.	Weights ⇑ during all years except during 1983.
Invertebrates	At control and treatment sites	Monthly during 1981	Hess sampler of 0.05 m^2 with a 200 µm mesh net. Five samples at each of two riffles within each site.	Few differences between control and treatment sites.
Fry diet - stomach contents of steelhead and coho fry.	At control and treatment sites	1984 – mid-June and late September 1985 – monthly samples	Fish preserved in 10% formalin and contents removed and identified from 10 fry/species/site.	Benthic invertebrates were primary food.

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[21] Fish habitat measures include temperature, turbidity, contaminants/nutrients, barriers, substrate, large wood, pools, off-channel habitat, channel condition, streamflows, watershed land use

[22] Fish population response measurements include redd / weir counts of spawners, age class of spawners, parr density / size, juvenile PIT tagging, juvenile emigrant abundance / size

[23] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Key Results:

Fertilization with inorganic P and N resulted in significant increases in the mean weights of juvenile salmonids and substantial increases in periphyton standing crop.

Overall Conclusion on Restoration Action Effectiveness

The results indicate that manipulation of inorganic nutrient concentrations to increase primary production can be a useful technique to increase fish growth in nutrient deficient streams. The increases in steelhead and coho fry sizes may have important effects on smolt output from the river due to overwinter survival increasing with fry size. Increased smolt numbers and size are likely to increase adult returns since smolt-to-adult survival increases with smolt size in steelhead (Ward and Slaney 1988) and in coho (Hagar and Noble 1976).

Effects of livestock exclosures on riparian vegetation, stream geomorphic features, and fish populations

RPA 183 Actions Identified:

- Compliance with water quality standards
    - Alteration of grazing practices
- Improved riparian conditions
    - Alteration of grazing practices

Reference:

Kauffman, J.B., P. Bayley, H. Li, P. McDowell, and R.L. Beschta. 2002. Final Report. Research/ Evaluate Restoration of NE Oregon Streams: Effects of livestock exclosures (corridor fencing) on riparian vegetation, stream geomorphic features, and fish populations. By Oregon State University and the University of Oregon, Eugene, OR. Submitted to Greg Baesler, The Bonneville Power Administration. 93 pp.

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Abstract:

Exclusion of cattle along stream riparian corridors has been suggested to be an effective means of riparian/stream restoration benefiting both terrestrial wildlife as well as the aquatic biota. Construction of corridor fencing to exclude livestock has been accomplished along hundreds of kilometers of streams in the Columbia Basin, yet no studies have been undertaken to evaluate their efficacy. We sampled riparian vegetation composition along 11-paired grazed and exclosed (ungrazed) reaches in Northeastern Oregon streams.

Exclosure ages ranged from 3 to >30 years and grazing treatment ranged from light grazing every one out of three years to heavy season-long grazing. Rather than examine one type of grazing strategy we were interested if vegetation patterns could be detected between riparian areas with and without livestock influences. Each reach consisted of 20 to 30 channel units. In the middle of each channel unit on each streambank, we sampled herbaceous vegetation composition in a 1 x 4 meter plot placed at the streambank edge (the greenline). Shrub cover was measured along the greenline of each streambank of each channel unit. Stream cover and cover of emergents was also measured.

Species diversity was higher in exclosed reaches for all streams. Analyses detected a significant increase in the abundance of native sedges (*Carex* spp) in ungrazed areas. In contrast exotic species adapted to grazing such as *Poa pratensis* and *Trifolium repens* were more abundant in grazed stream reaches. In exclosures, the wetland indicator scores of the vegetation composition significantly decreased compared to grazed reaches. This indicates that along exclosed stream reaches wetland plant communities are

replacing ones adapted to drier environments. Shrub responses were slower than the responses of the herbaceous composition. Riparian-obligate shrub cover along the streambank was higher in 7 of 8 of the exclosures that were older than 5 years.

We conclude that cessation of livestock grazing resulted in shifts in vegetation structure and composition that would be favorable to the native aquatic and terrestrial biota. We found that cessation of livestock grazing was effective in increasing the biological diversity of the streamside riparian plant communities. The benefits, ecosystem services, and values of the riparian/stream exclosures increase through time and may not be fully realized until decades after exclusion. With increases in structure, we would expect vegetation to positively affect other ecosystem processes such as allocthonous inputs and sediment retention, thereby affecting the aquatic biota, water quality and stream geomorphology.

Watershed Name & Location:

11 streams in the Columbia Basin in Northeast Oregon:

- Bear Creek (Silvies) *
- Camas Creek *
- Chesnimnus Creek *
- Camp Creek *
- Devil's Run Creek *
- Middle Fork John Day
- Murderers Creek *
- Phipps Meadow *
- Summit Creek *
- Lower Swamp Creek
- Upper Swamp Creek
- Tex Creek *

* streams used for analysis of fish.

Type of Habitat Restoration Actions and When Undertaken:

The study was done in the year 2000. Each study stream had two reaches – a grazed reach and an exclosed reach that were geomorphically similar as possible:

- Grazed – livestock grazing (mostly cattle) was dominant in riparian zone and surrounding uplands (Reach A).
- Exclosed – livestock grazing eliminated through construction of riparian exclosures or corridor fences. Ages of exclosures ranged from 3 – 37 years. (Reach B).

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Geomorphic Response to Exclosures

Aimed to address to general questions:

1. Does passive restoration (fencing) have positive effects on channel geomorphology? More specifically, do fenced reaches display better geomorphic characteristics than adjacent grazed reaches?
2. Does response to fencing vary among sites? If so, what kinds of streams are most positively affected by fencing?

H_1: Fenced reaches would be narrower and deeper than grazed reaches and they would have more pool area and deeper pools than grazed reaches.

H_2: The level of response to fencing would be influenced by factors such as age of fencing, vegetation cover on streambanks, stream competence and channel unconstraint.

Used regression analysis to determine response to treatment.

Fish Response

Goal was to determine whether densities of fish were different in exclosed reaches compared to densities in reaches exposed to livestock.

H_1: There is no difference between observed numbers of fish in pools within vegetation exclosures and those in adjacent reaches open to livestock, from a set of paired summer samples in NE Oregon streams.

A generalized linear model, using the negative binomial distribution (Venables and Ripley 1999), was used to analyze count data.

Response Measures Monitored (fish habitat, fish population):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)[24]
Vegetation composition (herbaceous, shrub and stream cover)	At streambank edge (greenline) in 20 – 30 channel units per reach.	2000	1X4 m plots Calculated species richness, diversity (Shannon index) and similarity	Shrub, herbaceous cover ⇑ Species richness ⇑ Species diversity ⇑ Wetland species composition dominance ⇑ Bare ground ⇓
Channel reach geomorphology (channel width, depth, pool abundance and depth)	Regularly spaced intervals along the length of each reach	2000	Standard procedures - took multiple measurements of width and depth Identified channel units and measured units dimensions.	Significant improvements in all sites together. Channel depth ⇑ Channel width ⇓ Pool area ⇑
Fish inventory	From bottom of each study section and moved upstream	August 2000	Standardized snorkeling counts – number and size estimates by species. Physical characteristics of pool also measured	Young of the year salmonids ⇑ Adult salmonids ⇔ Warm water fishes ⇓
Temperature	Top & bottom of study section & border between fenced and unfenced sections. Pool outlets	Continuous records from late June to mid September Point temperatures at the time and pool of fish counts	Water temperature loggers Calibrated thermocouple or mercury thermometer	No significant difference.

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[24] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Key Results:

Vegetation

- We found significant differences in the cover, composition and structure of vegetation in all grazed/exclosed reaches. In the majority of exclosed reaches there were increases in the cover of forbs, shrubs, and sedges. Exposed bare ground was more extensive in grazed reaches.
- Wetland indicator scores, based upon streamside vegetation composition, indicate that cessation of livestock grazing results in a shift to more mesic wetland riparian vegetation.
- Species adapted to herbivory and drier environments were more abundant in grazed riparian areas.
- Plant species diversity and richness were higher in exclosed stream reaches.
- Composition of shrubs varied between streams. In 88% of the streams where exclosures were over 5 years old, the cover of riparian obligate shrubs (e.g., willows, alder, etc.) was greater in exclosures, with the greatest differences in exclosures over 20 years old.

Geomorphology

- Considering all sites together, livestock exclusion resulted in statistically significant improvements in channel geomorphology. The channels in the exclosed reaches are narrower, deeper, and have more pool area than the channels in the grazed reaches.
- At the level of individual sites, in most cases the exclosed reach was clearly narrower, deeper and had more pool area than the grazed reach at the same site.
- We did not detect any differences between fenced and grazed reaches in maximum pool depth or residual pool depth.
- Geomorphic response to livestock exclusion appears to be influenced by multiple factors, including age, vegetation cover, hydraulic conditions, and site geomorphology. Younger exclosures show less vegetation difference with the paired grazed reach and are less likely to show geomorphic adjustment. Other conditions, such as stream power, channel constraint and sediment supply may also limit the effectiveness of restoration projects.

Fish

- Densities of young-of-the-year redband trout (*Oncorhynchus mykiss)* were significantly greater in exclosed reaches compared to grazed reaches. Moreover, the effects of fencing were negatively associated with the dominant warmwater fishes, redside shiners (Richardsonius balteatus) and speckled dace (Rhinichthys cataractae), which are relatively uncommon in the best trout habitats.
- Conversely, we could not detect significant differences in densities of combined juvenile and adult life stages of salmonids between exclosures and grazed reaches, suggesting that recruitment bottlenecks exist and/or diurnal migrations within home ranges that extend beyond exclosure lengths may be occurring.
- Fish responses to cattle exclosures were weak because the best experimental design that we could construct from existing exclosures was limited by their lengths which were very small compared to the total stream habitat available and to the home ranges of the fish species of interest.
- Another limitation was that six out of the nine exclosures were below reaches of stream that were disturbed by grazing. The downstream effects of livestock grazing on the water column would more likely compromise benefits of fencing a relatively short distance of a small exclosure.
- The foregoing limitation partly explains why temperatures between grazed and fenced sections of streams were not significantly different.

Relevance to Columbia Basin:

The size and age of exclosures in this study are representative of exclosures throughout the interior Columbia Basin. The study points out interesting challenges with respect to the scale of restoration actions and the life history stages that are most appropriate to monitor for each scale.

Overall Conclusion on Restoration Action Effectiveness

Grazing exclosures are a simple, holistic, and effective restoration strategy. Changes in vegetation composition structure as well as geomorphic features suggest that livestock exclusion succeeds in restoring many important components of productive wildlife and fish habitats. A significant increase in young of the year salmonid density was evident across exclosures but a difference was not detectable for larger fish whose home ranges greatly exceeded exclosure lengths of this study.

Response of vegetation and geomorphology was greatest in the oldest exclosures suggesting the quality of fish and wildlife habitats increase with increasing exclosure age. Land management agencies and landowners should be encouraged to maintain exclosures as long-term investments in habitat restoration.

Small exclosures that cover only a few hundred meters of channel length may result in locally improved vegetation cover, channel geomorphology, and young-of-the-year salmonids but improvements in the density of adult fish populations or water temperature were not detected. Effective restoration of water quality and fish populations will require exclosures to be significantly longer than most of the exclosures currently in place in the study area.

They conclude the scale of the exclosures sampled in this study, (in terms of size and time) is too small to produce anticipated improvements in juvenile and adult coldwater fishes. Larger areas of livestock exclusion for long time periods will be necessary to restore salmonids. We suggest that more effective and efficient restoration can be accomplished by a strategic approach at the sub-basin scale, taking into account the lengths of, and distances between, exclosures and their locations with respect to the migratory patterns of salmonids in each sub-basin.

Many key questions about how and where to do restoration projects remain unanswered. Despite their strenuous efforts in site selection, the ex post facto research design of this study limited the strength of the research results. Monitoring of effectiveness of restoration projects must be improved. Preconstruction monitoring and ten to twenty years of post-construction monitoring should be initiated in a large number of new restoration projects. Monitoring should focus on ecosystem, habitat, and fish population changes. Further monitoring and research will lead to better decisions about location, scale, and methods of restoration projects.

A model-based approach to assessing the potential response of chinook salmon to habitat improvements

RPA 183 Actions Identified:

- Improved riparian conditions
- Active stream restoration (includes instream structures)

Reference:

McHugh, P. (Aquatic, Watershed, and Earth Resources). 2003. A Model-Based Approach to Assessing the Potential Response of Chinook Salmon to Habitat Improvements. Utah State University, Logan, Utah. 153 pp.

M.Sc. Thesis.

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Abstract:

The current recovery strategy for threatened Snake River chinook salmon relies heavily on improvements to freshwater spawning and rearing habitat quality; however, the potential survival benefit resulting from these actions is unknown. To address this issue, I created a model for predicting salmon early freshwater survival (egg-to-smolt) as a function of easily measured physical habitat variables, and used this model to evaluate survival under five alternative future habitat states. Predictions were reasonably accurate for individual stocks, as was the trend in predictions across stocks. Results from future habitat scenarios suggest that the potential for improving survival through habitat restoration actions is high for a few populations and low to nonexistent for most others, while the potential for reductions in survival due to reduced habitat quality is great for all populations. The effects of modeled egg-to-smolt survival changes on survival across the entire salmon life cycle, however, remain unknown.

In addition to assessing survival potential, I addressed a more basic question relevant to a habitat restoration-based recovery strategy through my thesis research: that is, what constitutes good habitat? Based on patterns of spawning site selection for two salmon populations, I created logistic regression models relating spawning site use to three easily measured physical habitat variables: depth, velocity, and substrate size. Resulting patterns were similar for both populations. However, there appeared to be stream specificity for site selection with regards to depth, with salmon generally spawning at the deepest sites available in a given stream. This specificity likely explains the poor transferability of models between the two streams. This analysis provides information on spawning habitat selection with additional implications for others using a logistic regression approach to assess habitat suitability for spawning salmonids.

Through my analyses, I have quantitatively evaluated two important aspects of habitat quality and restoration activities, as they relate to salmon management in the Snake River Basin. Together, these analyses illustrate the utility of simulation and empirically based statistical models in habitat assessment and provide a quantitative framework useful to planning and implementation phases of salmon recovery efforts in the Snake River Basin.

Watershed Name & Location:

Snake River Basin. Field habitat and survival data were collected for six index stock in upper Grande Ronde River (UGR), combined Big Sheep Creek/Lick Creek (BSC/LIC), Imnaha River (IMN), Elk Creek (ELK), Sulphur Creek (SUL), and Minam River (MIN).

Type of Habitat Restoration Actions and When Undertaken:

None taken. Collected field habitat and survival data during the summers of 2001 and 2002.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Goals:

- To evaluate the benefits of habitat restoration efforts aimed at reversing Snake River spring/summer chinook salmon stock decline using a habitat-based early salmon life history model, which could be used to evaluate the potential stock-level survival response to hypothetical habitat improvements.
- To answer the question “what constitutes good or preferred habitat for the adult spawning life stage?”

They analyzed patterns of chinook salmon spawning site selection for two populations and constructed multivariate spawning habitat suitability models:

- Used published experimental data and habitat-survival functions to create a model that predicts egg-to-smolt survival for a given stock as a direct function of field habitat measurements.
- Used only variables that both are targeted for improvement and affect the survival or productive capacity of a stock in a mechanistically explainable way: three sediment-related and two temperature-related variables (see table below).
- Model computed the survival component related to each of the five habitat variables independently, and the survival rates were subsequently pooled. Used a Monte Carlo simulation approach.
- Model validated through a comparison of the median predicted egg-to-smolt survival rate to the observed estimate for three index stocks that were not used in the model calibration phase (ELK, SUL, and IMN), within a regression framework.
- Used model to predict egg-to-smolt survival assuming three general future habitat states: status quo, restoration, and degradation. Status quo and degradation scenarios were modeled for all stocks, while restoration scenarios were evaluated for only the UGR and ELK stocks.

Response Measures Monitored:

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)
Model:	Variables below measured in primary spawning and rearing index are detailed in Beamesderfer et al. (1997). Sample sites based on channel units with ~ 10% of each stream sampled.	Summers of 2001 and 2002	
Percent fines in spawning gravels	Potential spawning sites – pool tails.		Particle size distribution data collected using Wolman pebble count method (Wolman 1954).
Riffle & pool cobble embeddedness			Hoop method from Skille and King (1988)
Mean temperature from egg deposition to fry emergence			
Daily temperature during the summer parr rearing period	2 – 4 sites along length of each reach.		Onset Optic Stowaway temperature loggers. Summarized as average of 18 measurements taken through the day.
Egg-to-smolt survival estimates	Obtained from data collected in study as well as state and tribal agencies working in index areas and published reports (see Appendix B)		

Key Results:

Status Quo

- Predicted egg-to-smolt survival from 1,000 Monte Carlo trials ranged from a low of 0.07 (UGR and ELK) to a high of 0.19 (see table below).
- Variability in the range of predictions was similar across all streams, with coefficients of variation (CV) ranging from 22–45%. These predictions closely matched current field estimates of observed survival.

Restoration

- Potential change in survival assuming a future increase in habitat quality was large for the UGR and minor for the ELK index stocks.
- Due to the limited opportunities for habitat improvements in SUL, MIN, IMN, and BSC/LIC, restoration scenarios were not modeled.
- Fix All scenario — egg-to-smolt survival was predicted to be 179% higher than it currently is predicted to be for the UGR index stock (0.07 vs. 0.19), and 27% higher for the ELK stock (see table below).
- Fix Feasible scenario — survival was nearly double that of Status Quo for the for the UGR stock, while it increased by only 20% for ELK.

- CVs for Fix All and Fix Feasible scenarios were minimal, ranging from 19 – 35%.
- Suggests that there is great potential for improving survival for UGR, but limited for ELK, via habitat restoration.

Degradation

- Survival was predicted to be considerably lower under the two increased degradation scenarios.
- Worse1 scenario (conditions get approximately 50% worse) – survival was predicted to be as low as 0.02 (UGR) and as high as 0.11 (BSC/LIC), with these changes approximating a 69 and 41% decrease from Status Quo predictions, respectively (see Table below).
- Worse2 (conditions get approximately 100% worse) – predicted egg-to-smolt survival ranged from a low 0.01 (UGR and ELK) to a high of 0.06 (BSC/LIC).
- There was considerable variability in the distributions of predicted survival rates for the 1,000 Monte Carlo trials across the six stocks, with CVs averaging 58 and 82%, for the Worse1 and Worse2 scenarios, respectively.

Table A1.4. Predicted egg-to-smolt survival for modeled scenarios, by index stream. Δ from Status Quo is the percent change in median survival from the Status Quo scenario. All results are for 1,000 Monte Carlo trials. CV = SD/Mean x 100. Table A1.2.4 from McHugh (2003).

Index Stock	Scenario	Median	Δ from Status Quo (%)	Range	CV
Elk Creek	Status Quo	0.07	-	0.02-0.20	45
	Fix all	0.09	27	0.02-0.16	34
	Fix feasible	0.08	20	0.01-0.19	35
	Worse1	0.03	-63	0.00-0.17	89
	Worse2	0.01	-90	0.00-0.14	142
Sulphur Creek	Status Quo	0.09	-	0.02-0.20	34
	Fix all	-	-	-	NA
	Fix feasible	-	-	-	NA
	Worse1	0.05	-47	0.00-0.17	61
	Worse2	0.02	-80	0.00-0.16	87
Minam River	Status Quo	0.14	-	0.05-0.28	36
	Fix all	-	-	-	NA
	Fix feasible	-	-	-	NA
	Worse1	0.06	-56	0.01-0.18	59
	Worse2	0.03	-78	0.00-0.12	75
Upper Grande Ronde River	Status Quo	0.07	-	0.01-0.14	40
	Fix all	0.19	179	0.04-0.32	19
	Fix feasible	0.13	86	0.07-0.24	23
	Worse1	0.02	-69	0.00-0.07	62
	Worse2	0.01	-92	0.00-0.16	79
Big Sheep / Lick Creeks	Status Quo	0.19	-	0.05-0.31	22
	Fix all	-	-	-	NA
	Fix feasible	-	-	-	NA
	Worse1	0.11	-41	0.01-0.25	34
	Worse2	0.06	-69	0.00-0.16	44

Index Stock	Scenario	Median	Δ from Status Quo (%)	Range	CV
Imnaha River	Status Quo	0.16	-	0.11-0.28	22
	Fix all	-	-	-	NA
	Fix feasible	-	-	-	NA
	Worse1	0.08	-51	0.04-0.19	40
	Worse2	0.03	-80	0.01-0.13	64

Relevance to Columbia Basin:

This study provides a tool for exploring the benefits of habitat restoration for the regions to which it has been calibrated. It would be valuable to explore how applicable this tool may be to other regions and watershed perturbations, and how much work would be required to adapt it. This kind of approach may be helpful to NOAA Fisheries, the USFWS and other agencies as they attempt to estimate the range of survival improvements that can be expected from habitat restorations in different ESUs or Recovery Unit areas.

Overall Conclusion and Application of Model

- Opportunities for improving egg-to-smolt survival through habitat restoration are high for a few stocks (e.g., UGR), but minimal for others (e.g., ELK, SUL, MIN); this disparity in improvement potential likely arises from differences in initial habitat conditions, the geomorphic and land use settings of watersheds, and the naturally high variability in egg-to-smolt survival in populations.

Application

They offer two ways in which the model can be useful to managers concerned with evaluating recovery options involving freshwater spawning and rearing habitat restoration:

- The overall survival benefit (across the entire life cycle) of alternative habitat restoration strategies can be evaluated by coupling egg-to-smolt survival predictions made using the model with a total life cycle model to compute relevant population growth parameters (e.g., λ, the population growth rate). Knowledge of population growth rates under different management scenarios could better enable managers in selecting the best recovery strategy.
- The model can be used to prioritize restoration activities within watersheds - there is a need for an objective tool for identifying areas within high-priority watersheds, where localized restoration activities could provide the greatest survival benefit to stocks in question.

Enhancement Effects of Spawning Pink Salmon on Stream Rearing Juvenile Coho Salmon: Managing One Resource to Benefit Another

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients

Reference:

Michael Jr., J. H. 1995. Enhancement Effects of Spawning Pink Salmon on Stream Rearing Juvenile Coho Salmon: Managing One Resource to Benefit Another. Northwest Science. 69(3): 228-233.

Peer reviewed publication

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Abstract:

This paper examines the relationship between the number and biomass of pink salmon spawning in the Skagit River and the resulting return of adult coho salmon which were rearing as age-0 fish in the watershed at the time of spawning. From 1967 through 1985, during the odd-numbered years, there is strong direct correlation between the biomass of pink salmon spawners present in the Skagit River and recruit per spawner for coho salmon present in the system as age-0 fish at the time of pink salmon spawning. Moderate flows, or at least the lack of large freshets in October, increase the benefit that pink carcasses provide. Further, the streamflow in summer shows a strong positive influence on recruit per spawner for coho salmon. Traditional salmon management has concentrated on one species at a time. In order to take advantage of the enhancement benefit conferred by pink salmon spawners it will be necessary to examine interspecies impacts, reduced consumptive fisheries, changes in land use activities and changes in stream flows from a much broader perspective than is presently employed.

Watershed Name & Location:

Skagit River, Washington

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Pink salmon spawning escapement, carcass biomass (including adjusted biomass), coho spawning escapement, Puget Sound Index (PSI), and Skagit River flows in October were regressed against coho recruit per spawner (R/S). The data came from a variety of sources listed below:

Variable	Source
Pink and coho escapement	Estimates were based on visual counts of live and dead fish in selected sections of spawning streams by the Washington Department of Fish and Wildlife (WDFW)
Total biomass of spawning pink salmon/year	Calculated by using mean weight of pink salmon caught in Skagit Bay and Skagit River by commercial fishermen. Adjusted by multiplying the carcass biomass by the inverse ratio of flow in October in that year to overall mean flow for all years.
Puget Sound Index (PSI)	Measure of summer low flows from a representative group of streams which discharge into Puget Sound. Data taken from United States Geological Survey files.

Key Results:

The return of adult coho salmon, expressed as a ratio of returning adults to numbers of spawners, shows a strong positive correlation with the biomass of pink salmon which spawned while the coho salmon juveniles were rearing in the river. As the amount of pink salmon carcass biomass entrained in the Skagit River system increased, the number of coho salmon adults per spawner increased.

Table A1.5. Pink salmon and coho salmon run size and carcass biomass and Skagit River flows. 1967-1985.

	Pink		Coho			*Skagit River Flow		Adjusted Carcass Biomass	
Year	Escapement number	Kilograms (kg)	Escapement number	R/S	Puget Sound Index	Peak cm	Mean cm	Peak Flow (kg)	Mean Flow (kg)
1967	100,000	235,000	25,500	0.677	6.602	1755	351	123,000	197,000
1969	100,000	254,000	21,000	1.244	8.477	733	378	318,000	197,000
1971	300,000	694,000	21,800	1.240	9.370	521	250	1,222,000	816,000
1973	250,000	624,000	19,800	1.263	6.512	708	249	808,000	735,000
1975	100,000	1,290,000	31,800	1.400	12.274	1480	170	180,000	501,000
1977	500,000	1,338,000	16,000	3.442	8.385	357	198	3,440,000	1,982,000
1979	300,000	680,000	14,100	1.521	6.610	614	230	1,015,000	870,000
1981	100,000	213,000	25,500	1.375	8.821	931	408	210,000	153,000
1983	470,000	938,000	9,000	3.479	12.765	422	218	2,039,000	1,266,000
1985	710,000	1,642,000	35,600	1.169	7.513	1647	485	914,000	994,000
Mean	293,000	690,800	22,010	1.681	8.733	917	294	1,026,900	771,100

Table A1.6. Single and stepwise regression analyses for selected variables.

Variables	df	r-sq	F-value	p
Single regressions				
ping kg-adj peak	8	0.762	25.55	<<0.001
ping kg-adj mean	8	0.656	15.26	0.005
coho escapement	8	0.428	5.99	0.040
peak flow	8	0.402	5.38	0.049
mean flow	8	0.246	2.60	0.145
Puget Sound Index (PSI)	8	0.239	2.52	0.151
pink escapement	8	0.229	2.38	0.162
pink kilogrammes	8	0.227	2.35	0.164
Stepwise regression				
adj kg-peak, PSI	7	0.895	29.84	<<0.001

Overall Conclusion

Based on the relationship between pink salmon and coho salmon and the potential for interactions with other salmonid species, it is obvious that decisions regarding spawner escapement levels for one species need to consider the impacts on, and interactions with, other species. There is a need to further study the relationship between nutrient level in streams and resultant fish populations. The relationships between fish production and development in a basin needs to be evaluated so resource management and utilization decisions can be made which will integrate the entire ecosystem rather than isolate each piece with decisions made in a vacuum.

Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams

RPA 183 Actions Identified:

- Improved riparian conditions
    - Active stream restoration (includes instream structures)

Reference:

Nickelson, T. E., M. F. Solazzi, S. L. Johnson, and J. D. Rodgers. 1992. Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49: 790-794.

Peer reviewed publication

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Abstract:

We examined the use of constructed pools by juvenile coho salmon (*Oncorhynchus kisutch*) during summer and winter. Log, gabion, and rock structures placed across the full stream width provided good summer habitat but poor winter habitat for juvenile coho salmon. Rearing densities in constructed habitats during summer and winter were generally similar to those in natural habitats of the same type, except that constructed dammed pools supported lower densities during winter than natural dammed pools. The addition of brush bundles to pools created by fullstream-width structures increased the density to juvenile coho salmon in dammed pools during winter, but not in plunge pools. We concluded that the development of off-channel habitat has the greatest potential to increase production of wild coho salmon smolts in Oregon coastal streams.

Watershed Name & Location:

Not listed. 21 coastal Oregon streams.

Type of Habitat Restoration Actions and When Undertaken:

During 1986 – 1989, previously constructed pools were sampled. The first category were pools created by construction of structures places across the full width of the stream channel (most common in coastal Oregon streams). The second category included constructed alcoves, quiet water areas or ponds excavated into the streambank. Also sampled were pools created by placement of boulders, log deflectors and other techniques.

Brush bundles were cabled to the streambank of a subset of pools following a second summer's sampling.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Evaluation of Constructed Habitat

Objective was to determine:

1. the average density of juvenile coho salmon associated with each type of habitat
2. the extent to which that density varied seasonally.

Performance measures used:

- Kolmogorov Simirnov test for normality of distributions
- Bartlett's test for homogeneity of variances among pool types
- Natural logarithm transformation of habitat-specific densities
- ANOVA to compare means of juvenile coho salmon density among types of pools constructed during the summer (unable to make comparisons during winter).

Bush Placement Experiment

Objective was to:

- test whether the placement of bundles of small trees (brush bundles) in constructed pools would increase the winter carrying capacity of pools for juvenile coho salmon.

Performance measures used:

- ANOVA to compare treatment and controls.

Response Measures Monitored:

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Juvenile Coho density Evaluation of existing constructed habitat	199 pools in 21 streams in summers, 181 pools in 19 streams during winters (subset of summer)	1986 – 1989 August to mid-October for summer and December to mid-February for winter	Blocked pools with seines and did mark-recapture estimate using electrofishing. Estimated surface area and calculated density of coho for each pool. Pools classified according to type (plunge, dammed, scour or alcove)	No sig. diff. in density among types of constructed pools in summer. Constructed alcoves support greater density during winter plunge or dammed (not tested statistically) Density in constructed dammed pools in winter sign. < natural dammed pools.
Juvenile Coho density Evaluation of brush placement	Same as above	Same as above	Same as above	Density in pools with brush sig. > those without (dammed pools but not plunge pools) Addition of brush ⇑ density in constructed dammed pools in winter to a level not sig. different from natural pools.

Key Results:

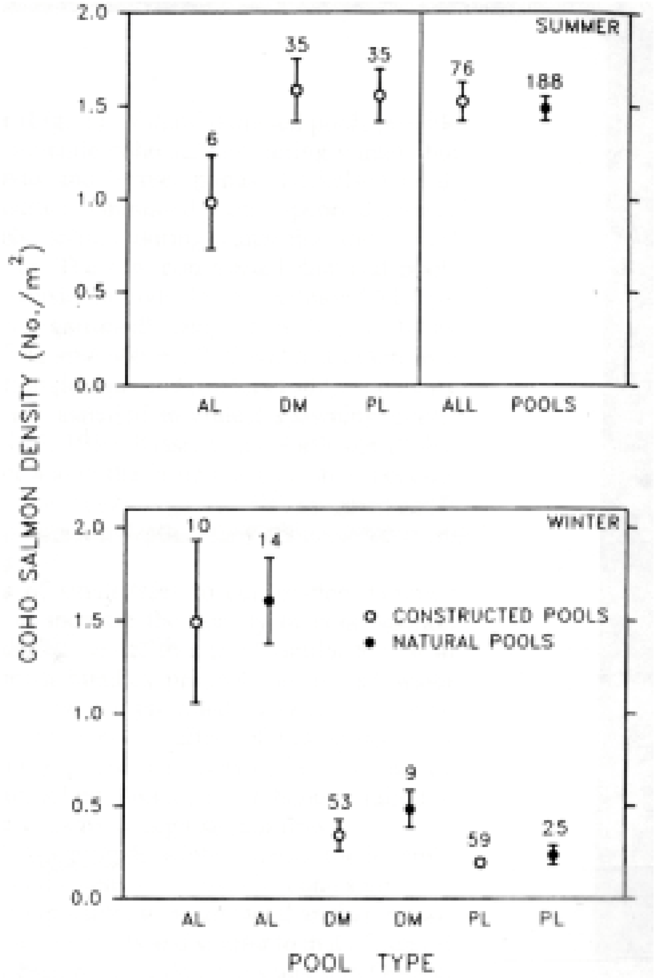

Figure A.4. Mean and standard error for density of juvenile coho salmon in constructed and natural pools during summer and winter. the standard error for constructed plunge pools is smaller than the point for the mean. Sample size is shown above each pool type. AL=alcove; DM=dammed pool; PL=plunge pool. (Figure 1 Nickelson et al. (1992))

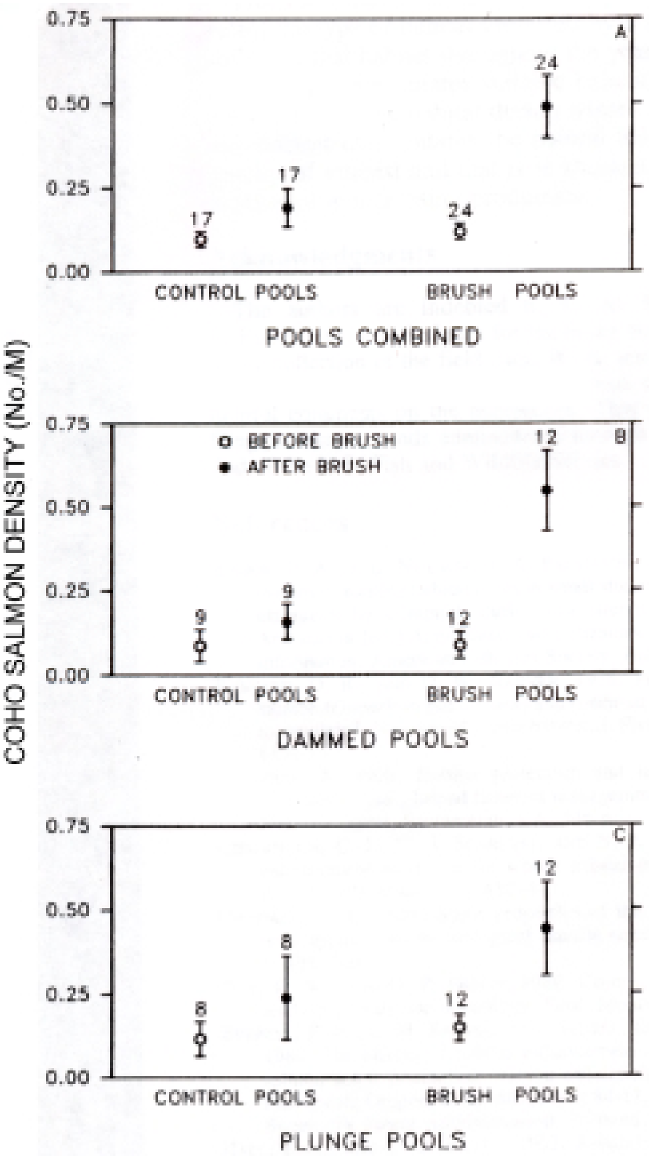

Figure A.5. Mean and standard error for winter density of juvenile coho salmon in constructed pools in the years before and after the addition of brush. The comparisons are between control pools, which received no brush, and brush pools, to which brush was added in the second year, for (A) all pools combined, (B) dammed pools, and (C) plunge pools. (Figure 2 Nickelson et al. (1992))

Adding bundles of small trees to constructed dammed pools increased the density of coho salmon inhabiting pools during the winter to a level similar to that in natural pools.

Relevance to Columbia Basin:

Coastal coho streams all in OR S of the Columbia. Relevant to Lower Columbia subbasins. General principle of identifying limiting factors *before* implementing habitat restoration is very relevant to all species.

Overall Conclusion on Restoration Action Effectiveness

The construction of full-width structures resulted in the creation of habitat suitable for rearing of juvenile coho salmon during the summer.

This study demonstrated that the type of habitat preferred by a species and the availability of that habitat throughout the year must be considered when planning habitat enhancement. Creation of suitable summer habitat may not create suitable winter habitat. Imitating the natural habitat preferred by the species of interest and that is in shortest supply will likely be successful in increasing production.

Statistical relationship between parr-to-smolt survival of Snake River spring-summer chinook salmon and indices of land use

Reference:

Paulsen, C. M., and T. R. Fisher. 2001. Statistical Relationship Between Parr-to-Smolt Survival of Snake River Spring-Summer Chinook Salmon and Indices of Land Use. TAFS 130: 347-358.

Peer reviewed publication

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Abstract:

We used simple regression models to demonstrate an association between land use and parr survival of chinook salmon *Oncorhynchus tshawytscha* from overwintering areas in the Snake River drainage of Idaho and Oregon to the first main-stem dam encountered during emigration to the Pacific Ocean. We used data on PIT-tagged (passive integrated transponder tags) releases of naturally produced Snake River spring-summer chinook parr and subsequent tag detections, as well as indices of land use, vegetation, and road density. We spot-checked the landuse and vegetation indices in a field survey of spawning and rearing areas in the summer of 1999, and we believe that they are reliable indicators of land-use patterns. The models also employed month of release, length of parr at release, and a drought index as independent variables. The models were developed and tested using parr tagged from 1992 through 1998.

Age-0 parr that reared in wilderness areas (a land-use category; not necessarily federally designated Wilderness Areas) had the highest survival during their last 6-9 months of freshwater residence. In contrast, parr that reared in young, dry forests (typically, intensively managed timber lands) had the lowest survival. Similarly, parr that reared in areas of low road density had substantially higher survival than those in areas of high road density.

We concluded that in the area studied there is a close association between land-use indices and survival of chinook salmon parr during their last 6-9 months of freshwater residence. This analysis suggests that road-building and associated land-use activities in the region may have a detrimental effect on the survival of juvenile chinook salmon and that mitigative changes in these activities could be warranted because Snake River spring-summer chinook salmon are listed as threatened under the Endangered Species Act.

Watershed Name & Location:

Snake River drainage of Idaho and Oregon to the first main-stem dam – Lower Granite.

Type of Habitat Restoration Actions and When Undertaken:

Not applicable.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Used three simple regression models (No land use, land use category and road density) to determine association between land use and coho parr survival. See paper for details.

Response Measures Monitored:

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Coho parr survival – marked age-0	20 release sites (see table 2 in paper)	1992 - 1998	Data taken from the regional database - PIT Tag Information system. Three models used with survival estimates.	NA

Key Results:

The model with no land use shows a positive, highly significant relationship between length at tagging and the drought index and survival, but month of tagging is not very important.

The land-use category model shows that fish overwintering in older dry forests and wilderness areas have significantly higher survivals than those in young, dry forests.

The model using road density shows a significant negative relationship between road density and survival, but it does not explain much more of the variance than does the null model.

The drought index shows a positive relationship with survival for all three models; cooler, wetter weather is evidently better for parr survival. Length at tagging also has a positive relationship with survival; bigger is better for all three models. Neither individual observations (those with a Cooke's D. 1) nor individual sites or years had much influence on the model results; estimated coefficients changed only slightly when single observations, all observations for a release site, or all observations for a single year were omitted from the models. The residuals satisfy tests for normality for both models.

Table A1.7. Estimated parameters for the three models (Table A1.7 Paulsen and Fisher (2001))

Parameter[a]	Definition	Estimate	SE	x^2	P
Model: No land use					
Intercept		-0.123	0.090	1.863	0.172
Length		0.003	0.001	15.424	<0.0001
PDSI	Palmer drought severity index, July-December, in year of tagging	0.018	0.003	30.330	<0.0001
Month	Month of tagging	0.013	0.012	1.240	0.265
Model: land use category					
Intercept		-0.402	0.094	18.286	0.0001
Ag	1 if agricultural (Ag) land use, else 0	0.50	0.029	2.966	0.085
Mdry	1 if moderate age, dry forest (Mdry) land use, else 0	0.056	0.025	4.920	0.085
Tran	1 if transitional forest (Tran) land use, else 0	0.014	0.024	0.344	0.0265
Wild	1 if wilderness area (Eild) land use, else 0	0.130	0.025	27.702	0.5575
Ydry	1 if young, dry forest (Ydry) land use, else 0	N/A	N/A		
Length	Mean chinook salmon total length at tagging (mm)	0.003	0.001	15.924	<0.0001
PDSI	Palmer drought severity index, July-December, in year of tagging	0.021	0.003	49.922	<0.0001
Month		0.037	0.011	11.117	0.0009
Model: Road density					
Intercept		-0.177	0.090	3.892	0.0485
Road density		-0.025	0.009	7.333	0.0068
Length		0.003	0.001	18.159	<0.0001
PDSI	Palmer drought severity index, July-December, in year of tagging	0.016	0.003	26.148	<0.0001
Month	Month of tagging	0.019	0.012	2.643	0.104

Relevance to Columbia Basin:

This study is helpful in showing that PIT-tag estimates of parr to smolt survival may be a very useful index for capturing the effects of habitat restoration actions which affect this life history stage.

Overall Conclusion

The results of their analysis suggest a strong association between land use and overwintering survival. The association seems to follow common knowledge. Wilderness areas are associated with the highest survival among the five land use categories. The wilderness area coefficient—a 13% increase in survival compared with young, dry forests (Table above) is particularly interesting. This increase may not seem very high, but the overall average survival for all sites and years is only 22%.

Increasing road density is also associated with lower overwinter survival. The other independent variables are also associated with survival in ways that seem sensible: larger fish are more likely to survive than smaller ones, fish tagged later in the year survive at higher rates than those tagged earlier, and cool and moist weather is beneficial to survival.

Fish habitat restoration in the Pacific Northwest: Fish Creek of Oregon

RPA 183 Actions Identified:

- Improved riparian conditions
    - Active stream restoration (includes instream structures)

Reference:

Reeves, G.H., D.B. Hohler, B.E. Hansen, F.H. Everst, J.R. Sedell, T.L. Hickman and D. Shively. 1997. Fish habitat restoration in the pacific northwest: Fish Creek of Oregon. Pp. 335-359 . in: J.E. Williams, C.A. Wood and M.P. Dombeck (Ed.). Watershed Restoration:Principles and Practices. American Fisheries Society, Bethesda, Maryland.

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Abstract:

None – book chapter. Key findings summarized below.

Watershed Name & Location:

Fish Creek watershed, north-central Oregon. Drains into the upper Clackamas River. Wash Creek

Type of Habitat Restoration Actions and When Undertaken:

- Construction was between 1983 and 1988.
- More than 500 structures were built that were combinations of logs and boulders anchored together with cable and epoxy and located along the streambank.
- Off-channel ponds were created at the lower end of Fish Creek.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

Goal was to increase the amount and complexity of pool habitat for summer and winter rearing and the amount of spawning habitat for all anadromous salmonids (coho salmon, steelhead, rainbow and cutthroat trout) and to rehabilitate riparian vegetation to increase shading and decrease water temperatures.

Response Measures Monitored:[25]

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Available habitat		Late summer 1982 – 1985 1985 - 1995	Surface area and volume of habitat units measures with a tape. Reach estimates summed and extrapolated to estimate total available habitat Estimated using procedure of Hankin and Reeves (1988). Five habitat types were identified (pools, riffles, glides, side channel & beaver ponds)	Pool habitat ⇑ from 11% in 1982 – 39% in 1995 Glide habitat ⇓.from 15% in 1986 to 4% in 1995 Riffle habitat ⇔.57%
# of juvenile anadromous salmonids	8 sites, 36 habitat units	Late summer, annually 1982 – 1984 1985 – 1995	Backpack electroshockers at small sites, snorkel counts at large sites. Method of Hankin and Reeves (1988) Data from 1982 & 1983 excluded	Fish Creek: Coho ⇓41.8% (not significant) ⇑ 14.8% longer (significant) Steelhead YOY ⇓ 53.2% (sig.) age-1 ⇑ 11.7% (NS) smolts ⇑ 27.7% (NS) YOY ⇑ 12.5% in length (sig.) Age-1 ⇑ 4.1% (sig.) Upper Clackamas No sig. diff from Fish Creek Coho ⇓ 19.8% Mean annual return: coho ⇓ 5.1% (NS) steelhead ⇓ 41.1% (NS)
# of smolts departing	0.2 mile upstream from mouth of creek – fish directed into trap.	Spring (mid-March through mid-June) 1985 – 1988 1989 - 1995	Captured in a modified Humphrey trap (Everest et al. 1988) Revolving helix-screw trap (Reeves et al. 1990)	Coho ⇑ 12.7% (not significant) ⇑ 6.8% longer (not significant)

Key Results:

- The restoration effort created habitat and increased the size and number of steelhead smolts and juveniles but not coho.
- Habitat changes favored older classes of steelhead – this could be due to complex nature of the pools created. This would have increased visual isolation among individuals, may have increased food production and availability and reduced energy expenditures for food capture, and may have increased survival.
- Major flooding occurred in Nov. 1995 and Feb. 1996 causing severe damage to stream channels and adjacent slopes – many landslides.
- 50% of habitat restoration structures were destroyed.

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[25] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Relevance to Columbia Basin:

The terrain is steep and mountainous with bluffs in the lower canyons typical of the Columbia River basalt formation. Study results should be applicable to coho and steelhead in similar terrain. Valuable general lessons (see next section).

Overall Conclusion on Restoration Action Effectiveness

- The physical objective of creating pool habitat was achieved fairly quickly after construction.
- The biological response is difficult to assess prior to the floods as few measures were statistically significant. However, the efforts did appear to be successful for steelhead prior to the floods. Cannot conclude that restoration was successful for coho salmon.
    - It is possible that factors of a spatial scale larger than the Fish Creek watershed may have confounded the evaluation of the habitat restoration on coho. The relatively steep nature of Fish Creek makes it marginal habitat for coho.
    - The magnitude of declines in juvenile coho was 8X > decline in upper Clackamus River – decline in juvenile #'s could have been partially attributable to declining adult returns.

Lessons

- Adaptive management through evaluation of restoration concurrently with the restoration effort allowed immediate feedback before finalizing designs.
- The criteria for assessing the success of the effort should have been established at the start of the project and not be based solely on statistical differences. They didn't establish a priori what expected increase in numbers of salmonids would indicate success. Other criteria such as changes in growth or survival rates could have been established.
- Different species/age-classes may not respond in the same manner and this should be recognized when establishing objectives and expectations for restoration.
- Successful restoration is dependent on restoring in-channel and upslope conditions. Efforts should have been made to address upslope conditions more aggressively in Fish Creek.

A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds

Reference:

Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M Pollock, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. N.A. J. Fish. Man. 22: 1-20.

Peer reviewed publication.

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Abstract:

Millions of dollars are spent annually on watershed restoration and stream habitat improvement in the U.S. Pacific Northwest in an effort to increase fish populations. It is generally accepted that watershed restoration should focus on restoring natural processes that create and maintain habitat rather than manipulating instream habitats. However, most process-based restoration is site-specific, that is, conducted on a short stream reach. To synthesize site-specific techniques into a process-based watershed restoration strategy, we reviewed the effectiveness of various restoration techniques at improving fish habitat and developed a hierarchical strategy for prioritizing them. The hierarchical strategy we present is based on three elements: (1) principles of watershed processes, (2) protecting existing high-quality habitats, and (3) current knowledge of the effectiveness of specific techniques. Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed.

Key Results:

Instream Habitat Restoration

Table A1.8. Summary of studies evaluating structure durability and function in the Pacific Northwest. Note that most studies did not break down success rate by structure type (NA = data not available).

Study	N	Years after placement	Percent of structures functioning					
			Log weirs	Rock weirs	Deflectors	Natural logs or jams	Gabions	Total
Ehlers (1956)[a]	41	18	33	0	50		0	24
Armantrout (1991)[b]	362	5	70	93		88	90	85
Frissell and Nawa (1992)[c]	155	1-5	32	46	33	74		39
Roper et al. (1998)[d]	3,946	NA	NA		NA	NA		84
House et al. (1989)[a]	812	1-8	NA	NA	NA	NA	NA	86
Thom (1997)[c]	143	1	NA	NA	NA	86		86
Crispin et al. (1993)[a]	200	1-4	NA	NA	NA	NA		98
House (1996)[a]	22	6-12	100	100	100	100	100	100

[a] Functioning defined as in place and functioning as intended.
[b] Functioning defined as improving habitat.
[c] Functioning defined as functioning as intended.
[d] Functioning defined as in place, or largely in place, but shifted.
[e] Functioning defined as no movement or movement less than one bankfull width.

Table A1.9. Summary of juvenile salmonid response (0 = no response, + = positive response, - = negative response) to instream habitat restoration from published studies in the Pacific Northwest; asterisks (*) indicate results were significant at $\alpha = 0.05$. Structure types were categorized as large woody debris structure (LS), naturally placed large woody debris (LN), gabion (G), and boulder clusters or structure (B). States or provinces include British Columbia (BC), California (CA), Idaho (ID), Oregon (OR), and Washington (WA). Trout fry were young-of-year cutthroat trout or steelhead; salmon species and other steelhead and cutthroat trout were age-0 parr, age-1, or older juveniles. Sources: Ward and Slaney (1981); Moreau (1984); House and Boehne (1986); House et al. (1989); V.A. Poulin and Associates (1991); Slaney et al. (1994); Chapman (1996); House (1996); Cederholm et al. (1997); Reeves et al. (1997); Solazzi et al. (2000).

Stream	Region	Years of monitoring	Structure type(s)	Coho salmon	Trout fry	Cutthroat trout	Steelhead	Chinook salmon
Summer sampling			LN	+*				
Bonanza Creek	BC	2	LS, B	+*			+*	
Keogh River	BC	3	LN					
MacMillan Creek	BC	3	LN	+				
Nechako River	BC	1	LN					+
Sachs Creek	BC	2	LN	+	-		+	
Southbay Creek	BC	3	LN		+			
Hurdygurdy Creek	CA	2	B				+	
Crooked Fork Lochsa River	ID	1	LS				0	0
Crooked River	ID	1	LS, LN, B				+*	0
East Fork Paopoose Creek	ID	1	LS		0		+*	

Stream	Region	Years of monitoring	Structure type(s)	Coho salmon	Trout fry	Cutthroat trout	Steelhead	Chinook salmon
Lolo Creek	ID	4	LS, B				0	+
Papoose Creek	ID	4	LS				+*	0
Red River	ID	1	LS, B				0	0
Squaw Creek	ID	4	LS				+*	+*
Alsea River	OR	8	LS, AL	+*	0	0	0	
East Beaver Creek	OR	6	G	+	+	+	0	
East Fork Lobster Creek	OR	9	B, G	+*	0	+*	0	
Fish Creek	OR	13	B, G	-	-		0	
J-Line Creek	OR	5	LS, B, G	+		-	-	
Little Lobster Creek	OR	5	B	+	0	-	-	
Lobster Creek	OR	3	B, LS	+	+	+	-	
Lower Elk Creek	OR	4	LS, B	+		0	-	
Nestucca River	OR	8	LS, AL	+*	0	0	0	
South Fork Lobster Creek	OR	2	LS		+	+		
Steamboat Creek	OR	1	LS, B				+*	
Tobe Creek	OR	3	G	+	+	+	+	
Upper Lobster Creek-1	OR	3	G	+	+	+	+	
Upper Lobster Creek 2	OR	5	B, LS	0	0	0	0	
Porter Creek	WA	6	LS, LN	0	0		0	
Winter sampling								
Steamboat Creek	OR	1	LS, B				+*	
Porter Creek	WA	6	LS, LN	+	0		0	
Spring sampling								
Nechako River	BC	1	LN					+*
Porter Creek	WA	6	LS, LN	0	0		0	
Spring smolt trapping								
Alsea River	OR	8	LS, AL	+*		+	+*	
Fish Creek	OR	13	LS, B, G	0	-*		+	
Nestucca River	OR	8	LS, AL	+*	0	+*	+*	
Porter Creek	WA	6	LS, LN	+*				

Relevance to Columbia Basin:

The paper includes studies inside and outside Columbia Basin; most helpful for suggesting a hierarchical approach to habitat restoration.

Overall Conclusion on Restoration Action Effectiveness

In general, restoration of instream structure with large woody debris and boulders has negligible to positive effects on local desnities of juvenile coho, cutthroat trout and steelhead; negative effects are much less commonly observed. Effects on overall smolt production pr spawner are not well established.

Knowledge about the effectiveness of most techniques is incomplete and comprehensive research and monitoring are needed. Even techniques that appear to be well studied, such as instream LWD placement, need more thorough evaluation and long-term monitoring.

Density and size of juvenile salmonids in response to placement of large woody debris in Western Oregon and Washington streams

RPA 183 Actions Identified:

- Improved riparian conditions
- Active stream restoration (includes instream structures)

Reference:

Roni, P. and T.P. Quinn. 2001. Density and Size of Juvenile Salmonids in Response to Placement of Large Woody Debris in Western Oregon and Washington Streams. Canadian Journal of Fisheries and Aquatic Sciences. 58: 282-292.

Peer reviewed publication.

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Abstract:

Thirty streams in western Oregon and Washington were sampled to determine the responses of juvenile salmonid populations to artificial large woody debris (LWD) placement. Total pool area, pool number, LWD loading, and LWD forming pools were higher in treatment (LWD placement) than paired reference reaches during summer or winter. Juvenile coho salmon (*Oncorhynchus kisutch*) densities were 1.8 and 3.2 times higher in treated reaches compared with reference reaches during summer and winter, respectively. The response (treatment minus reference) of coho density to LWD placement was correlated with the number of pieces of LWD forming pools during summer and total pool area during winter. Densities of age-1+ cutthroat trout (*Oncorhynchus clarki*) and steelhead trout (*Oncorhynchus mykiss*) did not differ between treatment and reference reaches during summer but were 1.7 times higher in treatment reaches during winter. Age-1+ steelhead density response to treatment during summer was negatively correlated with increases in pool area. Trout fry densities did not differ between reaches, but the response of trout fry to treatment was negatively correlated with pool area during winter. Our research indicates that LWD placement can lead to higher densities of juvenile coho during summer and winter and cutthroat and steelhead during winter.

Watershed Name & Location:

30 streams in western Oregon and Washington.

Type of Habitat Restoration Actions and When Undertaken:

Artificial placement of large woody debris. Sampled existing LWD projects. Age of restoration ranges from 1 to 10 years.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

H_0: Paired treatment and reference reaches would not differ in (i) densities of woody debris and pool area or (ii) densities of juvenile coho cutthroat and steelhead in summer and winter and that (iii) the magnitude of fish response to treatment would not depend on the magnitude of change in habitat and (iv) the sizes of the fish would not differ between treatment and reference reaches.

LWD classified into three categories:

1. Dominant – primary factor contributing to pool formation
2. Secondary – influences zone of channel scour but not responsible for pool formation
3. Negligible – may provide cover but not involved in scour.

Statistics:

- Differences in habitat, LWD and fish abundance between reaches were compared with paired *t* tests with a Bonferroni correction applied.
- Multiple regression used to examine response between fish response and difference in physical variables.

Response Measures Monitored:[26]

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
All	Treatment and reference reaches in same stream. Reference 200m or more upstream from treatment.	Summer and winter between August 1996 and April 1999.		
LWD loading			Modification of methods in Bisson et al. (1982)	Sig. ⇑ in treatment than reference in summer (20–80 vs. 8-63, $p < 0.01$; avg. 1.83) and winter (16–78 vs. 4-64, $p < 0.01$; avg. 1.89)
LWD forming pools (functioning)			"	⇑ 2.83 (summer) & 2.96 (winter)
Total pool area			"	⇑ 1.52 (summer) & 1.51 (winter)
Total wetted area			"	⇑ 1.11 (summer) & 1.08 (winter)
Total riffle area			"	⇔

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[26] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)
Pool number			“	⇑ 1.31 (summer) & 1.48 (winter)
Habitat units			“	⇑ 1.11 (summer) & 1.22 (winter)
Juvenile coho density			Multiple-removal electrofishing in summer (Carle and Strub 1978) Night snorkel surveys in winter (Roni and Fayram 2000) during outmigration.	1.8 and 3.2 times higher in treated during summer and winter (see table below for details)
Cutthroat trout age-1+ density			“	⇔ summer ⇑ 1.70 winter
Steelhead trout age-1+ density			“	⇔ summer ⇑ 1.73 winter
Trout fry density				⇔ summer or winter
Juvenile coho length				⇔ summer or winter
Cutthroat trout age-1+ length				⇔ summer or winter
Steelhead trout age-1+ length				⇔ summer or winter
Trout fry length				⇔ summer or winter

Key Results:

Table A1.10. Ratio (geometric mean) of salmonid densities for treatment to reference reaches for all 30 sites combined and separated by state.

Species	Oregon	Washington	All sites
Summer			
Coho salmon	2.08*	1.55	1.81*
Cutthroat trout (age 1+)	1.10	1.55	1.27
Steelhead trout (age 1+)	1.03	1.37	1.19
Trout fry	1.31	1.05	1.21
Winter			
Coho Salmon	4.25*	2.33*	3.23*
Cutthroat trout (age 1+)	1.90*	1.44	1.70*
Steelhead trout (age 1+)	1.82*	1.48	1.73*
Trout fry	1.25	1.24	1.25

Salmonid densities and LWD

Summer

- Positive linear relationship between response of summer coho and the number of functioning LWD (p <0.01 r^2 = 0.25)
- No significant relationship between coho and other physical variables
- No significant relationship between cutthroat trout response to treatment and any physical variables
- Negative linear relationship between response of age-1+ steelhead trout to the difference in pool area (p <0.01 r^2 = 0.32) and percent pool area (p <0.01 r^2 = 0.45).
- Positive linear relationship between response of age-1+ steelhead trout difference in riffle area (p <0.01) but not with any other variables.

Winter

- Positive linear relationship between response of coho and pool area and restoration type (p <0.01 r^2 = 0.38) but not with any other variables.
- No significant relationship between cutthroat or steelhead response to treatment and any physical variables.
- Negative relationship between trout fry and difference in percent pool area (p <0.01 r^2 = 0.20).

Relevance to Columbia Basin:

Some of the study streams were coastal streams in Oregon. All study streams were located in Washington and Oregon.

Overall Conclusion on Restoration Action Effectiveness

- Found an overall increase in pool area, number of pools and LWD loading.
- Results provide strong evidence that artificially places LWD leads to significantly higher densities of juvenile coho in summer and winter and higher densities of cutthroat and steelhead during winter, particularly at sites deficient in wood to begin with.
- Study was not designed to determine the effectiveness of individual projects but it does provide insight into factors that make project successful.
- Focus was on forested sites – urbanized and agricultural areas may be different.

Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams

RPA 183 Actions Identified:

- Improved riparian conditions
- Active stream restoration (includes instream structures)

Reference:

Solazzi, M. F., T.E. Nickelson, S.L. Johnson, and J.D. Rogers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences. 57: 906-914.

Peer reviewed publication.

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Abstract:

We used a BACI (before-after-control-impact) experimental design to examine the effects of increasing winter habitat on the abundance of downstream migrant salmonids. Two reference streams and two treatment streams were selected in the Alsea and Nestucca basins of Oregon. Population parameters for juvenile coho salmon (*Oncorhynchus kisutch*), age-0 trout (*Oncorhynchus* spp.), steelhead (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus clarki*) were estimated each year for 8 years in each stream. Stream habitat was modified to increase the quality and quantity of winter habitat during the summers of 1990 (Nestucca Basin) and 1991 (Alsea Basin). Complex habitat was constructed by adding large woody debris to newly created alcoves and dammed pools. Numbers of coho salmon summer juveniles and smolts increased in the treatment streams relative to the control streams during the post treatment period. Overwinter survival of juvenile coho salon also increased significantly in both treatment streams post treatment. Summer trout populations in the treatment streams did not change, but downstream migrant numbers the following spring did increase. These increases suggest that winter habitat was limiting abundance of all three species.

Watershed Name & Location:

East Fork Lobster Creek (control) and Upper Lobster Creek (treatment) in the Alsea Basin, OR and East Creek (treatment) and Moon Creek (control) in the Nestucca basin, OR.

Type of Habitat Restoration Actions and when Undertaken:

Complex habitat was constructed by adding large woody debris to newly created alcoves and dammed pools.

- A track hoe was used to place full-spanning logs into the stream channel to create large dam pools and was used to excavate the alcoves (off-channel rearing ponds).
- East Creek had 29 dam pools and 13 alcoves constructed along a 2.4 km reach in the summer of 1990.
- Upper Lobster Creek had 23 dam pools and 8 alcoves long a 3.2 km reach in the summer of 1991.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

- Experiment designed to evaluate the effects of habitat restoration projects on coho salmon smolt abundance in two coastal Oregon streams.
- BACI experimental design to assess changes in habitat and fish population parameters.
- For each habitat or fish population parameter they:
    - calculated the ratio of treatment to reference each year,
    - estimated the mean ratios for the pretreatment and post-treatment periods, and
    - used a t test to compare the means
- H_0: Coho salmon – the ratio during the post-treatment period was not greater than the ratio during the pretreatment period
- H_1: Coho salmon – the ratio during the post-treatment period was greater than the ratio during the pretreatment period due to habitat modification increasing the coho salmon populations
- H_0: Trout – the post-treatment ratio was not different from the pretreatment ratio because the possible effects of habitat modification were unknown.
- One-tailed test employed for Coho salmon, two-tailed test for trout. Logarithmic transformation of the ratios were used to equalize variances.
- H_2: Fast-water habitat will decrease because of habitat modification (expected to convert fast-water to slow-water.

Response Measures Monitored (fish habitat[27], fish population[28]):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% $\Delta \pm$ SE)
Changes in winter habitat: - surface area of coho salmon winter rearing habitat (slow water)	Pretreatment period – twice in the Alsea study streams and once in the Nestucca study streams. Post-treatment period – twice in all streams.	December – January of each year (1988/89, 1991/92, 1993/94)	Surface area for each habitat unit in each stream was visually estimated and every tenth unit was measured to calibrate estimates.	Alsea (one-tailed t test; $p = 0.025$: +700% in treatment, -30% in control Nestucca: +13X in treatment, ~ same in control
- surface area of coho salmon fast water habitat		August – September of each year (1988/89, 1991/92, 1993/94)		Alsea -30% in treatment, ~ same in control (not significant) Nestucca: -6000m^2 in treatment, ~ same in control
- total surface area				Alsea – no significant difference Nestucca – increase of 25%
Changes in coho salmon populations: - summer population	Pool, glide, riffle and rapid habitats	August – September of each year (1988 – 1993)	Electrofishing – mark-recapture estimates generally used in pool habitats characterized by a high degree of wood complexity or presented special sampling problems. Removal estimate with two or more passes. Snorkeling – 10 pools in each stream for calibrations.	Alsea (one-tailed t test; $p = 0.02$): +50% in treatment, -25% in control Nestucca (one-tailed t test; $p = 0.01$): -20% in treatment, -50% in control ratio increased
- overwinter survival rate				Alsea (one-tailed t test; $p = 0.04$): +150% in treatment, +115% in control Nestucca (one-tailed t test; $p = 0.007$): +250% in treatment, -33% in control
- estimated number of smolts				Alsea (one-tailed t test; $p = 0.024$): +200% in treatment, ~0% in control Nestucca (one-tailed t test; $p = 0.005$): +200% in treatment, -75% in control

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[27] Fish habitat measures include temperature, turbidity, contaminants/nutrients, barriers, substrate, large wood, pools, off-channel habitat, channel condition, streamflows, watershed land use

[28] Fish population response measurements include redd / weir counts of spawners, age class of spawners, parr density / size, juvenile PIT tagging, juvenile emigrant abundance / size

What was measured?	**Where were measurements taken? (include intended or possible control sites)**	**Frequency and Duration of Measurements (before and after treatment)**	**How (Sampling Method, Monitoring Protocol)**	**Measured Effect of Restoration Action (% Δ ± SE)**
Changes in trout populations: - summer populations of age-0+ trout, age-1+ steelhead and age-1+ cutthroat trout.	same as above	same as above	same as above	No significant differences in either study
- numbers of downstream-migrating steelhead and cutthroat trout				Steelhead: Alsea (one-tailed *t* test; $p = 0.005$): +800% in treatment, +65% in control Nestucca (one-tailed *t* test; $p = 0.037$): +400% in treatment, -40% in control Cutthroat: Alsea (one-tailed *t* test; $p = 0.025$): no sig. diff between treatment (5-fold increase) and control (2-fold increase) Nestucca (one-tailed *t* test; $p = 0.024$): +275% in treatment, -75% in control
Downstream migrants	Each stream	March – June of each year (1988 – 1993)	Modified incline plane traps. Captured fish removed daily and measured.	

Key Results:

See above table and abstract.

Relevance to Columbia Basin:

The two study areas were coastal streams but relatively high in the drainage basins, south of the Columbia basin. This type of habitat restoration may be appropriate for other areas with a lack of adequate winter rearing habitat. The BACI experimental design applied in this study is worthy of application in other areas.

Overall Conclusion on Restoration Action Effectiveness

- Habitat modification increased winter rearing habitat for anadromous salmonids.
- Due to a combination of improvement of marginal in-channel habitats and the creation of new off-channel habitats.
- Critical elements — creation of slow water habitat and addition of large quantities of wood.
- Resulted in increased coho salmon smolt abundance — key was increased overwinter survival.
- Results are specific to the particular type of habitat created and should not be interpreted as a general justification for all types of instream habitat restoration.

Effects of fertilization and instream structures on steelhead and coho (Keogh River, BC)

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients
- Improved riparian conditions
    - Active stream restoration (includes instream structures)

Reference:

Ward, B. R., D.J.F. McCubbing, and P.A. Slaney. 2002. Stream restoration for anadromous salmonids by the addition of habitat and nutrients. Sixth International Atlantic Salmon Symposium, held 15th - 18th July 2002, Edinburgh, Scotland. 23 pp.

Paper presented at a symposium.

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Abstract:

In an evaluation of the salmonid response to watershed rehabilitation treatments at the Keogh River, we document the positive trends in juvenile density, growth, survival, and smolt yield of steelhead trout and coho salmon observed in comparison to the untreated neighbouring Waukwaas River, on Northern Vancouver Island, British Columbia, Canada. Juvenile fish abundance in the Keogh River indicated positive effects of the increased watershed restoration, particularly that from the addition of habitat structures and nutrients. Steelhead parr densities in the Keogh River were significantly higher compared to untreated (both rivers) and pre-treatment values, and highest in reaches treated with both restoration techniques. Despite reductions in adult escapement, the abundance of coho fry in the Keogh River exceeded that in the Waukwaas River; densities in preferred habitat exceeded those of past surveys. Inorganic nutrient addition led to significant increases in salmonid fry and smolt weights. Increase in length and weight of steelhead parr improved survival over winter, culminating in increased smolt yield and a shift to predominantly 2-year-old smolts in 1999, 2000 and 2001. Smolt yield reflected significant improvements in juvenile production and survival in the freshwater phase in the Keogh River despite low brood year strength, and proved the better response variable; juvenile density was highly variable. Steelhead smolt yield in 2001 was >2,000 smolts. Coho smolt yield increased in 2001 from the Keogh River, but less so than in 2000, over the historically poor yield observed in 1998. Steelhead smolts produced per spawner in the Keogh River have risen from historic lows of <3 smolts per spawner (i.e., below replacement) from the 1996 brood to > 50 smolts per spawner from the 1998 brood year, the highest production per spawner of the 27-yr. record, offering hope for recovery despite low smolt-to-adult survivals. Further evaluation of effects to salmonid smolts will require a continued analysis of smolts-

per-spawner recruitment to at least 2004, to more fully describe the benefits of the watershed ecosystem approach to restoration.

Watershed Name & Location:

Keogh River (treatment), Waukwass River (control), N. Vancouver Island, BC, Canada

Type of Habitat Restoration Actions and when Undertaken:

- 450 instream structures (boulder, LWD) added to mainstem Keogh River
- Slow-release nutrient briquettes added to 36.5km of mainstem plus 11km of tributaries to Keogh River
- Actions implemented in staircase design over 1997-2001, first with fertilization implemented in lower reaches and structures in upper reaches (1998, 1999) then both treatments throughout watershed (2000, 2001)

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

- BACI design
- H_1: Structures and nutrients (both singly and in combination) increase the growth and abundance of juvenile coho and steelhead.
- H_2: Combined actions increase smolt yield per spawner of these species
- Staircase design to create contrasts while accounting for year effects
- Density, growth and smolt yield analyzed by ANOVA
- Looked at residuals from graph of ln (smolts/spawner) vs. spawners before and after treatment, using covariance analysis to test for differences in production regimes and effects of watershed restoration

Response Measures Monitored (fish habitat, fish population):

What was measured?	**Where were measurements taken? (include intended or possible control sites)**	**Frequency and Duration of Measurements (before and after treatment)**	**How (Sampling Method, Monitoring Protocol)**
Overall juvenile salmonid density	Stratified random sampling for juveniles based on reach and habitat type (proportional to habitat frequency)	Summer and autumn (1997-2001)	Mark-recapture using electro-shocking and seine netting techniques along 100m sections in each reach in proportion to habitat
Winter juvenile use of representative structures	Sampling of respresentative structures (46 out of 380)	Winter (1997-2001)	Electroshocking and minnow traps
Smolt yield and length	Smolt counts at mouth of Keogh River (treatment) and Waukwass River (control)	Outmigration period (1977-2001 for steelhead; 1995-2001 for coho)	Full-river counting fence at mouth of Keogh River; mark-recapture estimates using 2 RSTs on Waukwass River
Length of fry and parr	at density sites	1997-2001	Fry/parr split based on length confirmed by scales
Age estimates of juveniles	based on lenghts and confirmed by scale samples	1997-2001	Scales

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)
Relative frequency of habitat types (pool, flat, riffle, run)	representative lengths (250 m) assessef for habitat frequency in each region	1997?	Representative lengths (250m) assessed for habitat frequency in each reach
Abundance of adult steelhead males and females, and ages in Keogh River (mark-recapture)	entire Keough River (treatment) spawners not enumerated on Wankwass (control)	1977-2001	Mark-recapture Peterson estimate (upstream immigrants marked; down-stream kelts recaptured); Population estimates by Riley and Fausch (1992)
Electronic resistivity estimates of steelhead, coho and pink adults	Electronic resistivity fish counter near mouth of control and treated streams	1997-2001	Electronic resistivity fish counter (Logie 2100C)

Key Results:

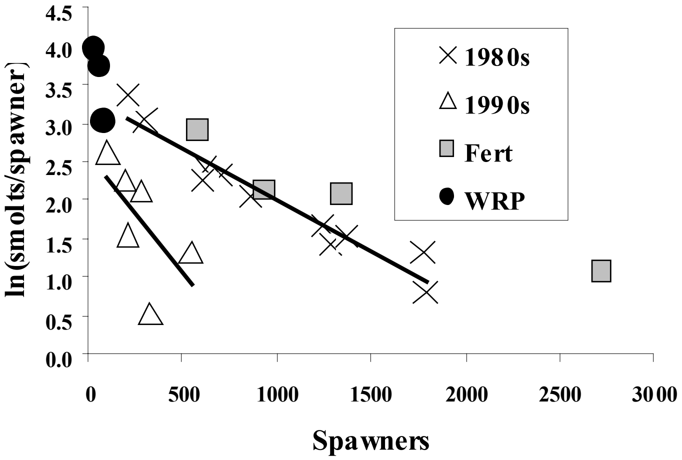

Figure A.6. The relationship between the natural logarithm of the steelhead smolts per spawner and the number of spawners in the Keogh River during the production regimes of the 1980s (X marker) and the 1990s (open triangles), during nutrient experiments in the mid-1980s (grey squares), and preliminary results from the period of watershed restoration treatments (solid circles). Source: Ward et al. (2002).

Table A1.12. Mean abundance of salmonid juveniles (no.•100m-1) in treated and untreated reaches of the Keogh and Waukwaas Rivers from 1997 to 2001. S= Structures added, F = fertilized, SF = structures and fertilization. Source: Ward et al. (2002).

	Waukwaas	Keogh	Keogh	Keogh	Keogh
River Treatment	None	None	S	F	SF
Number of samples	20	3	3	5	12

Species						
SHF	Average	298	14	14	145	168
	S.D.	311	20	8	94	105
SHP	Average	42	15	23	30	49
	S.D.	29	6	24	18	32
COF	Average	208	281	633	271	390
	S.D.	152	149	380	91	158

Relevance to Columbia Basin:

Though completed for a coastal stream in British Columbia, the responses of steelhead and coho populations should be relevant to some coastal, low nutrient systems of the Lower Columbia Basin. Note that this system had a very long pre-treatment history of data measurements. This points to the benefit of building action effectiveness studies on watersheds with an existing long time series of biological information.

Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales

This is a general paper suggesting possible directions for bull trout habitat restoration actions.

Reference:

Watson, G., and T. W. Hillman. 1997. Factors affecting the distribution and abundance of bull trout: an investigation at hierarchical scales. North American Journal of Fisheries Management 17: 237-252.

Peer reviewed publication.

Contact Information (Lead Author):

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Abstract:

The reported declines of many stocks of bull trout *Salvelinus confluentus* in the Pacific Northwest has generated much interest in developing conservation and management plans to protect and rebuild populations. These plans require knowledge of the specific requirements of bull trout throughout their range. We describe the relationships between distribution and abundance of bull trout and physical and biotic factors across a large portion of their historical range.

We surveyed 1,057 randomly selected sites from 93 streams within 18 major drainages throughout Washington, Idaho, and Montana for the presence of bull trout. We used logistic regression to assess the relationship between the occurrence of bull trout and several physical and biotic factors at site and habitat scales of analysis. Robust regression assessed relationships between densities of bull trout and physical parameters at site, stream, and basin scales of analysis.

Bull trout occurred significantly more often in sites within alluviated lowlands and valleys and in sites with undercut banks, large substrates, pools, and where trees and shrubs were the dominant riparian vegetation. Bull trout occurrence at the site scale was inversely related to the percentage of canopy cover and vegetation overhang and the presence of brook trout *S. fontinalis* and rainbow trout *Oncorhynchus mykiss*. At the habitat scale, bull trout most often used large, deep pools that lacked extensive canopy cover. They rarely used fast-water habitats with fine sediments, extensive canopy cover, and brook trout. Bull trout densities correlated positively with pool depth, undercut banks, and diverse gradients, and indirectly with fine sediments at both the stream and site scales of analysis. In addition, high densities of bull trout with less vegetation overhang and greater, but variable, percentages of wood and boulder cover at the site scale. The combinations of variables that correlated significantly with bull trout densities varied considerably among different basins. Additionally, the amount of variation in bull trout densities explained by significant variables decreased at finer scales of analysis.

These results indicate a hierarchical relationship between the distribution and density of bull trout and physical variables. Thus, land management for bull trout enhancement or protection should be site-specific and tailored within a similar hierarchical framework.

Relevance to Columbia Basin:

Data are relevant, since they were taken from watersheds within Columbia Basin. The results indicate a hierarchical relationship between the distribution and density of bull trout and physical variables, and suggest the kinds of habitat variables which could be improved to help recover bull trout populations. The authors suggest that land management for bull trout enhancement or protection should be site-specific and tailored within a similar hierarchical framework to that observed in this study. The study could be helpful in finding potential treatment-control pairs for future habitat manipulation studies.

Marine Subsidies in Freshwater Ecosystems: Salmon Carcasses Increase the Growth Rates of Stream-Resident Salmonids

RPA 183 Actions Identified:

- Enhanced levels of marine–derived nutrients

Reference:

Wipfli, M. S., J. P. Hudson, J.P. Caouette, and D.T. Chaloner. 2003. Marine Subsidies in Freshwater Ecosystems: Salmon Carcasses Increase the Growth Rates of Stream-Resident Salmonids. Trans. Amer. Fish. Soc. 132: 371-381.

Peer reviewed publication

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Abstract:

We tested the hypotheses that marine-derived resource subsidies (salmon carcasses) increase the growth rates of stream-resident salmonids in southeastern Alaska and that more carcasses translate into more growth. Five carcass treatments of pink salmon *Oncorhynchus gorbuscha* (0, 1, 2, 3, and 4 carcasses/m2 or 0, 1.9, 3.7, 5.6, and 7.4 kg wet mass/m2) were replicated six times in once-through artificial channels, then each channel was stocked with three live age-0 coho salmon *O. kisutch*. The experiment spanned more than 9 weeks: 16 August to 24 October 1998. The body mass and fork length of the young coho salmon significantly increased from carcass additions, but the incremental increases sharply diminished at carcass-loading levels above 1 carcasses/m2. Further, in a small stream in which we added salmon carcasses to a cumulative density of 0.54 carcasses/m2, both cutthroat trout *O. clarki* and Dolly Varden *Salvelinus malma* grew significantly faster during the 2 months in which carcasses were added (September-October) compared with fish in control reaches. Fish maintained their assimilated body mass through winter into the following spring. This study illustrates that marine nutrients and energy from salmon spawners increase growth rates of resident and anadromous salmonids in streams. This elevated growth should translate into increased survival and reproduction, ultimately elevating freshwater and marine salmon production. Ecological relationships between salmon runs and aquatic community nutrition and productivity may be important considerations for salmon stock protection and restoration and for freshwater and marine ecosystem management.

Watershed Name & Location:

Margaret Creek watershed (Margaret and Cedar creeks) on Revillagigedo Island near Ketchikan, Alaska.

Type of Habitat Restoration Actions and When Undertaken:

Pink salmon carcasses (flesh and eggs) were added to an artificial and natural stream experiments. The artificial stream (mesocosm) experiment occurred from August 16th to October 24th, 1998 and the natural stream experiment occurred from September 4th, 1998 through May 16th , 1999.

Restoration Action Hypotheses Tested (or Potentially Testable), Overall Experimental Design (e.g. staircase design, BACI, BA), and Statistical Methods:

H_1: Salmon carcasses provide a marine-derived resource subsidy that increases the growth rates of freshwater-rearing coho salmon, cutthroat trout and Dolly Varden.
H_2: The effects of this subsidy are larger at higher carcass-loading levels.

The mesocosm experiment used a randomized block, split-plot design, replicating five treatments (0, 1, 2, 3, and 4 carcasses/m^2) and three subtreatments (small, medium and large size-groups) across six blocks. Individual coho within a channel were subunits (split-plot) on which the subtreatment of size-group was applied). To minimize confounding between treatment and channel location, treatments were assigned to six channels across six platforms facilitating a 6X6 Latin square. Data were analyzed at $\alpha=0.05$.

For the natural stream experiment, they used a *t*-test, $\alpha=0.05$ to determine differences in percentage change in fish mass and fork length between the two reaches (control and treatment).

Response Measures Monitored (fish habitat, fish population):

What was measured?	Where were measurements taken? (include intended or possible control sites)	Frequency and Duration of Measurements (before and after treatment)	How (Sampling Method, Monitoring Protocol)	Measured Effect of Restoration Action (% Δ ± SE)[29]
Relative growth of age-0 coho – wet mass and fork length	Mesocosm control and treatment sites	Initially and every 3 weeks for 3 capture dates.	Captured, anesthetized, measured and released Relative growth calculated for individual fish as % change from initial wet mass & fork length.	Growth (mass and fork length) ⇑ in carcass-enriched channels; ⇔ between size-group and treatment. See Key Results below.
Benthic invertebrate density	Mesocosm control and treatment sites	3 weeks into experiment	Invertebrates in baskets were preserved, sorted and counted	Density ⇑ in carcass-enriched channels
Relative growth of Cutthroat trout and Dolly Varden – wet mass and fork length	Natural stream control and treatment sites	Initially captured, data recorded and PIT tagged and released. Recaptured and measured during Oct. 1998 and May 1999.	Relative growth	Cutthroat trout growth (mass and fork length) ⇑ in fall and spring (24X from Sept. – Oct., 2.5X from Sept. – May). Growth of control fish was only 2X higher in winter (Oct – May). Dolly Varden growth ⇑ in fall 5X. See Key Results below.

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[29] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Key Results:

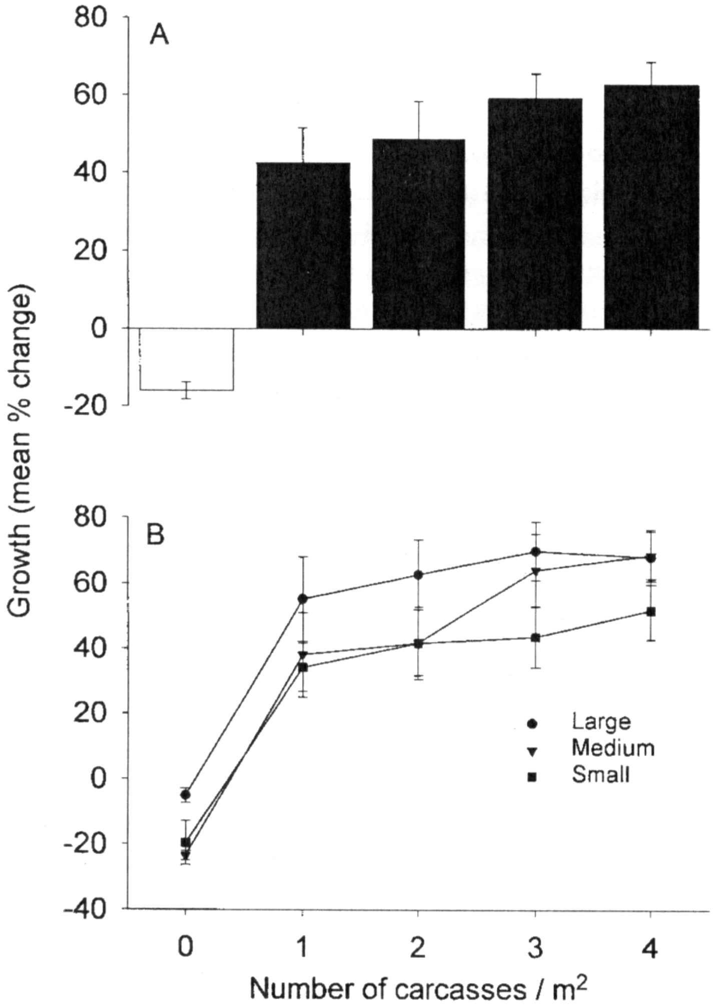

Figure A.7. Growth (mean percent change in wet mass over 66 d) of age-0 coho salmon exposed to five salmon carcass treatments in a mesocosm, as determined for (A) all size-groups combined and (B) each of three size-groups (error bars = 1 SE).

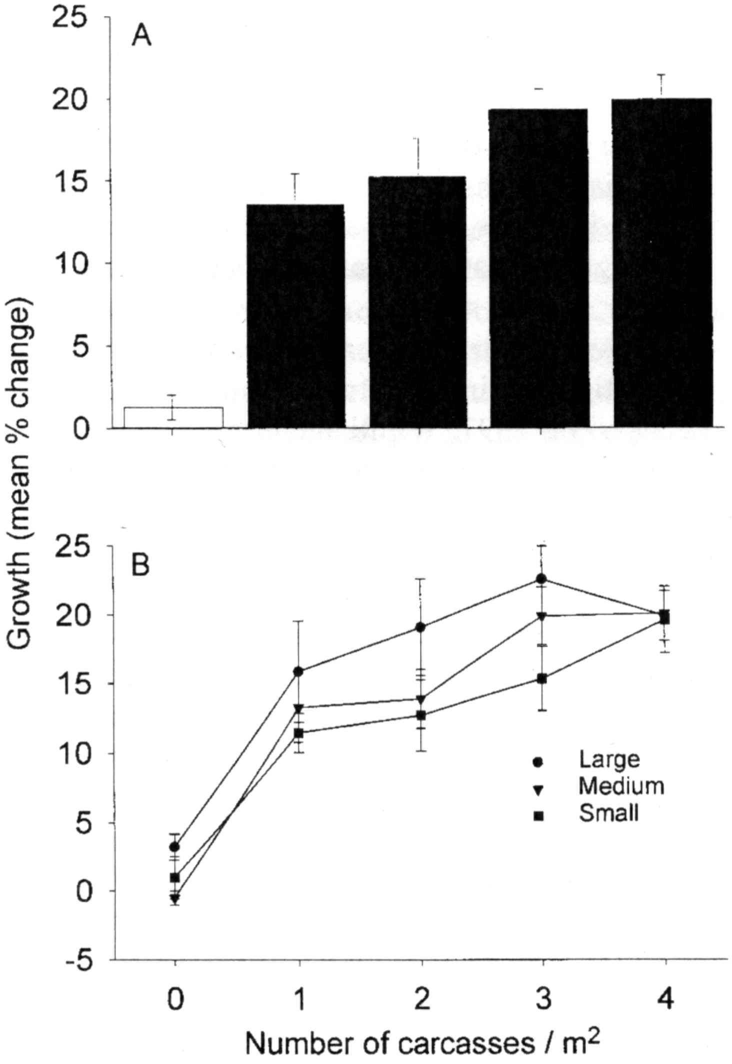

Figure A.8. Growth (mean percent change in fork length over 66 d) of age-0 coho salmon exposed to five salmon carcass treatments in a mesocosm, as determined for (A) all size-groups combined and (B) each of three size-groups (error bars = 1 SE).

Table A1.13. Analysis of variance results for percentage change in wet mass and fork length of age-0 coho salmon exposed to none (control) versus four treatment amounts of pink salmon carcass tissue and eggs. SS stands for sum of squares.

		Mass change (%)		Length change (%)	
Source of variation	**df**	**SS**	***P***	**SS**	***P***
Platform	5	0.448		0.022	
Treatment	5	12.018	<0.001	0.647	<0.001
Control versus carcass	1	11.541	<0.001	0.594	<0.001
Linear fit (slope $\neq 0$)	1	0.460	0.024	0.048	0.003
Lack of fit	3	0.014	0.916	0.004	0.672
Platform x treatment	25	1.993	<0.001	0.110	
Size group	2	0.679	0.596	0.029	0.003
Treatment x size class	10	0.254		0.017	0.647
Error	60	1.819		0.131	
Total	107				

Table A1.14. Growth of cutthroat trout and Dolly Varden in carcass-enriched (treatment) and unenriched (control) reaches of Cedar Creek, Alaska, as measured for three periods between September 1998 and May 1999. Growth was calculated as percent change in wet mass per day (SEs in parentheses).

Species and treatment type	N	Sep-May	Sep-Oct	Oct-May
Cutthroat Trout				
Carcass-enriched	9	0.59 (0.05)	2.60 (0.19)	0.13 (0.02)
Unenriched	5	0.24 (0.05)	0.11 (0.04)	0.25 (0.05)
t-test *P*-value		0.0008	<0.0001	0.0247
Dolly Varden				
Carcass-enriched	12	0.69 (0.05)	1.90 (0.23)	0.29 (0.02)
Unenriched	4		0.39 (0.25)	
t-test *P*-value			0.0045	

Relevance to Columbia Basin:

The results should contribute to a better ecological understanding of marine-freshwater linkages and aid in the design of fertilizaation treatments.

Overall Conclusion on Restoration Action Effectiveness:

The presence of salmon carcasses and eggs from spawning salmon dramatically increased the growth rates and body mass of the salmonids sampled in this study – even at relatively low densities. Because biomass provided by spawning salmon appears to increase productivity of multiple trophic levels in streams, maintaining this subsidy in freshwater appears to be important for sustaining fish production. Restoring and protecting salmon stocks may have as much to do with restoring nutrients, food abundance, and nutrition through generous escapements as restoring habitat, fish passage and genetic diversity.

Table A1.15. Summary of responses by fish performance measure.[30]

Action	Survival	Growth	Abundance	Reference
Compliance with water quality standards: - Alteration of grazing practices			Shrub, herbaceous cover ⇑ Species richness ⇑ Species diversity ⇑ Wetland species composition dominance ⇑ Bare ground ⇓ Channel depth ⇑ Channel width ⇓ Pool area ⇑ The above benefits, ⇑ through time and may not be fully realized until decades after exclusion. ⇑ vegetation is likely to positively affect other ecosystem processes such as allocthonous inputs and sediment retention, thereby affecting the aquatic biota, **water quality** and stream geomorphology.	Kauffman et al. (2002)
Compliance with water quality standards: - Reduction of sediment through road closures	Coho parr survival – marked age-0; 13% higher in pristine watersheds in wilderness areas than in dry watersheds subjected to forestry operations. Parr reared in areas of low density had significantly higher overwinter survival than in areas of high road density.			Paulsen and Fisher (2001)
Enhanced levels of marine–derived nutrients	coho smolt production per spawner ⇑ 50%	mean smolt length ⇑ 30% but only in 1 of 2 years		Ward et al. (2002)
		Condition factor of age 0^+ steelhead ⇑ in Salmon Creek; juvenile coho ⇑ in A400 Creek	Density of all ⇑ at A400 Creek; juvenile coho ⇔ at A400 and Wasberg creeks; age 0^+ steelhead ⇑ at A400 Creek; age1^+ 10X ⇑ at A400 Creek.	Bilby et al. (1998)
		Growth (mass and fork length) ⇑ in carcass-enriched channels for age-0 coho in artificial stream In natural stream, Cutthroat trout growth ⇑ in fall and spring (24X from Sept. – Oct., 2.5X from Sept. – May).		Wipfli et al. (2003)

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[30] ⇔ means no significant change; ⇑ means significant increase; ⇓ means significant decrease.

Action	Survival	Growth	Abundance	Reference
		Growth for control fish were 2X higher in winter (Oct – May). Dolly Varden growth ⇑ in fall 5X.		
		Juvenile coho and steelhead weights ⇑ during all treatment years except coho fry during 1983 when nutrient concentrations were below target values. Steelhead mean weight ⇑ 95% ; coho mean weight ⇑ 40%		Johnston et al. (1990)
Improved riparian conditions: - Alteration of grazing practice			Young of the year salmonids ⇑ Adult salmonids ⇔ Warm water fishes ⇓	Kauffman et al. (2002)
Improved riparian conditions: - Active stream restoration (includes instream structures)			Significant ⇑ in spring coho smolt in Porter creek, WA due to LWD; no significant difference for spring sampled juvenile coho, steelhead or trout fry; significant ⇑ in winter juvenile coho & no significant difference steelhead or trout fry; no significant difference for summer sampled juveniles. Significant ⇑ in spring juvenile chinook in Nechako River, BC due to LWD Significant ⇑ in spring and summer juvenile steelhead in Steamboat Creek, OR due to LWD and boulders. Significant ⇑ in summer juvenile coho in Nestucca River, OR due to LWD; no significant response from juvenile cutthroat, steelhead and trout fry. Significant ⇑ in summer juvenile coho and cutthroat in East Fork Lobster Creek, OR due to boulders and gabion; no significant response from juvenile steelhead and trout fry.	Roni et al. (2002)[31]
	coho overwinter survival rate ⇑ by 150% in one treatment and 250% in another		⇑ coho salmon smolt abundance by 200% in both treatments.	Solazzi et al. (2000)
			Rainbow & cutthroat fry and chinook parr ⇑ in 2001 compared to previous years but not stat. sign.	Clayton (2002)

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[31] Sources: Ward and Slaney (1981); Moreau (1984); House and Boehne (1986); House et al. (1989); V. A. Poulin and Associates (1991); Slaney et al. (1994); Chapman (1996); House (1996); Cederholm et al. (1997)

Action	Survival	Growth	Abundance	Reference
			Chinook parr densities increased gradually since 1998. Age 0 chinook density - NS diff. during and after restoration relative to control. Large variability, no strong trends in redd counts/	
			Food and the interaction between food and FWD had a strong effect on the distribution of juvenile coho salmon among pools.	Giannico (2000)
Improved riparian conditions: - Active stream restoration (includes instream structures)			Density of juvenile coho in pools with brush sig. > those without (dammed pools but not plunge pools) Addition of brush ⇑ density in constructed dammed pools in winter to a level not sig. different from natural pools.	Nickelson et al. (1992)
		Coho juveniles ⇑ 14.8% longer (significant) Coho smolts departing ⇑ 6.8% longer (not significant) Steelhead YOY ⇑ 12.5% in length (sig.) Age-1 ⇑ 4.1% (sig.)	Coho juveniles ⇓41.8% (not significant) Coho smolts departing ⇑ 12.7% (not significant) Steelhead YOY ⇓ 53.2% (sig.) age-1 ⇑ 11.7% (NS) smolts ⇑ 27.7% (NS)	Reeves et al. (1997)
		No significant difference between treatment and reference for juvenile coho, cutthroat and steelhead trout and trout fry.	Juvenile coho was 1.8 and 3.2 times higher in treated reaches during summer and winter. Cutthroat and steelhead age-1+ was 1.70 and 1.73 in winter, respectively.	Roni and Quinn (2001)
Other actions (e.g. not differentiated)				

Appendix 2 – Habitat Project Inventory

FX = “Would this project affect…?”

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Enhance passage of juvenile and adult fish in Idaho's anadromous fish corridors by consolidation and elimination of irrigation diversions. Minimize adverse fish impacts of irrigation diversion dams by screening pump intakes and canals.	Clearwater	Diversion Screening	Y	Y	2001	Clear Creek (River Mile 2.0-9.57)	Clear Cr.	CLEARC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1984	Crooked Fork Creek	Crooked Fork Cr.	CROOKC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1988	Shotgun Creek	Crooked Fork Cr.	CROOKC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1984	Hopeful Creek	Crooked Fork Cr.	CROOKC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1988	Spruce Creek	Crooked Fork Cr.	CROOKC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Habitat Features	Y	Y	1983	Crooked Fork Creek	Crooked Fork Cr.	CROOKC	
BPA	Crooked River Passage	The Crooked River Bridge replaced the culvert. This had the potential of increasing steelhead production by 18,690 smolts annually.	Clearwater	Fish Passage Improvement	Y	Y	1984	Crooked River Rd. MP 8.2	Crooked R.	CROOKR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Habitat Features	Y	Y	1984	Crooked River	Crooked R.	CROOKR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reconnect Existing Off-channel Habitat	Y	Y	1984	Crooked River	Crooked R.	CROOKR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Streambank Stabilization	Y	Y	1984	Crooked River	Crooked R.	CROOKR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Floodplain creation	Y	Y	1985	Crooked River	Crooked R.	CROOKR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Floodplain creation	Y	Y	1985	Crooked River "Reaches I & II"	Crooked R.	CROOKR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Habitat Features	Y	Y	1985	Crooked River "Reaches I & II"	Crooked R.	CROOKR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reconnect Existing Off-channel Habitat	Y	Y	1985	Crooked River "Reaches I & II"	Crooked R.	CROOKR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Streambank Stabilization	Y	Y	1985	Crooked River "Reaches I & II"	Crooked R.	CROOKR	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Habitat Features	Y	Y	1983	Lolo Creek	Lolo Cr.	LOLOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Habitat Features	Y	Y	1985	Eldorado Creek mouth to approx. mile 6.6	Lolo Cr.	LOLOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1986	Lolo Creek	Lolo Cr.	LOLOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Riparian Re-vegetation	Y	Y	1988	Lolo Creek	Lolo Cr.	LOLOC	
CSWCD	Lolo Cr. Road Stabilization	Removed & replaced culverts on 4 miles of road on Lolo Cr.	Clearwater	Reduce Sediment Load	Y	Y	1997	Lolo Creek road crossing 12 miles from mouth	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1997	Musselshell and Jim Brown Creek watersheds	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1997	Lolo Creek	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Streambank Stabilization	Y	Y	2000	Jim Brown Creek	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Riparian Re-vegetation	Y	Y	2001	Jim Brown Creek	Lolo Cr.	LOLOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
NRCS	Lolo Cr. WQPA	Idaho Ag program. 7,734 acres treated to date with BMP implementation	Clearwater	Reduce Sediment Load	Y	N	1994	Upper breaks of Lolo Creek - effect is seen on middle reaches of Lolo Creek	Lolo Cr.	LOLOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1987	Musselshell Creek (Jim Brown in PNW RRH file)	Lolo Cr.	LOLOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1987	Yoosa Creek	Lolo Cr.	LOLOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Fish Passage Improvement	Y	N	1984	Eldorado Creek falls 0.5 mi. from mouth	Lolo Cr.	LOLOC	
BPA	Nez Perce NF Early Action Watershed Projects	Vegetation management, site restoration, instream and bank construction.	Clearwater	Fish Passage Improvement	Y	N	1996	Eldorado Creek falls 0.5 mi. from mouth	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Obliterate unnecessary roads	Y	N	1998	Musselshell Creek watershed	Lolo Cr.	LOLOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Obliterate unnecessary roads	Y	N	1999	Eldorado Creek watershed	Lolo Cr.	LOLOC	
BPA	Protect and Restore Lolo Creek Watershed	Protect, restore, and enhance the Lolo Creek Watershed to provide quality habitat for anadromous and resident fish. This will be accomplished by watershed resotration projects such as culvert replacement, road obliteration, and streambank stabilization.	Clearwater	Obliterate unnecessary roads	Y	N	1997	Lolo Creek watershed from Yakus Creek to Jim Brown Creek	Lolo Cr.	LOLOC	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reduce Sediment Load	Y	Y	1984	Haysfork Gloryhole	Newsome Cr.	NEWSOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Haysfork Gloryhole Rehabilitation	Haysfork Gloryhole has been an ongoing source of sediment for a number of years. Numerous projects have been completed which have improved the condition of the hillside, seriously eroding as the result of past mining activities. The objective of this project is to further reduce erosion by vegetative plantings and fencing improvements to exclude livestock grazing. Sediment ponds will be emptied to provide for additional collection of sediment. An additional objective is to provide one time maintenance of a previously funded BPA project site on the nearby Red River. In the 1960's the Forest Service planted some conifers in the gloryhole. No major activity occurred in the gloryhole again until 1984. In 1984, in an effort to revegetate the gloryhole, the upper portion was laid back to a slope of approximately 45% . The excavated fill material was cast over the side and not compacted. A bench was constructed just below the upper portion. The primary purpose of the bench was to carry water off the top portion of th	Clearwater	Reduce Sediment Load	Y	Y	1984	Haysfork Gloryhole	Newsome Cr.	NEWSOC	
BPA	Protecting and Restoring the Fishing Cr. to Legendary Bear Cr. Watersheds Analysis Area	This project identifies sedimentation and fish barriers at road crossings as major limiting factors in fish habitat. This project has obliterated 140 miles of road, stabilizing a total of 62,041 cubic yds. of fillslope material, in which 20,371 cubic yds. were from stream crossings with failing structures. Three barrier culverts were replaced for fish passage, returning access to 10 miles of spawning, rearing and overwintering habitat.	Clearwater	Fish Passage Improvement	N	N	2002	Parachute Creek	Legendary Bear Cr.	PAPOOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Clearwater NF	Legendary Bear, Fishing and Doe Creek Habitat Improvements	Legendary Bear, Fishing and Doe Creek Habitat Improvements	Clearwater	Streambank Stabilization	Y	Y	1985	Legendary Bear Creek	Legendary Bear Cr.	PAPOOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Habitat Features	Y	Y	1986	Legendary Bear Creek	Legendary Bear Cr.	PAPOOC	
BPA	Lolo, Crooked Fork & El Dorado Creeks Habitat Work	Creation of a passage through a series of falls on El Dorado Creek opening up new salmonid habit. Evaluation of about 30 streams in the Clearwater Basin. Instream work and riparian fencing on selected tributaries of Lolo Creek & Lochsa River.	Clearwater	Habitat Features	Y	Y	1986	East Fork Legendary Bear Creek	Legendary Bear Cr.	PAPOOC	
BPA	Protecting and Restoring the Fishing Cr. to Legendary Bear Cr. Watersheds Analysis Area	This project identifies sedimentation and fish barriers at road crossings as major limiting factors in fish habitat. This project has obliterated 140 miles of road, stabilizing a total of 62,041 cubic yds. of fillslope material, in which 20,371 cubic yds. were from stream crossings with failing structures. Three barrier culverts were replaced for fish passage, returning access to 10 miles of spawning, rearing and overwintering habitat.	Clearwater	Road Obliteration	Y	N	1998	Legendary Bear Creek	Legendary Bear Cr.	PAPOOC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red R. WMA	The RRWMA was purchased to 1) maintain and/or enhance quality wildlife, fisheries, scenic values and overall biodiversity, 2) Provide a setting for natural resource-oriented educational, research and study opportunities, 3) Provide a meeting facility for natural resource-oriented agencies and organizations, and the local community, and 4) Promote continued use of the RRWMA for recreational purposes consistent with other goals. Used by University of Idaho, National Science Foundation and local schools. Interpretive sites being developed. Various monitoring surveys conducted as funding permits.	Clearwater	Land Acquisition	N	N	1994	Red R. WMA	Red R.	REDR	
BPA	Red River Fish Habitat Improvement	Work on this project on the Red River, a tributary of the South Fork of the ClearwaterRiver, included installation of instream structures, bank protection through riparian fencing, bank stabilization through planting of both conifers and deciduous trees and shrubs, and seeding and fertilizing of disturbed sites.	Clearwater	Habitat Features	Y	Y	1983	Red River	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1983	Red River	Red R.	REDR	
BPA	Red River Fish Habitat Improvement	Work on this project on the Red River, a tributary of the South Fork of the ClearwaterRiver, included installation of instream structures, bank protection through riparian fencing, bank stabilization through planting of both conifers and deciduous trees and shrubs, and seeding and fertilizing of disturbed sites.	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1983	Red River	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Riparian Re-vegetation	Y	Y	1983	Red River; number is less than actual	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red River Fish Habitat Improvement	Work on this project on the Red River, a tributary of the South Fork of the ClearwaterRiver, included installation of instream structures, bank protection through riparian fencing, bank stabilization through planting of both conifers and deciduous trees and shrubs, and seeding and fertilizing of disturbed sites.	Clearwater	Riparian Re-vegetation	Y	Y	1983	Red River	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Streambank Stabilization	Y	Y	1983	Red River	Red R.	REDR	
BPA	Red River Fish Habitat Improvement	Work on this project on the Red River, a tributary of the South Fork of the ClearwaterRiver, included installation of instream structures, bank protection through riparian fencing, bank stabilization through planting of both conifers and deciduous trees and shrubs, and seeding and fertilizing of disturbed sites.	Clearwater	Streambank Stabilization	Y	Y	1983	Red River	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Habitat Features	Y	Y	1984	Red River	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Habitat Features	Y	Y	1985	Red River "Reach II"	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Off-channel Habitat	Y	Y	1985	Red River "Reach II"	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reconnect Existing Off-channel Habitat	Y	Y	1985	Red River	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reconnect Existing Off-channel Habitat	Y	Y	1985	Red River "Reach II"	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Riparian Re-vegetation	Y	Y	1985	Red River "Reach II"	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Streambank Stabilization	Y	Y	1985	Red River "Reach II"	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Reduce Sediment Load	Y	Y	1990	Cal-Idaho Gloryhole	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Channel Lengthening	Y	Y	1991	Red River 460 m on Mullins property	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Habitat Features	Y	Y	1991	Red River 460 m on Mullins property	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Off-channel Habitat	Y	Y	1991	Red River 460 m on Mullins property	Red R.	REDR	
BPA	Red & Crooked Rivers Habitat/ Passage Improvements	The Forest Service, in cooperation with the Idaho Department of Fish and Game and private landowners, replaced a culvert on Crooked Creek and improved fish habitat on the Red River by installing stream structures to improve the riverbanks and to increase spawning and rearing habitat. They planted trees and shrubs to stabilize streambanks and to provide shade for juvenile fish, and fence the riparian areas on private ranch land to protect streamside plants from grazing animals. Reclamation work was done on two glory holes: Haysfork and Cal-Idaho and studies on two others: Legget and Fisher Placers.	Clearwater	Riparian Re-vegetation	Y	Y	1991	Red River 460 m on Mullins property	Red R.	REDR	
BPA	Enhance Fish, Riparian, and Wildlife Habitat Within the Red River Watershed	Restore physical and biological processes to create a self-sustaining river/meadow ecosystem using a holistic approach and adapative management principles to enhance fish, riparian, and wildlife habitat and water quality within the Red River watershed	Clearwater	Channel Lengthening	Y	Y	1996	Red River WMA	Red R.	REDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Enhance Fish, Riparian, and Wildlife Habitat Within the Red River Watershed	Restore physical and biological processes to create a self-sustaining river/meadow ecosystem using a holistic approach and adapative management principles to enhance fish, riparian, and wildlife habitat and water quality within the Red River watershed	Clearwater	Habitat Features	Y	Y	1996	Red River WMA	Red R.	REDR	
BPA	Enhance Fish, Riparian, and Wildlife Habitat Within the Red River Watershed	Restore physical and biological processes to create a self-sustaining river/meadow ecosystem using a holistic approach and adapative management principles to enhance fish, riparian, and wildlife habitat and water quality within the Red River watershed	Clearwater	Reconnect Existing Off-channel Habitat	Y	Y	1996	Red River WMA	Red R.	REDR	
BPA	Enhance Fish, Riparian, and Wildlife Habitat Within the Red River Watershed	Restore physical and biological processes to create a self-sustaining river/meadow ecosystem using a holistic approach and adapative management principles to enhance fish, riparian, and wildlife habitat and water quality within the Red River watershed	Clearwater	Riparian Fencing/ Grazing Management	Y	Y	1996	Red River WMA	Red R.	REDR	
BPA	Enhance Fish, Riparian, and Wildlife Habitat Within the Red River Watershed	Restore physical and biological processes to create a self-sustaining river/meadow ecosystem using a holistic approach and adapative management principles to enhance fish, riparian, and wildlife habitat and water quality within the Red River watershed	Clearwater	Streambank Stabilization	Y	Y	1996	Red River WMA	Red R.	REDR	
BPA / GRMWP	Upper Grande Ronde Sediment Reduction - FS	Obliterate, close and waterbar sediment producing roads	Grande Ronde	Road Obliteration	Y	N	1995	Catherine Creek & Upper Grande Ronde watersheds	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Division Fence	Cross fencing	Grande Ronde	Riparian Fencing/ Grazing Management	Y	N	1997	Catherine Creek Allotment	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Division Fence	Cross fencing	Grande Ronde	Riparian Fencing/ Grazing Management	Y	N	1997	Catherine Creek Allotment	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Upper Grande Ronde FS Roads - Sediment Reduction	Close & obliterate sediment producing roads, clean, repair & install road drainage structures	Grande Ronde	Road Obliteration; Reduce Sediment Load	Y	N	1992	Upper Grande Ronde & Catherine Crk watersheds	Catherine Cr.	CATHEC	
BPA / GRMWP	Upper Grande Ronde Road Improvements - FS	Close & obliterate roads, relocate 1 draw bottom road	Grande Ronde	Road Obliteration; Reduce Sediment Load	Y	N	1988	Upper Grande Ronde WS and small area in Catherine Crk WS	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek/Wright-Hempe-Hutchinson Fishway /Diversion Upgrade	Complete modification to diversion structure to meet ODFW fish passage standards	Grande Ronde	Fish Passage Improvement	Y	N	1997	Catherine Creek in City of Union	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek/Hefner Irrigation System Improvement	Irrigation system efficiency improvements	Grande Ronde	Restore Instream Flows	Y	N	2001	Dobbs Ditch/Catherine Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Road Erosion Project - Addendum	Seeding/planting on cut slopes for erosion/sediment control	Grande Ronde	Reduce Sediment Load	Y	N	1998	Hwy 203 near confluence of Catherine Crk & Milk Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Union County 1998 Ditch Lining Projects - BOR	Line irrigation ditches to conserve water	Grande Ronde	Restore Instream Flows	Y	N	1998	Union County at Prescott Ditch (Catherine Crk), Nesley Ditch and Gekeler Ditch (Grande Ronde River)	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Union County 1998 Ditch Lining Projects - BOR	Line irrigation ditches to conserve water	Grande Ronde	Restore Instream Flows	Y	N	1998	Union County at Prescott Ditch (Catherine Crk), Nesley Ditch and Gekeler Ditch (Grande Ronde River)	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Allotment Division Fence - USFS	Livestock pasture division fence	Grande Ronde	Riparian Fencing/Grazing Management	Y	N	2000	Little Catherine Crk subwatershed	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Allotment Division Fence - USFS	Livestock pasture division fence	Grande Ronde	Riparian Fencing/ Grazing Management	Y	N	2000	Little Catherine Crk subwatershed	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Allotment Division Fence - USFS	Livestock pasture division fence	Grande Ronde	Riparian Fencing/ Grazing Management	Y	N	2000	Little Catherine Crk subwatershed	Catherine Cr.	CATHEC	
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	N	N	1995	Howard Creek/Grossman Creek and Minam River/Wallowa River subwatersheds, Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	N	N	1995	Howard Creek/Grossman Creek and Minam River/ Wallowa River subwatersheds, Little Catherine Creek	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	N	N	1995	Howard Creek/Grossman Creek and Minam River/Wallowa River subwatersheds, Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Pole Creek Fence & Water Development	Drift fence, cattleguard & livestock water development	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	1996	Pole Creek grazing allotment, S.F. Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Division Fence	Cross fencing	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	1997	Catherine Creek Allotment	Catherine Cr.	CATHEC	
BPA / GRMWP	Little Catherine Creek Watershed Enhancement - BCC/DEQ	Cross fencing, livestock water development maintenance, road closures & seeding, upland & riparian plantings	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load	N	N	1995	Little Catherine Crk, Little Crk, Potters Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Little Catherine Creek Watershed Enhancement - BCC/DEQ	Cross fencing, livestock water development maintenance, road closures & seeding, upland & riparian plantings	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load	N	N	1995	Little Catherine Crk, Little Crk, Potters Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Little Catherine Creek Watershed Enhancement - BCC/DEQ	Cross fencing, livestock water development maintenance, road closures & seeding, upland & riparian plantings	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load	N	N	1995	Little Catherine Crk, Little Crk, Potters Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Milk Creek Riparian Fence & Trough Relocation - FS	Riparian exclosure & trough relocation	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	1993	Milk Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Ladd Creek\Tule Lake Restoration Project	Restore stream channel, floodplain and lake habitat, riparian & upland planting, water control structures.	Grande Ronde	Restore Stream Complexity; Floodplain Creation; Riparian Re-vegetation; Restore Instream Flows	N	N	2002	Ladd Creek, Tule Lake	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Grande Ronde Basin Instream Structure Enhancement	Block grant to fund use of trakhoe or track mounted log loader for instream placement of large woody material and/or boulders.	Grande Ronde	Habitat Features	N	N	1999	Eaton Creek, Ladd Canyon tributary, McCoy Creek, Milk Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Grande Ronde Basin Instream Structure Enhancement	Block grant to fund use of trakhoe or track mounted log loader for instream placement of large woody material and/or boulders.	Grande Ronde	Habitat Features	N	N	1999	Eaton Creek, Ladd Canyon tributary, McCoy Creek, Milk Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Ladd Creek Alternative Watering System	Riparian exclosure fence and livestock water development	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	2000	Ladd Creek, just above confluence with Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	N	N	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	N	N	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	N	N	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	N	N	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	Little Catherine Creek Tributary Riparian Exclosure Fence - USFS	Riparian exclosure fence	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	2000	Tributary to Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek - ODFW Fish Habitat/Sheehy	Land/stream lease, riparian exclosure fence	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1986	Catherine Creek	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Little Catherine Creek Meadows Riparian Fence - FS	Riparian exclosure fence	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1992	Little Catherine Crk trib. @ Little Catherine Meadows	Catherine Cr.	CATHEC	
BPA / GRMWP	Milk Creek Riparian Fence & Trough Relocation - FS	Riparian exclosure & trough relocation	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1993	Milk Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Murphy/Sheehy Streambank Restoration	Streambank stabilization and planting, riparian exclosure fencing	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Streambank Stabilization	Y	Y	1994	Catherine Crk rm 15.5, downstream from Union	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Fish Passage	Construct fish passage structures at 3 irrigation diversion dams	Grande Ronde	Fish Passage Improvement	Y	Y	1995	Catherine Creek, rm 17-20.25, Swackhammer, Union Intake & Wright-Hempe-Hutchinson dams	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Fish Passage	Construct fish passage structures at 3 irrigation diversion dams	Grande Ronde	Fish Passage Improvement	Y	Y	1995	Catherine Creek, rm 17-20.25, Swackhammer, Union Intake & Wright-Hempe-Hutchinson dams	Catherine Cr.	CATHEC	
BPA / GRMWP	Miller Grazing Management/Riparian Restoration	Riparian exclosure fencing & cross fencing	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1995	North Fork and mainstem Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Hefner Catherine Creek Riparian Restoration	Riparian exclosure fence and planting	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation	Y	Y	1995	Catherine Crk, rm 16	Catherine Cr.	CATHEC	
BPA / GRMWP	Little Catherine Creek Watershed Enhancement - BCC/DEQ	Cross fencing, livestock water development maintenance, road closures & seeding, upland & riparian plantings	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load	Y	Y	1995	Little Catherine Crk, Little Crk, Potters Crk	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	Y	Y	1995	Howard Creek/Grossman Creek and Minam River/Wallowa River subwatersheds, Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	Y	Y	1995	Howard Creek/Grossman Creek and Minam River/Wallowa River subwatersheds, Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Scott Streambank	Streambank rock barbs, vegetative revetments, planting, riparian exclosure fence & cross fencing	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Streambank Stabilization	Y	Y	1995	Lower Catherine Creek, rm 7, South of Gekeler Ln downstream from Ladd Crk and upstream from confluence with Grande Ronde	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Erosion Control	Streambank rock & log structures, riparian exclosure fencing and planting	Grande Ronde	Riparian Fencing/ Grazing Management; Riparian Re-vegetation; Streambank Stabilization	Y	Y	1995	Catherine Creek within city limits of Union	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek State Park - Union High School/Oregon State Park Div.	Campground relocation, footbridge construction, riparian vegetation planting, interpretive signs	Grande Ronde	Riparian Re-vegetation; Streambank Stabilization	Y	Y	1995	Catherine Creek State Park, Catherine Crk, rm 26	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Rock Barbs & Planting - NRCS/Smith	Streambank rock barbs & plantings	Grande Ronde	Riparian Re-vegetation; Streambank Stabilization	Y	Y	1995	Catherine Crk ~ rm 22	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Little Catherine Creek Headcut Stabilization & Restoration	Boulder weirs, streambank riprap, pool construction	Grande Ronde	Habitat Features; Streambank Stabilization	Y	Y	1996	Little Catherine Creek @ Little Catherine Meadows	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Road Erosion Project	Reshape & plant cut slope, install drainage culverts, divert runoff	Grande Ronde	Reduce Sediment Load	Y	Y	1996	Hwy 203 near confluence of Catherine Crk & Milk Crk	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Watershed Enhancement - USFS	Riparian pasture	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1996	South Fork Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Pole Creek Fence & Water Development	Drift fence, cattleguard & livestock water development	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1996	Pole Creek grazing allotment, S.F. Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Pole Creek Fence & Water Development	Drift fence, cattleguard & livestock water development	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1996	Pole Creek grazing allotment, S.F. Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Streambank Stabilization & Spring Chinook Habitat Enhancement	Streambank stabilization & sewage treatment plant protection (rock barbs, log revetment, rock weir, rock rip rap), fish passage structure improvement (laddered weirs & inlet), spring chinook rearing channel improvement (diversion to provide continuous flo	Grande Ronde	Fish Passage Improvement; Off-channel Habitat; Streambank Stabilization	Y	Y	1997	Catherine Creek in City of Union (City of Union Treatment Plant, City Union Intake Ponds, & 2 urban locations	Catherine Cr.	CATHEC	
BPA / GRMWP	Catherine Creek Riparian Pasture & Off-Site Water Development	Riparian pasture fence & livestock water developments	Grande Ronde	Riparian Fencing/ Grazing Management	Y	Y	1998	Little Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Grande Ronde Basin Instream Structure Enhancement	Block grant to fund use of trakhoe or track mounted log loader for instream placement of large woody material and/or boulders.	Grande Ronde	Habitat Features	Y	Y	1999	Eaton Creek, Ladd Canyon tributary, McCoy Creek, Milk Creek	Catherine Cr.	CATHEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Grande Ronde Basin Instream Structure Enhancement	Block grant to fund use of trakhoe or track mounted log loader for instream placement of large woody material and/or boulders.	Grande Ronde	Habitat Features	Y	Y	1999	Eaton Creek, Ladd Canyon tributary, McCoy Creek, Milk Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	Y	Y	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	Y	Y	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	Y	Y	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Grande Ronde	Riparian Fencing/ Grazing Management; Habitat Features	Y	Y	2000	Catherine Creek watershed	Catherine Cr.	CATHEC	
BPA / GRMWP	Milk/Catherine Cr. Channel Meander-Fish Passage Establishment	Relocate/restore stream from ditch to historic channel, replace undersized culvert.	Grande Ronde	Fish Passage Improvement; Channel Lengthening	Y	Y	2001	Milk Creek, near confluence with Catherine Creek	Catherine Cr.	CATHEC	
BPA / GRMWP	Upper Grande Ronde Sediment Reduction - FS	Obliterate, close and waterbar sediment producing roads	Grande Ronde	Road Obliteration	Y	N	1995	Catherine Creek & Upper Grande Ronde watersheds	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde FS Roads - Sediment Reduction	Close & obliterate sediment producing roads, clean, repair & install road drainage structures	Grande Ronde	Road Obliteration; Reduce Sediment Load	Y	N	1992	Upper Grande Ronde & Catherine Crk watersheds	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Upper Grande Ronde User Established Campsite Closures	Close user established campsites and replace with 1 campground and 8 dispersed campgrounds	Grande Ronde	Restore Riparian Function	Y	N	1988	Upper Grande Ronde rm 184-192	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Road Improvements - FS	Close & obliterate roads, relocate 1 draw bottom road	Grande Ronde	Road Obliteration; Reduce Sediment Load	Y	N	1988	Upper Grande Ronde WS and small area in Catherine Crk WS	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Warm Spring Creek Off-Stream Water Development	Riparian exclosure fencing, livestock water development improvements	Grande Ronde	Riparian Fencing/ Grazing Management	N	N	1995	Warm Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Project 1	Instream structures, streambank stabilization, road obliteration	Grande Ronde	Road Obliteration; Streambank Stabilization; Habitat Features	N	N	1994	Warm Spring Creek & Grande Ronde R	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Phase II	Crossfencing, livestock water developments, riparian tree planting, instream log weirs and rock barbs, streambank vegetation planting, gate for traffic control.	Grande Ronde	Riparian Fencing/ Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Streambank Stabilization; Habitat Features	N	N	1995	Upper Grande Ronde mainstem, Meadow & Warm Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Phase II	Crossfencing, livestock water developments, riparian tree planting, instream log weirs and rock barbs, streambank vegetation planting, gate for traffic control.	Grande Ronde	Riparian Fencing/ Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Streambank Stabilization; Habitat Features	N	N	1995	Upper Grande Ronde mainstem, Meadow & Warm Spring Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Streambank Restoration - Biomat	Erosion control mats, logs, large woody material, riparian planting, stream channel reconstruction	Grande Ronde	Streambank Stabilization; Restore Riparian Function; Riparian Re-vegetation; Habitat Features; Restore Stream Complexity	N	N	1996	Lower Tanner Gulch, West Chicken Creek, Five Points Tributary, Last Chance Creek (tributary to Grande Ronde R), and South Fork Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Streambank Restoration - Biomat	Erosion control mats, logs, large woody material, riparian planting, stream channel reconstruction	Grande Ronde	Streambank Stabilization; Restore Riparian Function; Riparian Re-vegetation; Habitat Features; Restore Stream Complexity	N	N	1996	Lower Tanner Gulch, West Chicken Creek, Five Points Tributary, Last Chance Creek (tributary to Grande Ronde R), and South Fork Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Camp Carson Mine Slide Rehabilitation - USFS	Stabilize slide area and divert surface water	Grande Ronde	Reduce Sediment Load	N	N	1997	Tanner Gulch Crk, slide area upland from creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Warm Spring Riparian Fence - FS/BPA	Riparian exclosure fence	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1992	Warm Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Winter Canyon Spring Trough Relocation & Riparian Pasture Fence - FS	Reconstruct & relocate riparian pasture fence, relocate livestock water out of stream channel	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1993	Winter Canyon	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Tanner Fire Rehabilitation - FS	Sediment trapping & filtration measures, upland seeding, contour lines & straw bales, instream straw bale/log jam sediment traps	Grande Ronde	Habitat Features; Reduce Sediment Load	N	N	1990	East Fork Grande Ronde River, unnamed tribs to EF and mainstem Grande Ronde River	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	N	N	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	N	N	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	N	N	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	N	N	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Ranch Riparian Project	Riparian exclosure fence improvements & new construction	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1997	East Sheep Creek, Sheep Creek, Fly Crk & tribs.	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Ranch Riparian Project	Riparian exclosure fence improvements & new construction	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1997	East Sheep Creek, Sheep Creek, Fly Crk & tribs.	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Ranch Riparian Project	Riparian exclosure fence improvements & new construction	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1997	East Sheep Creek, Sheep Creek, Fly Crk & tribs.	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Warm Spring Creek Riparian Improvement Project	Relocate riparian exclusion fence & add gates	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1997	Warm Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Creek Watershed Restoration Project	Livestock water developments, close livestock watering gaps in riparian fence, riparian planting, instream placement of large woody material, thin conifer stands bordering or containing stream channels	Grande Ronde	Riparian Fencing/Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Habitat Features	N	N	1999	Sheep Creek and East Fork Sheep Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Little Fly Meadow Headcut Rehabilitation	Reestablish groundwater and overbank flow into meadow by installing french drains, contour/stabilize/plant streambanks, install vortex rock weirs and wood structures	Grande Ronde	Restore Instream Flows; Restore Riparian Function; Riparian Re-vegetation; Streambank Stabilization; Habitat Features	N	N	2000	Little Fly Creek, @ crossing with 5160 road	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Chicken-Dry Creek Wet Meadow Restoration	Wet meadow restoration, raise water table with log grade control structures, road obliteration, thin overstocked conifer stands.	Grande Ronde	Habitat Features; Road Obliteration	N	N	2000	Chicken Creek, Dry Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Grande Ronde River Fencing Project	Riparian protection livestock drift fence, draw bottom/mid-slope road obliteration/recontour	Grande Ronde	Riparian Fencing/Grazing Management; Road Obliteration; Reduce Sediment Load	N	N	2001	Upper Grande Ronde River, Dry beaver Creek and unnamed tributaries of the Grande Ronde R	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Fly Creek - ODFW/BPA Fish Habitat/Smith	Land/stream lease, riparian exclosure fencing	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1987	Fly Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Creek - ODFW/BPA Fish Habitat/Schiller	Land/stream lease, riparian exclosure fencing & planting, livestock water developments, log weirs & large organic material	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features	Y	Y	1987	Sheep Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Creek Structures & Riparian Fence/Planting - FS/BPA	Log structures, riparian exclosure fence & planting	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features; Streambank Stabilization	Y	Y	1987	Sheep Creek, rm 6.5-10.5	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Fly Creek Log Structures - FS/BPA	Log structures	Grande Ronde	Habitat Features; Streambank Stabilization	Y	Y	1988	Fly Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Log Structures, Phase I - FS/BPA	Log structures	Grande Ronde	Habitat Features; Streambank Stabilization	Y	Y	1988	Grande Ronde River, rm 198.5-200	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Creek - ODFW/BPA Fish Habitat/BLM	Land/stream lease, riparian exclosure fencing, log weirs	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features	Y	Y	1988	Sheep Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Tanner Fire Rehabilitation - FS	Sediment trapping & filtration measures, upland seeding, contour lines & straw bales, instream straw bale/log jam sediment traps	Grande Ronde	Habitat Features; Reduce Sediment Load	Y	Y	1990	East Fork Grande Ronde River, unnamed tribs to EF and mainstem Grande Ronde River	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde - ODFW/BPA Fish Habitat/Bowman /Hoeft	Land/Stream lease, riparian exclosure fencing & planting, rock weirs, jetties, boulder placement, large organic material	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features; Streambank Stabilization	Y	Y	1990	Upper Grande Ronde, between confluences with Meadow Creek & Fly Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Log Structures, Phase II - FS/BPA	Log structures	Grande Ronde	Habitat Features; Streambank Stabilization	Y	Y	1991	Grande Ronde R, rm 200-202.5	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde - ODFW/BPA Fish Habitat/Delve	Land/stream lease, riparian exclosure fencing & planting, boulders, large woody material, water developments	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features; Streambank Stabilization	Y	Y	1991	upper Grande Ronde between confluences with Meadow Crk & Fly Crk	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Limber Jim Creek Log Structure & Riparian Fence - FS/BPA	Log structures & riparian exclosures	Grande Ronde	Riparian Fencing/Grazing Management; Habitat Features; Streambank Stabilization	Y	Y	1991	Limber Jim Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Boulder Structures - FS	Boulder berms & clusters	Grande Ronde	Habitat Features; Streambank Stabilization	Y	Y	1993	Grande Ronde from Fly Crk to 5115 Bridge, same reach treated with whole trees in 1995 (#1025)	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Grande Ronde/Meadow Creek Livestock Water - NRCS/Tsiatsos	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1993	Grande Ronde R & Meadow Crk	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Grande Ronde/Meadow Creek Livestock Water - NRCS/Tsiatsos	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1993	Grande Ronde R & Meadow Crk	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Fly Creek Riparian Restoration	Riparian exclosure fence, livestock water	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1994	Fly Creek @ confluence w/ Grande Ronde River	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Project 1	Instream structures, streambank stabilization, road obliteration	Grande Ronde	Road Obliteration; Streambank Stabilization; Habitat Features	Y	Y	1994	Warm Spring Creek & Grande Ronde R	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Grande Ronde River Fish Habitat	Instream placement of whole trees	Grande Ronde	Habitat Features	Y	Y	1995	Grande Ronde R from Fly Crk to 5115 bridge (Rm 184-188)	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Fly Creek Whole Tree Placement - FS	Instream placement of whole trees	Grande Ronde	Habitat Features	Y	Y	1995	Fly Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Phase II	Crossfencing, livestock water developments, riparian tree planting, instream log weirs and rock barbs, streambank vegetation planting, gate for traffic control.	Grande Ronde	Riparian Fencing/Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Streambank Stabilization; Habitat Features	Y	Y	1995	Upper Grande Ronde mainstem, Meadow & Warm Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Starkey Cattlemen - Phase II	Crossfencing, livestock water developments, riparian tree planting, instream log weirs and rock barbs, streambank vegetation planting, gate for traffic control.	Grande Ronde	Riparian Fencing/Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Streambank Stabilization; Habitat Features	Y	Y	1995	Upper Grande Ronde mainstem, Meadow & Warm Spring Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	Y	Y	1996	Minam and Mt. Harris Management Units (BCC)	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Dispersed Campsite Closures	Close & sign campsites in riparian areas	Grande Ronde	Restore Riparian Function	Y	Y	1996	McCoy Creek, Sheep Creek, Grande Ronde River, Chicken Crk	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Dispersed Campsite Closures	Close & sign campsites in riparian areas	Grande Ronde	Restore Riparian Function	Y	Y	1996	McCoy Creek, Sheep Creek, Grande Ronde River, Chicken Crk	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Dispersed Campsite Closures	Close & sign campsites in riparian areas	Grande Ronde	Restore Riparian Function	Y	Y	1996	McCoy Creek, Sheep Creek, Grande Ronde River, Chicken Crk	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde Floodplain Rehabilitation	Campground & road obliteration & planting	Grande Ronde	Road Obliteration; Streambank Stabilization; Riparian Re-vegetation	Y	Y	1996	Grande Ronde River, Sherwood & Woodley Campgrounds	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Streambank Restoration - Biomat	Erosion control mats, logs, large woody material, riparian planting, stream channel reconstruction	Grande Ronde	Streambank Stabilization; Restore Riparian Function; Riparian Re-vegetation; Habitat Features; Restore Stream Complexity	Y	Y	1996	Lower Tanner Gulch, West Chicken Creek, Five Points Tributary, Last Chance Creek (tributary to Grande Ronde R), and South Fork Spring Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Streambank Restoration - Biomat	Erosion control mats, logs, large woody material, riparian planting, stream channel reconstruction	Grande Ronde	Streambank Stabilization; Restore Riparian Function; Riparian Re-vegetation; Habitat Features; Restore Stream Complexity	Y	Y	1996	Lower Tanner Gulch, West Chicken Creek, Five Points Tributary, Last Chance Creek (tributary to Grande Ronde R), and South Fork Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Streambank Restoration - Biomat	Erosion control mats, logs, large woody material, riparian planting, stream channel reconstruction	Grande Ronde	Streambank Stabilization; Restore Riparian Function; Riparian Re-vegetation; Habitat Features; Restore Stream Complexity	Y	Y	1996	Lower Tanner Gulch, West Chicken Creek, Five Points Tributary, Last Chance Creek (tributary to Grande Ronde R), and South Fork Spring Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	1997 Whole Tree Project	Instream placement of whole trees and boulders	Grande Ronde	Habitat Features	Y	Y	1997	Grande Ronde River from FS 5115 road upstream to FS boundary	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Chicken Creek Fence & Water Development	Riparian/upland exclosure fence & livestock water development	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1997	Chicken & West Chicken Creek, Sheep Ranch Allotment	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Chicken Creek Fence & Water Development	Riparian/upland exclosure fence & livestock water development	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1997	Chicken & West Chicken Creek, Sheep Ranch Allotment	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Ranch Riparian Project	Riparian exclosure fence improvements & new construction	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1997	East Sheep Creek, Sheep Creek, Fly Crk & tribs.	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Sheep Ranch Riparian Project	Riparian exclosure fence improvements & new construction	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1997	East Sheep Creek, Sheep Creek, Fly Crk & tribs.	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River & Sheep Creek Instream Structure Modifications	Instream placement of woody material & boulders, pool excavation, improve/remove existing structures, streambank stabilization & planting	Grande Ronde	Streambank Stabilization; Riparian Re-vegetation; Habitat Features	Y	Y	1997	Upper Grande Ronde R from Woodley Campground upstream 3mi, Sheep Crk from NFS boundary upstream 2.5mi	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River & Sheep Creek Instream Structure Modifications	Instream placement of woody material & boulders, pool excavation, improve/remove existing structures, streambank stabilization & planting	Grande Ronde	Streambank Stabilization; Riparian Re-vegetation; Habitat Features	Y	Y	1997	Upper Grande Ronde R from Woodley Campground upstream 3mi, Sheep Crk from NFS boundary upstream 2.5mi	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	Y	Y	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	Y	Y	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	Y	Y	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	Y	Y	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Upper Grande Ronde River Riparian Rehabilitation	Pre-commercial thinning of riparian/upland timber stands	Grande Ronde	Restore Riparian Function	Y	Y	1998	Little Clear Crk, Meadow Crk, Waucup Crk, Upper/Little Fly, Limber Jim Crk, West Chicken Creek, Grande Ronde River, Sheep Crk, and Pelican Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Sheep Creek Watershed Restoration Project	Livestock water developments, close livestock watering gaps in riparian fence, riparian planting, instream placement of large woody material, thin conifer stands bordering or containing stream channels	Grande Ronde	Riparian Fencing/Grazing Management; Restore Riparian Function; Riparian Re-vegetation; Habitat Features	Y	Y	1999	Sheep Creek and East Fork Sheep Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Chicken-Dry Creek Wet Meadow Restoration	Wet meadow restoration, raise water table with log grade control structures, road obliteration, thin overstocked conifer stands.	Grande Ronde	Habitat Features; Road Obliteration	Y	Y	2000	Chicken Creek, Dry Creek	Upper Grande Ronde R.	GRANDR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Chicken-Dry Creek Wet Meadow Restoration	Wet meadow restoration, raise water table with log grade control structures, road obliteration, thin overstocked conifer stands.	Grande Ronde	Habitat Features; Road Obliteration	Y	Y	2000	Chicken Creek, Dry Creek	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Grande Ronde River Fencing Project	Riparian protection livestock drift fence, draw bottom/mid-slope road obliteration/recontour	Grande Ronde	Riparian Fencing/Grazing Management; Road Obliteration; Reduce Sediment Load	Y	Y	2001	Upper Grande Ronde River, Dry beaver Creek and unnamed tributaries of the Grande Ronde R	Upper Grande Ronde R.	GRANDR	
BPA / GRMWP	Walla Walla RD Road Obliteration - FS	Road obliteration	Grande Ronde	Road Obliteration	N	N	1995	Lookingglass, Jarboe, Cabin and Phillips Crk Watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Walla Walla RD Road Obliteration - FS	Road obliteration	Grande Ronde	Road Obliteration	N	N	1995	Lookingglass, Jarboe, Cabin and Phillips Crk Watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Walla Walla Ranger District Road Obliteration & Culvert Removal	Road obliteration and culvert removal	Grande Ronde	Obliterate unnecessary roads	N	N	1997	Phillips Creek & Little Lookingglass watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Walla Walla Ranger District Road Obliteration & Culvert Removal	Road obliteration and culvert removal	Grande Ronde	Obliterate unnecessary roads	N	N	1997	Phillips Creek & Little Lookingglass watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Walla Walla RD Road Obliteration - FS	Road obliteration	Grande Ronde	Road Obliteration	Y	Y	1995	Lookingglass, Jarboe, Cabin and Phillips Crk Watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Lookingglass Creek Streambank Stabilization - EWP/Nielson	Lookingglass Creek Streambank Stabilization - EWP/Nielson	Grande Ronde	Streambank Stabilization; Reconnect Existing Off-channel Habitat	Y	Y	1996	Lookingglass Crk, ~rm 5.5	Lookingglass Cr.	LOOKGC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Lookingglass Creek Road Obliteration	Obliterate and stabilize roads	Grande Ronde	Road Obliteration	Y	Y	1999	Lookingglass Creek subwatershed	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Walla Walla Ranger District Road Obliteration & Culvert Removal	Road obliteration and culvert removal	Grande Ronde	Obliterate unnecessary roads	Y	N	1997	Phillips Creek & Little Lookingglass watersheds	Lookingglass Cr.	LOOKGC	
BPA / GRMWP	Millar-Wolfe Pond	Dredge, fence & plant seepage channel and pond, livestock water development	Grande Ronde	Restore Instream Flows; Riparian Fencing/Grazing Management	N	N	1997	Wetland area below Clearwater Ditch, flows into Wallowa River just below confluence with Lostine R	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Improvement (GWEB)	Relocate feedlot, livestock water developments, ditch exclosure fencing	Grande Ronde	Improve Water Quality; Riparian Fencing/Grazing Management	N	N	1995	Spring Branch flowing into Clearwater Ditch	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Fence - NRCS/Carman	Ditch exclusion fence	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1993	Clearwater Ditch	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Fencing - NRCS/Makens	Ditch livestock exclosure fencing	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1998	Spring Branch Clearwater Ditch	Lostine R.	LOSTIR	
BPA / GRMWP	Westside Ditch Lining/Fence & Livestock Water - NRCS/BOR/Rocking Eleven	Ditch lining & livestock exclosure fence, livestock water development	Grande Ronde	Riparian Fencing/Grazing Management; Restore Instream Flows	N	N	1998	Westside Ditch	Lostine R.	LOSTIR	
BPA / GRMWP	Lower Valley Ditch Crossing - BOR	Road crossing construction to permit connection of ditches at consolidated diversion structure	Grande Ronde	None	N	N	1995	Wallowa River, rm 22.5	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Lining - BOR/Clearwater Ditch Co.	Ditch lining	Grande Ronde	Restore Instream Flows	N	N	1997	Clearwater Ditch	Lostine R.	LOSTIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Lostine River Tributary Enhancement - NRCS/Coleman	Riparian exclosure fence & plantings, livestock water development	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1999	Unnamed trib. to Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Lower Valley Consolidated Diversion Structure	Consolidate diversion structures into 1 improved structure	Grande Ronde	Fish Passage Improvement	Y	Y	1995	Wallowa River, rm 22.5	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Diversion Structure	Construct permanent diversion structure	Grande Ronde	Fish Passage Improvement	Y	Y	1995	Lostine River, rm 3.5	Lostine R.	LOSTIR	
BPA / GRMWP	Clearwater Ditch Improvement	Ditch fencing & improvements, livestock water developments, feedlot relocation, cross fencing	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1995	Clearwater Ditch & Lostine River, 2mi east of Wallowa	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine Riparian Fencing - Pyeatt	Riparian exclosure fencing	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1995	Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine Riparian Fencing - Jones	Riparian exclosure fencing	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1995	Lostine River, rm 6.5-7	Lostine R.	LOSTIR	
BPA / GRMWP	Wallowa River Corridor Fence - ODFW/McCrae	Wallowa River Corridor Fence - ODFW/McCrae	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1995	Wallowa R, ~ rm 23.5	Lostine R.	LOSTIR	
BPA / GRMWP	Sheep Ridge Ditch Fencing - Moholt	Ditch exclusion fencing & planting	Grande Ronde	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	1995	Lostine River watershed, Sheep Ridge Ditch	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine River Campgrounds	Altered or moved 19 campsites and closed 2.25 mi road	Grande Ronde	Road Obliteration; Restore Riparian Function	Y	Y	1995	Lostine River Campground, from Williamson CG site to Two Pan CG site	Lostine R.	LOSTIR	
BPA / GRMWP	Tulley-Hill Diversion Structure	Permanent diversion dam with fish ladder/weir	Grande Ronde	Fish Passage Improvement	Y	Y	1996	Lostine R ~rm 1.7	Lostine R.	LOSTIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Krieger Lostine River	Improve diversion & place boulders, riparian exclosure fencing & planting, expand & improve off-channel wetland/smolt winter habitat	Grande Ronde	Fish Passage Improvement; Habitat Features; Riparian Fencing/Grazing Management; Riparian Re-vegetation; Off-channel Habitat	Y	Y	1996	Lostine River, rm 10.5-11.5	Lostine R.	LOSTIR	
BPA / GRMWP	Miles Ditch Diversion	Permanent diversion structure	Grande Ronde	Fish Passage Improvement	Y	Y	1997	Lostine River near Cross Country Canal confluence	Lostine R.	LOSTIR	
BPA / GRMWP	Poley Allen Ditch	Permanent diversion structure	Grande Ronde	Fish Passage Improvement	Y	Y	1997	Lostine River near South Fork Ready Mix Plant	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine River Riparian Fence (ODFW) & Feedlot/ Irrigation Improvements (NRCS/BOR) - Johnston	Riparian exclosure fence, conversion to gated pipe, feedlot improvements	Grande Ronde	Riparian Fencing/Grazing Management; Improve Water Quality	Y	Y	1997	Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine River Livestock Water & Irrigation Improvements - NRCS/Jones	Install well, pipe to troughs, convert from flood to sprinkler irrigation.	Grande Ronde	Restore Instream Flows	Y	Y	1998	Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Poley Allen Ditch/Wetland Enhancement - NRCS/Larabee	Ditch/wetland exclosure fence & livestock water development	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1999	Poley Allen Ditch/ Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine River Fence - ODFW/Lostine R Ranch	Riparian exclosure fence	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1999	Lostine River	Lostine R.	LOSTIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Lostine River/Bill Norman Riparian Area Enhancement	Riparian exclosure fence, streambank rock barbs and root wads.	Grande Ronde	Riparian Fencing/Grazing Management; Streambank Stabilization	Y	Y	1999	Lostine River, ~ 2mi south of Lostine	Lostine R.	LOSTIR	
BPA / GRMWP	Lostine Wild & Scenic River Restoration	Campground improvements, recreation livestock watering development, limit vehicle & livestock access	Grande Ronde	Restore Riparian Function; Riparian Fencing/Grazing Management	Y	N	1996	Lostine River Campground	Lostine R.	LOSTIR	
BPA / GRMWP	Wallowa River Riparian Fence - ODFW/ NRCS/Krebs	Riparian exclosure fence, streambank jetties	Grande Ronde	Riparian Fencing/Grazing Management; Streambank Stabilization	Y	N	1993	Wallowa River below Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Krebs Streambank Protection	Streambank riprap	Grande Ronde	Streambank Stabilization	Y	N	1997	Wallowa River, ~0.5mi below confluence with Lostine R	Lostine R.	LOSTIR	
BPA / GRMWP	Baker Streambank Protection	Riparian exclosure fence & planting, streambank rock barbs	Grande Ronde	Riparian Fencing/Grazing Management; Streambank Stabilization; Riparian Re-vegetation	Y	N	1998	Wallowa River, ~rm 21 below town of Wallowa	Lostine R.	LOSTIR	
BPA / GRMWP	Wallowa River ODFW/BPA Fish Habitat & NRCS/FSA Irrigation Improvements - Wiseman	Riparian exclosure fence & plantings, large woody debris placement, livestock water development, conversion to gated pipe irrigation	Grande Ronde	Riparian Fencing/Grazing Management; Streambank Stabilization; Riparian Re-vegetation; Restore Riparian Function; Restore Instream Flows	Y	N	1998	Wallowa River, just SE of Wallowa	Lostine R.	LOSTIR	
BPA / GRMWP	Wallowa River ODFW/BPA Fish Habitat - Cox/McCrae/Johnson/Burrows	Riparian exclosure fence, large woody debris placement, livestock water development	Grande Ronde	Riparian Fencing/Grazing Management; Restore Riparian Function	Y	N	1998	Wallowa River, just SE of Wallowa	Lostine R.	LOSTIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Attebury Irrigation Improvement Project	Convert from flood to sprinkler irrigation.	Grande Ronde	Restore Instream Flows	Y	N	1999	Poley Allen Ditch/Lostine River	Lostine R.	LOSTIR	
BPA / GRMWP	Wallowa Band Nez Perce Trail Interpretive Center Land Improvements - Phase I	Meadow restoration and upland slope stabilization; livestock water developments, settling pond construction, riparian and upland plantings	Grande Ronde	Riparian Fencing/Grazing Management; Reduce Sediment Load; Riparian Re-vegetation; Improve Water Quality	Y	N	2000	Wallowa River, next to City of Wallowa	Lostine R.	LOSTIR	
BPA / GRMWP	Larabee Irrigation Improvement Project	Convert from flood to sprinkler irrigation.	Grande Ronde	Restore Instream Flows	Y	N	2001	Westside & Poley Allen Ditches/Lostine River, west of city of Lostine	Lostine R.	LOSTIR	
BPA / GRMWP	Minam Watershed Improvement	Crossfencing, modification of grazing system, livestock water development improvements, fish population inventories.	Grande Ronde	Riparian Fencing/Grazing Management	N	N	1994	Minam River scenic waterway and uplands	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Minam/Mt. Harris Road Improvement	Road drainage structures, rocking & road closures	Grande Ronde	Reduce Sediment Load	N	N	1996	Minam and Mt. Harris Management Units (BCC)	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	

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BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	N	N	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Minam Watershed Improvement	Crossfencing, modification of grazing system, livestock water development improvements, fish population inventories.	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1994	Minam River scenic waterway and uplands	Minam R.	MINAMR	
BPA / GRMWP	Minam Watershed Improvement	Crossfencing, modification of grazing system, livestock water development improvements, fish population inventories.	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	1994	Minam River scenic waterway and uplands	Minam R.	MINAMR	
BPA / GRMWP	OSU/BCC Grazing System Development & Habitat Improvement	Stabilize & improve roads, livestock water developments, riparian pasture fencing, cross fencing, riparian & meadow planting, develop & demonstrate DSS model.	Grande Ronde	Riparian Fencing/Grazing Management; Riparian Re-vegetation; Reduce Sediment Load; Streambank Stabilization	Y	Y	1995	Howard Creek/Grossman Creek and Minam River/Wallowa River subwatersheds, Little Catherine Creek	Minam R.	MINAMR	
BPA / GRMWP	Spring and Pond Developments	Livestock water developments	Grande Ronde	Riparian Fencing/Grazing Management	Y	Y	2001	Five Points Creek, Ladd Canyon, Rock Creek, Minam River	Minam R.	MINAMR	
BPA / GRMWP	Catherine Creek Division Fence	Cross fencing	Imnaha	Riparian Fencing/Grazing Management	Y	N	1997	Catherine Creek Allotment	Imnaha R.	IMNAHR	
BPA / GRMWP	McCully Creek Riparian Fence - Olcott	Riparian/upland exclosure fence, livestock water development, road improvements	Imnaha	Riparian Fencing/Grazing Management; Reduce Sediment Load	N	N	1996	McCully Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Carrol Creek Riparian Enhancement - USFS	Riparian exclosure & planting	Imnaha	Riparian Fencing/Grazing Management; Riparian Re-vegetation	N	N	1993	Carrol Creek & E. Fork Carrol Crk	Imnaha R.	IMNAHR	

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BPA / GRMWP	Carrol Creek Riparian Enhancement - USFS	Riparian exclosure & planting	Imnaha	Riparian Fencing/Grazing Management; Riparian Re-vegetation	N	N	1993	Carrol Creek & E. Fork Carrol Crk	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep & Salt Creek Riparian Planting - USFS	Riparian planting	Imnaha	Riparian Re-vegetation	N	N	1990	Little Sheep, & Salt Crk & Wallowa Valley Improvement Canal	Imnaha R.	IMNAHR	
BPA / GRMWP	Kinney Lake/McCully Creek Riparian Improvements - NRCS/Olcott	Riparian exclusion fence at lake and cross fence	Imnaha	Riparian Fencing/Grazing Management	N	N	1993	Kinney Lake & McCully Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Road Canyon Headwaters Fencing - FS	Spring/pond/gully exclosure fence	Imnaha	Riparian Fencing/Grazing Management	N	N	1995	Road Canyon	Imnaha R.	IMNAHR	
BPA / GRMWP	Brigham Creek & Bird Canyon Spring - TNC/ODFW/USFS	Headwater spring fencing & livestock water	Imnaha	Riparian Fencing/Grazing Management	N	N	1993	TNC's Clear Lake Ridge Natural Area, Brigham Crk & Bird Canyon	Imnaha R.	IMNAHR	
BPA / GRMWP	Brigham Creek & Bird Canyon Spring - TNC/ODFW/USFS	Headwater spring fencing & livestock water	Imnaha	Riparian Fencing/Grazing Management	N	N	1993	TNC's Clear Lake Ridge Natural Area, Brigham Crk & Bird Canyon	Imnaha R.	IMNAHR	
BPA / GRMWP	Rich Creek/Shadow Canyon Riparian Enhancement - USFS	Riparian exclosure fence and large woody material	Imnaha	Riparian Fencing/Grazing Management; Habitat Features	N	N	1997	Rich Creek and Shadow Canyon (tributary to Rich Creek)	Imnaha R.	IMNAHR	
BPA / GRMWP	Rich Creek/Shadow Canyon Riparian Enhancement - USFS	Riparian exclosure fence and large woody material	Imnaha	Riparian Fencing/Grazing Management; Habitat Features	N	N	1997	Rich Creek and Shadow Canyon (tributary to Rich Creek)	Imnaha R.	IMNAHR	

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BPA / GRMWP	Aspen by Harl Butte Lookout Riparian Enhancement - USFS	Wetland/riparian exclosure	Imnaha	Riparian Fencing/Grazing Management	N	N	1997	wetland in Needham Crk subwatershed	Imnaha R.	IMNAHR	
BPA / GRMWP	Needham Butte Riparian Enhancement - USFS	Riparian exclosure fence	Imnaha	Riparian Fencing/Grazing Management	N	N	1997	Unnamed tributary to SF Squaw Crk	Imnaha R.	IMNAHR	
BPA / GRMWP	Skookum Creek Large Woody Debris Placement - USFS	Instream placement of large woody debris	Imnaha	Habitat Features	N	N	1998	Skookum Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Grizzly Creek Stream Restoration - USFS	Repair channelization from 1997 flood, included instream channel reconstruction, instream placement of large woody debris and boulders and riparian plantings	Imnaha	Channel Lengthening; Habitat Features; Streambank Stabilization; Riparian Re-vegetation	N	N	1998	Grizzly Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Gumboot Creek In-Stream Rehabilitation - USFS	Rehabilitate stream habitat altered in 1997 flood, included instream placement of large woody debris and boulders, log weirs, boulder weirs & floodplain restoration	Imnaha	Channel Lengthening; Habitat Features; Streambank Stabilization; Riparian Re-vegetation	N	N	1998	Gumboot Crk	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep/Carrol Creek Instream and Riparian Habitat Improvements - USFS	Instream placement of rootwads, log and rock structures, riparian planting and rehabilitation	Imnaha	Restore Riparian Function; Riparian Re-vegetation; Habitat Features	N	N	2000	Big Sheep & Carrol Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Gumboot Creek Riparian Planting - USFS	Riparian planting of area damaged in 1997 flood	Imnaha	Riparian Re-vegetation	N	N	2000	Gumboot Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Eastside Fire Riparian Rehabilitation - USFS	Riparian habitat rehabilitation	Imnaha	Restore Riparian Function; Riparian Re-vegetation	N	N	2000	lower Imnaha River tributaries, Thorn & Tulley Creek	Imnaha R.	IMNAHR	

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BPA / GRMWP	Eastside Fire Riparian Rehabilitation - USFS	Riparian habitat rehabilitation	Imnaha	Restore Riparian Function; Riparian Re-vegetation	N	N	2000	lower Imnaha River tributaries, Thorn & Tulley Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep & Salt Creek Riparian Planting - USFS	Riparian planting	Imnaha	Riparian Re-vegetation	Y	Y	1990	Little Sheep, & Salt Crk & Wallowa Valley Improvement Canal	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek Riparian Fence - ODFW/Voss	Riparian exclosure fence in winter feeding area	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1991	Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Imnaha River Riparian Enhancement - USFS	Large woody material	Imnaha	Restore Riparian Function	Y	Y	1992	Imnaha River	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek Fence - NRCS/Talbott	Riparian exclusion fence	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1992	Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Lick Creek Riparian Fence - FS	Riparian exclosure fence	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1992	Lick Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Creek Riparian Enhancement - USFS	Riparian planting	Imnaha	Riparian Re-vegetation	Y	Y	1992	Big Sheep Creek & small portion of Lick Crk	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Creek Riparian Enhancement - USFS	Riparian planting	Imnaha	Riparian Re-vegetation	Y	Y	1992	Big Sheep Creek & small portion of Lick Crk	Imnaha R.	IMNAHR	
BPA / GRMWP	Imnaha Riparian Fence - NRCS/Hubbard	Riparian exclosure fence	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1993	Imnaha River	Imnaha R.	IMNAHR	

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BPA / GRMWP	Upper Imnaha Fish & Recreation Enhancement - 94/95 FS	Campground riparian plantings, interpretive signs, road closures	Imnaha	Restore Riparian Function; Riparian Re-vegetation	Y	Y	1995	Upper Imnaha R rm 58.5-64.5, Cloverdale CG & dispersed campsites	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Riparian Pasture Fencing & Trough Replacement	Riparian pasture fencing	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1995	Big Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Riparian Fence - Buhler	Riparian exclosure fence	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1995	lower end of Big Sheep Creek, ~rm 4-6	Imnaha R.	IMNAHR	
BPA / GRMWP	Lick Creek Riparian Zone Woody Debris - FS	Woody debris placed in riparian area to exclude cattle	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1995	Lick Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Creek Riparian Fence	Riparian exclosure fencing and planting	Imnaha	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	1995	Lower Big Sheep Creek above confluence with Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Riparian Fence and Revegetation - Suarez	Riparian pasture fencing & planting	Imnaha	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	1995	Big Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Upper Imnaha Fisheries & Recreation Enhancement	Campground riparian planting, interpretive signs, road/trail closure	Imnaha	Restore Riparian Function; Riparian Re-vegetation	Y	Y	1996	Upper Imnaha River, rm 59-66, Evergreen Campground, Cloverdale CG & 065 campsite dispersed campsite	Imnaha R.	IMNAHR	
BPA / GRMWP	Marr Flat/ Big Sheep Riparian Pasture Fencing	Riparian pasture fencing	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1996	Big sheep Creek, rm 26-34 and Lick Creek rm 0-1	Imnaha R.	IMNAHR	

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BPA / GRMWP	Marr Flat/ Big Sheep Riparian Pasture Fencing	Riparian pasture fencing	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1996	Big sheep Creek, rm 26-34 and Lick Creek rm 0-1	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek Fencing - Martin	Riparian exclosure fencing and planting	Imnaha	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	1996	Little Sheep Creek, near junction of Imnaha Hwy & Wallowa Loop Rd	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep Creek Riparian Enhancement - Huber	Streambank rock structures and riparian/upland exclosure fencing	Imnaha	Riparian Fencing/Grazing Management; Streambank Stabilization	Y	Y	1996	Big Sheep Creek at confluence with Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek - Streambank Stabilization - NRCS	Streambank rip rap, log/barb/vegetative plantings, rock weirs	Imnaha	Streambank Stabilization; Riparian Re-vegetation; Habitat Features	Y	Y	1996	Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Whiskey Riparian Corridor Fencing and Trough Replacement	Riparian corridor exclosure fence & trough improvements	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1997	Big Sheep Creek, rm 17-20.5	Imnaha R.	IMNAHR	
BPA / GRMWP	Divide Riparian Pasture Fencing	Riparian pasture fencing w/cattleguard	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1997	Big Sheep Creek, rm 26-36, Lick Creek rm 0-3	Imnaha R.	IMNAHR	
BPA / GRMWP	Divide Riparian Pasture Fencing	Riparian pasture fencing w/cattleguard	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1997	Big Sheep Creek, rm 26-36, Lick Creek rm 0-3	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek Streambank Protection	Streambank stabilization, road/culvert improvements, streambank plantings	Imnaha	Streambank Stabilization; Riparian Re-vegetation; Reduce Sediment Load	Y	Y	1997	Little Sheep Creek, 3 sites @ ~rm 0.5, 20, 21	Imnaha R.	IMNAHR	
BPA / GRMWP	Lightning Creek Road - Phase I	Relocate road out of creek bottom and construct stream crossing fords	Imnaha	Restore Riparian Function; Reduce Sediment Load	Y	Y	1998	Lightning Creek Road along Lightning Creek and Imnaha River	Imnaha R.	IMNAHR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Upper Imnaha Recreation & Fish Enhancement CCS Project - USFS	Campground riparian planting and road closures	Imnaha	Restore Riparian Function; Riparian Re-vegetation	Y	Y	1998	Imnaha River at Indian Crossing, Evergreen, and Cloverdale Campgrounds	Imnaha R.	IMNAHR	
BPA / GRMWP	Witherrite/ Imnaha	Streambank barbs, channel excavation, streambank plantings	Imnaha	Streambank Stabilization; Riparian Re-vegetation; Habitat Features	Y	Y	1998	Imnaha R, ~rm 23	Imnaha R.	IMNAHR	
BPA / GRMWP	Williams Imnaha Fencing & Spring Development	Riparian exclosure fence, riparian pasture fence, livestock water developments.	Imnaha	Riparian Fencing/Grazing Management	Y	Y	1999	Imnaha River	Imnaha R.	IMNAHR	
BPA / GRMWP	Upper Imnaha Recreation & Fish Enhancement CCS Project 1999-2000 - USFS	Campground riparian planting, campground closure and road obilteration	Imnaha	Restore Riparian Function; Riparian Re-vegetation	Y	Y	2000	Lower Imnaha River, Hidden, Evergreen & Cloverdale Campgrounds	Imnaha R.	IMNAHR	
BPA / GRMWP	Big Sheep/Carrol Creek Instream and Riparian Habitat Improvements - USFS	Instream placement of rootwads, log and rock structures, riparian planting and rehabilitation	Imnaha	Restore Riparian Function; Riparian Re-vegetation; Habitat Features	Y	Y	2000	Big Sheep & Carrol Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Lower Imnaha River Exclosure Fence - USFS	Riparian exclosure fence	Imnaha	Riparian Fencing/Grazing Management	Y	Y	2000	Imnaha River, ~rm 10.5	Imnaha R.	IMNAHR	
BPA / GRMWP	North Fork Catherine Watershed Restoration	Restore wet meadow, instream grade control structures, riparian exclosure fence, cross-fencing, thin overstocked conifer stands.	Imnaha	Riparian Fencing/Grazing Management; Habitat Features	Y	Y	2000	Catherine Creek watershed	Imnaha R.	IMNAHR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA / GRMWP	Bragg Investment Riparian Improvement, Imnaha River	Riparian exclosure fence and livestock water developments.	Imnaha	Riparian Fencing/Grazing Management	Y	Y	2001	Imnaha River, ~ 10 miles upstream of town of Imnaha	Imnaha R.	IMNAHR	
BPA / GRMWP	Little Sheep Creek Large Wood Placement and Culvert Replacement	Replace fish impassable culverts and place large woody material	Imnaha	Fish Passage Improvement; Habitat Features	Y	Y	2002	Little Sheep Creek	Imnaha R.	IMNAHR	
BPA / GRMWP	Imnaha/Parks Ditch Water Conservation Project	Improve irrigation delivery system, implement Allocation of Conserved Water process	Imnaha	Restore Instream Flows	Y	Y	2002	Imnaha River	Imnaha R.	IMNAHR	
USBR		The project will remove the existing L3 and L3A push-up dams and install rock weirs.	Lemhi	Fish Passage Improvement	Y	N	2002	Lemhi River	Lemhi R.	LEMHIR	
BPA	Improve irrigation efficiency below L-7	The Paul Fisher sprinkler conversion and Don Olson Ranch change in point-of-diversion were part of the USBR project and both improved irrigation efficiency by eliminating two diversions.	Lemhi	Fish Passage Improvement; Restore Instream Flows	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	creating new rearing habitat using Existing irrigation canals or old slough channels	The old L-5 canal was converted to rearing habitat by IDFG as part of the USBR project to eliminate L-5 diversion.	Lemhi	Off-channel Habitat	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Beyeler Ranch	1.6 miles of fence constructed and willows established to create a grazing system	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Neibaur Ranch	3.25 miles of fence constructed to create a 6-pasture grazing system	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Bob Amonson Ranch	.83 mile of fence constructed to create a 5-pasture grazing system	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Kelly Thomas Ranch	2.25 miles of fence constructed on 1 1/2 miles of river to create a 5-pasture system	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Ellsworth Angus Ranch	6 miles of corridor fence constructed to protect 3 miles of stream	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Lemhi Habitat Enhancement Project	Hanna Slough habitat protection and Lemhi River habitat enhancement.	Lemhi	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Karl Tyler Ranch	Constructing 15 miles of fence on 8.5 miles of stream in upper Lemhi River on Karl Tyler Ranch. This site was identified in Model Watershed Plan as critical area for chinook spawning and rearing habitat. Noranda Mining Company is the funding agency through off-site mitigation. The Model Watershed has been instrumental at finding a desirable location and negotiating the site-specific needs of landowner, mining company, and law suit trustees.	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	Isom Ranch (Karl Tyler)	1 mile of fence constructed to create a 2-pasture system	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	Snook Ranch	.9 mile of corridor fence	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	Kesl Ranch fence	Constructed 3/4 miles of fence on Kesl Ranch on Lemhi River. This will protect critical spawning and habitat areas. This fence was designed by NRCS and funded with a grant to Lemhi SCD on cost-share with landowner. Labor is partially contracted by YEP with assistance from landowner, BLM, and IDFG.	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA		1 mile stream fenced	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA		0.9 miles stream fenced	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
Idaho Department of Transportation	Bitterroot Ranch	placement of 10 rock vortex weirs. Riparian fencing.	Lemhi	Riparian Fencing/Grazing Management; Habitat Features	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	Sager Ranch bank stabilization	Constructed streambank stabilization on Rick Sager property to improve stream habitat in lower Lemhi River while providing peak flow flood control. This installed an offchannel flood control dike away from the River bank, reducing water velocities to keep a healthy strip of riparian trees and vegetation. Lemhi SCD was funding agency through a grant from Bureau of Reclamation.	Lemhi	Streambank Stabilization; Riparian Fencing/Grazing Management	Y	Y	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	creating new rearing habitat using Existing irrigation canals or old slough channels	IDFG created rearing habitat in a slough below the L-43C diversion.	Lemhi	Off-channel Habitat	Y	Y	1998	Lemhi River	Lemhi R.	LEMHIR	
BPA		Rock structures and vegetation planting	Lemhi	Habitat Features; Riparian Re-vegetation	Y	Y	1999	Lemhi River	Lemhi R.	LEMHIR	
BPA		AFO Feedlot project	Lemhi	Improve Water Quality	Y	Y	1999	Lemhi River	Lemhi R.	LEMHIR	
BPA		1.3 miles stream fenced	Lemhi	Riparian Fencing/Grazing Management	Y	Y	1999	Lemhi River	Lemhi R.	LEMHIR	
BPA	Muleshoe Ranch	0.5 miles stream fenced and irrigation improvement	Lemhi	Riparian Fencing/Grazing Management; Improve Water Quality	Y	Y	1999	Lemhi River	Lemhi R.	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Provide additional pool habitat near Tendoy	A major project of five rock weirs was constructed in the river reach bordering Bitterroot Ranch and Idaho 28 below Tendoy in 2000 (Photo 13). This project was funded by Idaho Department of Transportation (IDOT) as mitigation for channelization associated with five bridge projects on the river. Additional rock weirs have been designed for this reach, however, MWP will evaluate possible icing effects prior to the installation of additional projects.	Lemhi	Habitat Features	Y	Y	2000	Lemhi River	Lemhi R.	LEMHIR	
		0.2 miles stream fenced	Lemhi	Riparian Fencing/Grazing Management	Y	Y	2000	Lemhi River	Lemhi R.	LEMHIR	
		0.98 miles stream fenced	Lemhi	Riparian Fencing/Grazing Management	Y	Y	2000	Lemhi River	Lemhi R.	LEMHIR	
		AFO Feedlot project; 0.27 miles stream fenced	Lemhi	Improve Water Quality; Riparian Fencing/Grazing Management	Y	Y	2001	Lemhi River	Lemhi R.	LEMHIR	
BPA	Idaho Model Watershed Habitat Projects	Installed .33 miles of riparian fence on the Lemhi.	Lemhi	Riparian Fencing/Grazing Management	Y	Y	2001	Lemhi River	Lemhi R.	LEMHIR	
BPA	Idaho Model Watershed Habitat Projects	Installed .75 miles of riparian fence on the Lemhi.	Lemhi	Riparian Fencing/Grazing Management	Y	Y	2001	Lemhi River	Lemhi R.	LEMHIR	
BPA	Idaho Model Watershed Habitat Projects	Installed 1 miles of riparian fence on the Lemhi.	Lemhi	Riparian Fencing/Grazing Management	Y	Y	2001	Lemhi River	Lemhi R.	LEMHIR	
Landowner		Replace rock ford and wooden bridge with railcar bridge; fence 2 miles of stream	Lemhi	Streambank Stabilization; Reduce Sediment Load; Riparian Fencing/Grazing Management	Y	Y	2002	Lemhi River	Lemhi R.	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-01 Sova Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1991	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-01 Sova Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1991	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02 Mill Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02 Mill Ditch; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02 Mill Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02B Mill Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02B Mill Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02C Mill Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-02C Mill Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-03 Stokes/Young; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-03A Clark Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-03B Lamar Cockrell; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-04 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-04 ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-05 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-05 ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-06 (USBR) Beers Slough Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-06 (USBR) Beers Slough Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-07(USBR) Town Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-07(USBR) Town Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-07(USBR) Town Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-07A (USBR) Town Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-08 Stoddard Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-08A Aldous Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-08A Aldous Ditch; Screen ; Dam Rock Vortex Weir	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-08A(NRCS) Aldous Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1999	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-09 Hagel Irr. Co.; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-10 Reese Ditch; Screen Replaced; Dam Improved, Needs Work	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-10 Reese Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-11 Old Van Scriver; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-11 Old Van Scriver; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-12 Old Hagel Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-14 Town Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-15 Withington Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-16 Mulkey Ditch-01; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-16 Mulkey Ditch-01; Screen; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-16/17 Mulkey Ditch-01; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-17 Mulkey Ditch-01; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-18 Herbst-Mulkey Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-18A Herbst-Mulkey Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-18A Herbst-Mulkey Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-19 Snook Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	2000	Lemhi River @ RM 15.7	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-19A Snook Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1990	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-19A Snook Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1990	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-20 Charlotte's Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-21 Quentin's Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-22 Company Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-22A ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	

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BPA	Idaho Fish Screen Improvement	Diversion L-22A ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-22A/23 ; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-23 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-23 ; Screen ; Dam Improved	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-24 Andreason #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-25 Andreason #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-26 Ziegler Ditch #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-27 Shoup Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-28 Mahaffey-Shoup; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-29 Mahaffey River; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-30 Swanson Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	2000	Lemhi River @ RM 27.9	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-30A Swanson Ditch; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-30AO Swanson Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1999	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-31 Pattee-Mahaffey River; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-31 Pattee-Mahaffey River; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-31A Indian Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-31B Island Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-32 Pattee-Morphy; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-33 Company Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-34 Langfitt Ditch #1; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-35 Langfitt Ditch #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-36 Bauman Ditch; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-36 Bauman Ditch; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-37 Bauman Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-37(p) Bauman Ditch; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-38 Wm. Mahaffey #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-39 Wm. Mahaffey #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-40 Walter Whitson; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-41 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-41 ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-42 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-43 Mahaffey Brothers; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	2000	Lemhi River @ RM 31.5	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-43A Mahaffey #1 (consol); Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-43B Mahaffey #2 (consol); Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-43C Mahaffey #3 (consol); Screen Not to Criteria; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-44 Yearian Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-44 Yearian Ditch #1; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45 Yearian Ditch #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45A Russell Yearian; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45A Russell Yearian; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45B McKinney Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45C Yearian-McKinney; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45C Yearian-McKinney; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45C/D Yearian-McKinney; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-45D Yearian-McKinney; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-46 Yearian Upper; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-46 Yearian Upper; Screen; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-46/46A Yearian Upper; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-46A Yearian Upper; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-47 McKinney Ditch #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-48 Spahn Main; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-48 Spahn Main; Screen; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-48/49 Spahn Main; Screen; Dam Step-Up Pools	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-49 Spahn Main; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-49 Spahn Main; Screen; Dam Step-up Pools	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-50 Amonson Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-50 Amonson Ditch #1; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-51 Amonson Ditch #2; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1992	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-51A Amonson Ditch #3; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-52 Upper McFarland; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-52A Island Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-52A Island Ditch; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-53 Mahaffey Ditch #1; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-53 Mahaffey Ditch #1; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-54 Taylor Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-54 Taylor Ditch #1; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-54 Taylor Ditch #1; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-57 Mahaffey Ditch #1; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-58 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-58A Ellsworth Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-58A Ellsworth Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-58B Benedict Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion L-58C Tage Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-59 McKinney Ditch #3; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-60 Lower Stroud Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-60 Lower Stroud Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1994	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-61 Upper Stroud Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-62 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1996	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-62 ; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1998	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-63 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion L-64 ; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-01 Quinn Rigan; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1994	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-01A Quinn Rigan; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	1996	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-03 Cope-Aiken; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	

Sponsor Agency	**Project Title**	**Project Summary**	**Subbasin**	**Model Action Type**	**FX chinook?**	**FX juv surv?**	**Year Started**	**Location**	**PIT Stock(s)**	**Stock 1**	**Stock 2**
BPA	Idaho Fish Screen Improvement	Diversion LHC-04 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-04 ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-04/06/07 ; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-05 High Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-05 High Ditch; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-06 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-06 ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-07 ; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-08 Schlehuber Ditch; Screen Replaced; Dam	Lemhi	Diversion Screening	Y	Y	1993	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-08A Tobias-01 Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-08A Tobias-01 Ditch; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-08B Tobias-01 Ditch; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion LHC-08B Tobias-01 Ditch; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-09 ; Screen ; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-09 ; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-09/09B ; Screen ; Dam Improved	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-09B ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-09B ; Screen ; Dam Eliminated	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-10 Stoll-02; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-10 Stoll-02; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1996	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-11 Clark Ditch; Screen New; Dam	Lemhi	Diversion Screening	Y	Y	1996	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-11 Clark Ditch; Screen; Dam Headgates	Lemhi	Diversion Screening	Y	Y	1999	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHC-HATCHERY Hayden Creek Fish Hatchery; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	1995	Hayden Creek	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LHCP-5.5 Magics; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Hayden Creek	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion LP-0.8 ; Screen Passive; Dam	Lemhi	Diversion Screening	Y	Y	2000	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-10.0 / 7.45 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-10.1 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-12.23 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-12.32 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-12.44 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-13.55 Sager; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-17.85 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-18.0 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-18.11 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-24.19 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-26.625 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion LP-26.626 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-28.0 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-31.64 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-31.64 ; Screen Passive; Dam	Lemhi	Diversion Screening	Y	Y	2000	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-31.66 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-41.8 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-5.9 / 31.66 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2001	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-7.34 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-7.341 ; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-7.45 La Pierre; Screen Pump Screened; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-7.49 (USBR) ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-8.00 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion LP-8.24 ; Screen Eliminated; Dam	Lemhi	Diversion Screening	Y	Y	1997	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-9.5 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2002	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-9.60 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2002	Lemhi River	Lemhi	LEMHIR	
BPA	Idaho Fish Screen Improvement	Diversion LP-9.61 ; Screen Screened; Dam	Lemhi	Diversion Screening	Y	Y	2002	Lemhi River	Lemhi	LEMHIR	
BPA	Model Watershed Studies - Lemhi River Basin	Bureau of Reclamation Irrigation Diversion Consolidation/Elimination Program - L4 elimination	Lemhi	Fish Passage Improvement; Restore Instream Flows	Y	N	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Model Watershed Studies - Lemhi River Basin	Bureau of Reclamation Irrigation Diversion Consolidation/Elimination Program - L6, L7 consolidations	Lemhi	Fish Passage Improvement; Restore Instream Flows	Y	N	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	Model Watershed Studies - Lemhi River Basin	Bureau of Reclamation Irrigation Diversion Consolidation/Elimination Program - L5 elimination (NRCS and BOR project)	Lemhi	Fish Passage Improvement; Restore Instream Flows	Y	N	1996	Lemhi River	Lemhi R.	LEMHIR	
BPA	L-3A Canal Fish Ladder	Construct a fish ladder on the L-3 spillway	Lemhi	Fish Passage Improvement	Y	N	1997	Lemhi River	Lemhi R.	LEMHIR	
BPA	Protect Bear Valley Wild Salmon, Steelhead, Bull Trout Spawning and Rearing Habitat	Permanently eliminate livestock grazing impacts on the Bear Valley and Deer Creek Allotments in the Bear Valley Creek watershed.	M Fk Salmon	Riparian Fencing/Grazing Management	Y	Y	2002	Bear Valley And Deer Creek watersheds	Bear Valley Cr. & Elk Cr.	BEARVC	ELKC
BPA	Bear Valley, Yankee & East Forks Habitat Work	Dredge mine sediment reduction and rehabilitation of 1.5 miles of the Portland Mine	M Fk Salmon	Streambank Stabilization; Riparian Re-vegetation; Reduce Sediment Load	Y	Y	1984	Bear Valley Creek	Bear Valley Cr.	BEARVC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Bear Valley Sediment Reduction	The objective of the project was to stabilize eroding stream banks by preventing further erosion and trapping silt and debris to build up the banks. Once sediment has been trapped, willows and grasses can colonize the area.	M Fk Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1988	Bear Valley Creek	Bear Valley Cr.	BEARVC	
West Region	Taylor Ranch Projects	streambank erosion project (Big Creek subwatershed) Construction of 3 log jams along bank	M Fk Salmon	Streambank Stabilization	N	N	2001	Big Creek, MFSR	Big Cr.	BIGC	
West Region	Taylor Ranch Projects	water inlet project (Pioneer Creek subwatershed) Replace inlet and rock check dam with screened diversion	M Fk Salmon	Fish Passage Improvement	N	N	2001	Pioneer Creek, tributary to Big Creek, MFSR	Big Cr.	BIGC	
BPA	Camas Creek	In 1987-88, 4.3 miles of fence was constructed establishing a riparian livestock exclosure in the Meyers Cove area of Camas Creek. One end-gap and two water-crossing corridors were constructed in 1989 to complete the fence system. Areas within the riparian exclosure have been fertilized with phosphorous-rich fertilizer to promote tree and shrub root growth and meadow recovery. A stream crossing ford was stabilized with angular cobble. Streambank stabilization/habitat cover work was completed at three sites and three additional habitat structures were placed. Extensive habitat inventories were completed to identify quality/quantity of habitat available to anadromous fish.	M Fk Salmon	Riparian Fencing/Grazing Management; Riparian Re-vegetation; Habitat Features; Streambank Stabilization	Y	Y	1987	Camas Creek	Camas Cr.	CAMASC	
Salmon Challis NF, Salmon Cobalt RD		Reclaim 1 mile of stream side road constructed to access illegal placer mining operation	M Fk Salmon	Road Obliteration	Y	Y	2000	Silver Creek, tributary to Camas Creek	Camas Cr.	CAMASC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Bear Valley Sediment Reduction	The outside bank of an eroding meander was treated with juniper in 1988 and a single pole fence constructed to locally control grazing effects at this meander.	M Fk Salmon	Riparian Fencing/Grazing Management; Riparian Re-vegetation; Streambank Stabilization	Y	Y	1988	Elk Creek	Elk Cr.	ELKC	
BPA	Marsh, Elk Creek & Upper Salmon River Habitat Work	At this site, Elk Creek had been actively eroding into a glacial terrace comprised of predominantly sand-sized sediments. Nearly 20 feet of lateral erosion into a lo-foot high terrace along approximately 300 feet of channel had released an estimated 2,500 cubic yards of sediment into Elk Creek over a 3-year period. Continued bank erosion was anticipated and thus this project was initiated for the purpose of stopping additional erosion. The project consisted of constructing a meander cutoff and stabilizing the new channel with rock weirs and riprap. Approximately 500 feet of a meander was replaced with 100 feet of steeper gradient channel associated with the rock weirs.	M Fk Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1988	Bearskin Creek cutoff, Elk Creek	Elk Cr.	ELKC	
Boise NF; Cascade RD and Shoban tirbes		Close entire grazing allotment to livestock	M Fk Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	Elk Creek, tributary to Bear Valley Creek	Elk Cr.	ELKC	
BPA	Marsh, Elk Creek & Upper Salmon River Habitat Work	In 1990 a series of low rock check dams were installed along more than a mile of eroding channel. The erosion from this intermittent stream channel apparently represented a major source of sediment in the drainage.	M Fk Salmon	Streambank Stabilization; Reduce Sediment Load	N	N	1990	Dry Creek, trib. Marsh Creek	Marsh Cr.	MARSHC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Marsh, Elk Creek & Upper Salmon River Habitat Work	In 1987 a rock diversion structure with bypass channel was installed in Knapp Creek. Its purpose was to provide upstream access to several miles of spawning and rearing habitat for anadromous fish. The Existing wooden diversion structure was blocking upstream migration. Because the constructed diversion was located upstream of the Existing wooden structure, a bypass channel was needed to allow the movement of upstream adults and downstream smolts past the Existing wooden structure. The bypass channel was constructed though a meadow and incorporated several rock structures to prevent channel downcutting.	M Fk Salmon	Fish Passage Improvement	Y	Y	1987	Knapp Creek	Marsh Cr.	MARSHC	
BPA	Idaho Fish Screen Improvement	Diversion SMFMCKC-01 USFS; Screen Screened; Dam	M Fk Salmon	Diversion Screening	Y	Y	1998	Knapp Creek	Marsh Cr.	MARSHC	
BPA	Idaho Fish Screen Improvement	Diversion SMFMCKC-02 USFS; Screen Screened; Dam	M Fk Salmon	Diversion Screening	Y	Y	1998	Knapp Creek	Marsh Cr.	MARSHC	
BLM		Upgrade of pipeline to eliminate large, unscreened irrigation diversion on the Pahsimeroi River	Pahsimeroi	Fish Passage Improvement	Y	Y	1995	Pahsimeroi River near Lawson Creek	Pahsimeroi R.	PAHSIR	
BPA	Idaho Model Watershed Habitat Projects	The Starr Coleman fence for .75 miles of corridor fence along the Pahsimeroi was constructed by the Tribes in March of 1996.	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Dowton 3X Ranch	.3 mile corridor fence attached to .75 miles constructed by operator	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Dowton 3S Ranch	.2 mile corridor fencing	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Chewning	1.1 miles corridor fencing	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Brent Cutler Ranch	1.25 miles of corridor fencing	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Coleman Ranch	2.8 miles of corridor fencing	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Spengler Ranch	2.9 miles of fence constructed to create a 3-pasture grazing system	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Latimer Ranch	1.4 miles of corridor fencing	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Parkinson Irrigation Project	Restore 6 cfs to the the Pahsimeroi R. via irrigation ditch and 4 cfs to Patterson Creek, both from PBSC3 diversion. Replace Ellis diversion, located at confluence of above ditch and Pahsimeroi R. Restored fish access by restoring a 300 foot dewatered section of stream. A new headgate with fish ladder was installed on the Pahsimeroi along with a new metal screw gate on the Ellis division ditch to maintain 6 cfs flow in the 300 feet river section. The water rights were then transferred to the main stem Salmon River. This necessitated construction of an enlarged pumping station. Restored fish access to 2 miles of Pahsimeroi River and 6 miles of Patterson/ Big Springs Creek.	Pahsimeroi	Fish Passage Improvement; Restore Instream Flows	Y	Y	1997	Patterson / Big Springs Creek and Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BLM	Poison Springs	pipeline to provide off-channel watering for livestock; reduce livestock pressure on exclosure fences	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1998	Poison Springs in the Upper Pahsimeroi River	Pahsimeroi R.	PAHSIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BLM		8 Miles of exclosure fence to exclude livestock from the Pahsimeroi River and restore streamside vegetation, reduce sedimentation and stabilize streambanks	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1999	Pahsimeroi River from Mahogany Creek to Burnt Creek	Pahsimeroi R.	PAHSIR	
BLM		Riparian exclosure fence to exclude livestock grazing from 7 miles of fish bearing stream.	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1999	Upper Pahsimeroi River Burnt Creek to Double Springs Creek)	Pahsimeroi R.	PAHSIR	
BPA	Gydeson Ranch	1.1 miles of fence constructed to create a grazing system	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1999	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA		0.8 miles of stream fenced	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1999	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA		1.1 miles of stream fenced	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	1999	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Develop water conservation agreements to reduce levels of stream diversion	A project was developed by IDFG and NRCS and completed in 2000 to convert the Jim Dowton Ranch and part of the Moen Ranch to center pivot sprinklers in an effort to leave more water in this critical reach. Five pivots were installed. This project eliminated the P-8A diversion and an unscreened pump diversion below 8A. The cross ditch from Big Spring Creek to the Pahsimeroi River will be used only when needed to deliver water to P-9 (Photo 17 – before; Photo 18 – after). The project involved a water conservation agreement with the potential to keep 11.2 cfs in the river. Several other landowners are also involved in this project.	Pahsimeroi	Fish Passage Improvement; Restore Instream Flows	Y	Y	2000	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Latimer Ranch	About 30 small rock bank barbs were installed in the Latimer Ranch reach of the river.	Pahsimeroi	Habitat Features	Y	Y	2000	Pahsimeroi River	Pahsimeroi R.	PAHSIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Custer Soil & Water Conservation District Salmon River Fish Passage Enhancement	Completed two diversion modifications including one consolidation that reconnects approximately 6 miles of stream in the Pahsimeroi.	Pahsimeroi	Fish Passage Improvement; Restore Instream Flows	Y	Y	2001	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Mahogany Ditch pipeline	The Mahogany Ditch project provides off-site stock water, along with corridor fencing and water gaps, provides protection to the upper reach of the Pahsimeroi River.	Pahsimeroi	Riparian Fencing/Grazing Management	Y	Y	2001	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
US Fish and Wildlife Service		1800 feet of Jack Fence along the border of the property for the exclusion of livestock from 12 acres. Willow and Cottonwood plantings will be placed on 300 feet of unstable stream bank	Pahsimeroi	Riparian Fencing/Grazing Management; Riparian Re-vegetation	Y	Y	2002	Pahsimeroi River, Chewning Property	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-01A (Temp. eliminated); Screen Modular; Dam	Pahsimeroi	Diversion Screening	Y	Y	2001	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-02 Furey-Marlatt; Screen Eliminated; Dam	Pahsimeroi	Diversion Screening	Y	Y	1990	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-02 Furey-Marlatt; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-02/03 Furey-Marlatt; Screen ; Dam Headgates	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-03 Furey-Marlatt; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-04 Burstedt Ditch; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-05 COMPANY DITCH; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1999	Pahsimeroi River	Pahsimeroi R.	PAHSIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion P-06 Watson-Marlatt; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-06 Watson-Marlatt; Screen ; Dam Headgates	Pahsimeroi	Diversion Screening	Y	Y	1997	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-07 Ellis-Burns Ditch; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-07 Ellis-Burns Ditch; Screen ; Dam Headgates	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-08 Dowton Ditch; Screen Replaced; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-08 Dowton Ditch; Screen ; Dam Headgates	Pahsimeroi	Diversion Screening	Y	Y	1997	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-08A Dowton-Emery; Screen Eliminated; Dam	Pahsimeroi	Diversion Screening	Y	Y	2000	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-09 ELLIS DITCH; Screen Not to Criteria; Dam Fish Ladder	Pahsimeroi	Diversion Screening	Y	Y	1999	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion P-10 SHORT DITCH; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	2000	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion Parkinson#1 ; Screen Pump Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion Parkinson#2 ; Screen Pump Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion Parkinson#3 ; Screen Pump Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1996	Pahsimeroi River	Pahsimeroi R.	PAHSIR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion PHATCH-01 Pahsimeroi Fish Hatchery; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1994	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion PHATCH-02 Pahsimeroi Fish Hatchery; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	1994	Pahsimeroi River	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion PP-5.6 ; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	2000	Pahsimeroi River @ RM 5.6	Pahsimeroi R.	PAHSIR	
BPA	Idaho Fish Screen Improvement	Diversion PP-9.3 ; Screen Screened; Dam	Pahsimeroi	Diversion Screening	Y	Y	2000	Pahsimeroi River @ RM 9.3	Pahsimeroi R.	PAHSIR	
USFS	Thunderbolt Project, Johnson Cr. Road #413	Spot gravel 5 miles of the road surface; replace or extend asphalt surface approaches for about 100 feet at six stream crossings; armor sections of ditchlines; install and extend culverts; revegitate cut and fill slopes	South Fork Salmon	Reduce Sediment Load	N	N	1996	Johnson Creek	Johnson Cr.	JOHNSC	
USFS	Johnson Cr.-Thunderbolt project, Road # 410 (Ditch Cr.)	Relocate gate and restrict motrized use from Oct. 1st to June 1st. Obliterate 0.5 miles of road past trailhead along unnamed tributary of ditch creek.	South Fork Salmon	Reduce Sediment Load	N	N	1996	Johnson Creek	Johnson Cr.	JOHNSC	
USFS	Johnson Creek-Lunch Creek Road #415 spurs	Road Closure	South Fork Salmon	Reduce Sediment Load	N	N	1991	Lunch Creek	Johnson Cr.	JOHNSC	
USFS	Riordan Creek-Lower Johnson Creek drainage. Above Riordan Lake	Riordan Trail rehabilitation	South Fork Salmon	Reduce Sediment Load	N	N	1997	Riordan Creek trib. To Johnson Creek	Johnson Cr.	JOHNSC	
USFS	Johnson Creek-Sheep Creek Road #454 spurs	Road Closure	South Fork Salmon	Reduce Sediment Load	N	N	1991	Sheep Creek	Johnson Cr.	JOHNSC	
BPA	Johnson Creek barrier removal	a complete barrier to chinook migration was removed at the Cascades	South Fork Salmon	Fish Passage Improvement	Y	Y	1984	Johnson Creek	Johnson Cr.	JOHNSC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	S FK Salmon River Anadromous Fish Enhancement	Instream & bank construction	South Fork Salmon	Habitat Features	Y	Y	1993	Johnson Creek	Johnson Cr.	JOHNSC	
USFS	Johnson Creek-SFSR- miles 1-12	Road ditchline armoring and road resurfacing for sediment abatement and direct runoff to streams	South Fork Salmon	Reduce Sediment Load	Y	Y	1993	Johnson Creek	Johnson Cr.	JOHNSC	
BPA	S FK Salmon River Anadromous Fish Enhancement	Vegetation management (plant, log, burn, treat)	South Fork Salmon	Riparian Re-vegetation	Y	Y	1993	Johnson Creek	Johnson Cr.	JOHNSC	
BPA	S FK Salmon River Anadromous Fish Enhancement	Site restoration (mine, road, campground); Worked on reducing sediment in the South Fork of the Salmon River and two of its tributaries, Johnson Creek and Lake Creek. Contract 1993AI94794 for $31,364 was issued in 1993. Mod 1 added $112,739 in 1994. Mod 2 was a no-cost time extension in 1995. The contract was closed in 2000.	South Fork Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1993	Johnson Creek	Johnson Cr.	JOHNSC	
Boise NF; Cascade RD		Install gates and restrict motorized use of the road from Oct. 1st to June 1st; Install or replace culverts at fords; harden the first (lowest) ford on both the Cabin Cr. and Trout Cr. sides; relocate and harden 2nd ford on Trout Cr. Side	South Fork Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1996	Thunderbolt Project, Trout Cr. To Cabin Cr. Road #467	Johnson Cr.	JOHNSC	
BPA	Nez Perce NF Early Action Watershed Projects	Cox Ranch fencing, riparian revegetation, bank stabilization, culvert replacement	South Fork Salmon	Riparian Fencing/Grazing Management; Fish Passage Improvement; Riparian Re-vegetation; Streambank Stabilization	Y	Y	1997	Cox Ranch, Johnson Creek	Johnson Cr.	JOHNSC	
BPA	S FK Salmon River Anadromous Fish Enhancement	Fencing	South Fork Salmon	Riparian Fencing/Grazing Management	Y	Y	1993	Lake Creek	Lake Cr.	LAKEC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Burgdorf Meadows	Purchase of conservation easement at Burgdorf Meadows, Idaho Co. ID.	South Fork Salmon	Land Acquisition	Y	Y	1998	Lake Creek	Lake Cr.	LAKEC	
BPA		In 1998 BPA and Rocky Mountain Elk Foundation purchased a permanent conservation easement on approximately 95 acres along Lake Creek and associated wetlands. IDFG and Nez Perce Tribe were granted joint fish and wildlife mitigation authority.	South Fork Salmon	Restore Riparian Function	Y	Y	1998	Burgdorf Meadows, Lake Creek (Secesh)	Lake Cr.	LAKEC	
USFS	Upper SFSR-SF Rice Creek Road Spurs #478, 488, 470, 471	Road Closure	South Fork Salmon	Reduce Sediment Load	Y	N	1991	Bear, Camp, Reeves, and Rice Creeks	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-SF Rice Creek Road Spurs #478, 488, 470, 471	Road Closure	South Fork Salmon	Reduce Sediment Load	Y	N	1991	Bear, Camp, Reeves, and Rice Creeks	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-Dollar Creek #495 spurs	Road Closure	South Fork Salmon	Reduce Sediment Load	Y	N	1993	Dollar Creek	S. Fk. Salmon R.	SALRSF	
BPA	Dollar Creek	Debris jam barriers that partially blocked passage were selectively removed.	South Fork Salmon	Fish Passage Improvement	Y	N	1987	Dollar Creek	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-SF Rice Creek Road Spurs #478, 488, 470, 471	Road Closure	South Fork Salmon	Reduce Sediment Load	Y	N	1991	Bear, Camp, Reeves, and Rice Creeks	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-SF Rice Creek Road Spurs #478, 488, 470, 471	Road Closure	South Fork Salmon	Reduce Sediment Load	Y	N	1991	Bear, Camp, Reeves, and Rice Creeks	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-Vulcan Hot Springs Trailhead	Rework trailhead area	South Fork Salmon	Reduce Sediment Load	Y	N	1993	South Fork Salmon River	S. Fk. Salmon R.	SALRSF	

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USFS	Upper SFSR-Scotty's mine road #483A	road stabilization	South Fork Salmon	Reduce Sediment Load	N	N	1992	Unnamed Creek trib. SFSR near Bear Creek	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR Thunderbolt project, Road # 401 (Penny Springs)	Install gates and restrict motorized use of the road from Oct. 1st to June 1st; Obliterate 0.6 miles from Roaring Cr. To intersection of 474E and 401; obliterate 0.3 from helicopter pad to Goat Cr.	South Fork Salmon	Reduce Sediment Load	N	N	1995	Roaring and Goat Creeks SFSR tribs	S. Fk. Salmon R.	SALRSF	
USFS	Warm lake Hwy. (FH-22) at 409 junction. Upper SFSR/Trail Creek	Repair of 1997 rain-on-snow road fill slope and prism mass wasting failure of FH-22 into Trail Creek	South Fork Salmon	Reduce Sediment Load	N	N	1998	Trail Creek trib. To SFSR	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR-NF Dollar Creek Road #495	Road Obliteration	South Fork Salmon	Reduce Sediment Load	N	N	1993	North Fork Dollar Creek	S. Fk. Salmon R.	SALRSF	
USFS	Upper SFSR Thunderbolt project, Road # 401 (Penny Springs)	Install gates and restrict motorized use of the road from Oct. 1st to June 1st; Obliterate 0.6 miles from Roaring Cr. To intersection of 474E and 401; obliterate 0.3 from helicopter pad to Goat Cr.	South Fork Salmon	Reduce Sediment Load	N	N	1995	Roaring and Goat Creeks SFSR tribs	S. Fk. Salmon R.	SALRSF	
BPA	S FK Salmon River Anadromous Fish Enhancement	Camp Creek sediment trap	South Fork Salmon	Reduce Sediment Load	Y	Y	1993	Salmon River, South Fork	S. Fk. Salmon R.	SALRSF	
USFS	SFSR Trail Bridge at Vulcan Hot Springs	Install 2 trail bridges across salmon spawning habitat. Installed vault toilet at trailhead.	South Fork Salmon	Reduce Sediment Load	Y	Y	1995	South Fork Salmon River	S. Fk. Salmon R.	SALRSF	
			South Fork Salmon		N	N			Secesh R.	SECESR	
BPA	Bear Valley, Yankee & East Forks Habitat Work	Herd Creek riparian fence	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1991	Herd Creek	Herd Cr.	HERDC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Salmon River Habitat Enhancement M & E	Fencing constructed on Herd Creek to discourage livestock use of streambank and riparian areas, thus improving streambank stability and reducing sediment input into the stream.	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2001	Herd Creek	Herd Cr.	HERDC	
BLM - Salmon Field Office		Replace two culverts to improve fish passage	Upper Salmon	Barrier Removal	Y	Y	2002	Lake Creek, tributary to Herd Creek	Herd Cr.	HERDC	
BPA	Idaho Fish Screen Improvement	Diversion SEFHC-01 Gossi Ditch #1; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	Herd Creek	Herd Cr.	HERDC	
BPA	Idaho Fish Screen Improvement	Diversion SEFHC-01 Gossi Ditch #1; Screen ; Dam Step-up Pools	Upper Salmon	Diversion Screening	Y	Y	1997	Herd Creek	Herd Cr.	HERDC	
BPA	Idaho Fish Screen Improvement	Diversion SEFHC-02 Gossi Ditch #2; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	Herd Creek	Herd Cr.	HERDC	
BPA	Idaho Fish Screen Improvement	Diversion SEFHC-02 Gossi Ditch #2; Screen ; Dam Step-up Pools	Upper Salmon	Diversion Screening	Y	Y	1998	Herd Creek	Herd Cr.	HERDC	
BPA	Idaho Fish Screen Improvement	Diversion SEFHC-02 Gossi Ditch #2; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1998	Herd Creek	Herd Cr.	HERDC	
Sawtooth NRA	Fisher Creek, trib to Salmon River	Pass Creek Ford. Habitat restoration – close and rehabilitate a user established deteriorating ford through Fisher Creek.	Upper Salmon	Restore Riparian Function	N	N	1999	Fisher Creek, trib to Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Fisher Creek Road.	Habitat maintenance – Reconstruct 1.5 miles of Fisher Creek Road to reduce the effects of road produced sediment .	Upper Salmon	Reduce Sediment Load	N	N	1993	Fisher Creek	Upper Salmon R.	SALR	
Sawtooth NRA	Washington Basin Trail.	Habitat and watershed restoration – relocate several deteriorating segments of the trail, many in or adjacent to headwater tributaries. Enhance trail drainage throughout.	Upper Salmon	Reduce Sediment Load	N	N	1990	Fourth of July and Washington Lake Creeks	Upper Salmon R.	SALR	
Sawtooth NRA	Fourth of July Party Meadow Rehab.	Meadow restoration – rehabilitate approximately 1 acre of seasonally wet meadow severely damaged by vehicle play.	Upper Salmon	Restore Riparian Function	N	N	2001	Fourth of July Creek, trib to Salmon River	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Sawtooth NRA	Decker Flat Burn.	Habitat restoration – implement prescribed burn in over mature sagebrush habitat to increase habitat complexity and ecotone.	Upper Salmon	Restore Riparian Function	N	N	1993	Salmon River and Huckleberry Creek	Upper Salmon R.	SALR	
Sawtooth NRA	Sawtooth Valley Ditches.	Watershed restoration – rehabilitate 29 miles of secondary and distributary ditches no longer used within the former Busterback Ranch.	Upper Salmon	Restore Riparian Function	N	N	2000	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Busterback Purchase	rehabilitate small length of unused irrigation ditch	Upper Salmon	Restore Riparian Function	N	N	1998	Salmon River	Upper Salmon R.	SALR	
BPA	Pole Creek Irrigation Diversion Screening	Chinook salmon and steelhead trout production in Pole Creek, a tributary to the Salmon River near Sawtooth City, Idaho, has for many years been limited by irrigation diversion. The abstracted water rights (65.6 cfs), diverted from seven points along the stream, exceeded the total flow instream throughout most of the irrigation season, leaving the mouth of Pole Creek dewatered. In 1982 the mode of irrigation on those lands adjacent to Pole Creek was changed from flood to "overhead sprinkler". The new irrigation system requires only 12-18 cfs drawn from one point, and leaves enough water instream to reestablish chinook and steelhead runs to Pole Creek. As an essential component of efforts to reestablish anadromous stocks in Pole Creek, a fish screen on the diversion has been constructed to protect downstream migrating smolts.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	1982	Pole Creek	Upper Salmon R.	SALR	

Sponsor Agency	**Project Title**	**Project Summary**	**Subbasin**	**Model Action Type**	**FX chinook?**	**FX juv surv?**	**Year Started**	**Location**	**PIT Stock(s)**	**Stock 1**	**Stock 2**
BPA	Pole Creek fence	A riparian easement allowing fence construction and maintenance was obtained from the Salmon Falls Sheep Company. Construction began on 2.1 miles of fence on the private land. The fence was 75 percent completed before snow and freezing weather forced the contractor to delay construction until spring of 1989 l	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1988	Pole Creek	Upper Salmon R.	SALR	
BPA	Upper Salmon structures (Rember/ Massey Ranches)	At this site the Salmon River was actively eroding the prehistoric floodplain and valley sediments. Channel widening was occurring at a rapid pace and essentially excavating private land along the east side of the river. In 1988 a low rock weir was extended across several braided channels in an attempt to stop bank erosion and braiding of the river. This effort was also an attempt to recover deep holes for adult salmon holding along the west side of the valley where the river formerly flowed along relatively large cobble and boulders that represented natural armoring of stable glacial deposits.	Upper Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1988	Upper Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA, and BPA	Hanson Landing	Habitat maintenance – install 3 boulder barbs/sills to prevent further River pressure against highway 75.	Upper Salmon	Restore Stream Complexity	Y	Y	1990	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA, and BPA	Salmon River S42/S43 (Decker Flat) Diversions	Passage maintenance – install several boulder drop structures to halt and reverse River downcutting in relation to the use of the S42 and S43 diversions.	Upper Salmon	Restore Stream Complexity	Y	Y	1990	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA, and BPA	Pole Creek Meadows.	Habitat restoration – install boulder drop structures in cutoff gully to prevent further deterioration.	Upper Salmon	Streambank Stabilization; Reduce Sediment Load	Y	Y	1990	Pole Creek, trib to Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Aspen Regeneration.	Habitat restoration – cutting of aspen clones to promote regeneration within the Gold Creek drainage.	Upper Salmon	Restore Riparian Function	Y	Y	1991	Gold Creek	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Sawtooth NRA	Salmon Falls C&H Pole Creek Fence.	Habitat maintenance – construct 4 miles of riparian fence along the Pole Creek preclude livestock access.	Upper Salmon	Restore Riparian Function	Y	Y	1991	Pole Creek, trib to Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Fourth of July Road.	Habitat restoration – Reconstruct 8 miles of Fourth of July Creek Road to reduce the effects of road produced sediments.	Upper Salmon	Reduce Sediment Load	Y	Y	1992	Fourth of July Creek	Upper Salmon R.	SALR	
Sawtooth NRA and BPA	Busterback Purchase.	Passage restoration – purchase former Busterback Ranch, and discontinue irrigation withdrawals	Upper Salmon	Restore Instream Flows	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Salmon 45 Diversion.	Passage restoration – modify S45 diversion for passage	Upper Salmon	Restore Instream Flows	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Headwaters Road.	Habitat restoration – close and rehabilitate ½ mile of user established route and ford through Salmon River.	Upper Salmon	Reduce Sediment Load	Y	Y	1993	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Decker Flat Burn.	Habitat restoration – implement prescribed burn in over mature sagebrush habitat to increase habitat complexity and ecotone.	Upper Salmon	Restore Riparian Function	Y	Y	1993	Salmon River and Huckleberry Creek	Upper Salmon R.	SALR	
Sawtooth NRA	Stewart Wetland.	Habitat restoration – Purchase and restore wetland source for a Williams Creek tributary formerly drained with a network of ditches.	Upper Salmon	Restore Riparian Function	Y	Y	1994	Williams Creek	Upper Salmon R.	SALR	
Sawtooth NRA, and BPA	Sawtooth Valley Ditches.	Habitat restoration – Fill and rehabilitate four miles of large supply and drainage ditches of the former Busterback Ranch. Reconnect formerly severed backwater channel.	Upper Salmon	Restore Riparian Function	Y	Y	1995	Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Rupert Mine Reclamation.	Watershed restoration – close and rehabilitate several miles of former mine operation roads.	Upper Salmon	Reduce Sediment Load	Y	Y	1998	Fourth of July Creek, trib to Salmon River	Upper Salmon R.	SALR	
Sawtooth NRA	Aspen Ripping.	Habitat enhancement – rip perimeter of aspen clones within the headwaters, Pole and Forth of July Creek drainages to stimulate stand regeneration and expansion.	Upper Salmon	Restore Riparian Function	Y	Y	1998	Salmon River headwaters	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Sawtooth NRA	Frenchman Creek, trib to Salmon River	Good Hope Mine Reclamation. Watershed restoration – close and rehabilitate several miles of former mine operation roads including fords and streamside segments.	Upper Salmon	Reduce Sediment Load	Y	Y	1999	Frenchman Creek	Upper Salmon R.	SALR	
BPA		1 mile stream fenced	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
BPA		1 mile stream fenced	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
IDFG	Gold Creek, trib to Salmon River	Gold Creek Fish Screens. Passage restoration – consolidate and install fish screen on GOC2 and 3 diversions (on private land) and install fish screen on GOC4.	Upper Salmon	Fish Passage Improvement	Y	Y	2000	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Rocky Mountain Ranch	IDFG in cooperation with Idaho Rocky Mountain Ranch reconnected Williams Creek and Gold Creek during the drought summer of 2000.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	2000	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Rocky Mountain Ranch	IDFG in cooperation with Idaho Rocky Mountain Ranch reconnected Williams Creek and Gold Creek during the drought summer of 2000.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	2000	Williams and Gold Creeks	Upper Salmon R.	SALR	
Sawtooth NRA	Frenchman Ford.	Habitat restoration – ½ mile of Road 195 relocated out of compromised and deteriorating ford and wetland area of Frenchman Creek to nearby upland route and new bridge. Former route and ford rehabilitated.	Upper Salmon	Restore Riparian Function	Y	Y	2000	Frenchman Creek	Upper Salmon R.	SALR	
BPA		1.02 miles stream fenced	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2001	Williams Creek	Upper Salmon R.	SALR	
BPA		1.02 miles stream fenced	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2001	Williams Creek	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
IDFG	Fourth of July Fish Screens.	Passage restoration – install fish screens on FCJ1, 2, and 3 diversions (all).	Upper Salmon	Fish Passage Improvement	Y	Y	2002	Fourth of July Creek, trib to Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-40 USFS/ ROCKY MT RANCH; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Salmon River @ RM 388	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-41 USFS Carstensen; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-41 USFS Carstensen; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1999	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-42 USFS/Hans Carstensen; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-43 USFS/Rob Brady; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-44 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-44 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-45 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-45 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1992	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-46 Tierney; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-46 Tierney; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1996	Salmon River	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion S-47 Salmon Falls Sheep Co; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S-47 Salmon Falls Sheep Co; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1999	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion S4THJC-03 ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	2001	Fourth of July Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SGCP-01 ; Screen Pump Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SGOLDC-01 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SGOLDC-02 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SGOLDC-03 ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SP-399.5 ; Screen Passive; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	Salmon River	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SPC-01 USFS/Salmon Falls S; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Pole Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SPCP-0.02 ; Screen Pump Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Pole Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SPSCP-3.0 ; Screen Passive; Dam	Upper Salmon	Diversion Screening	Y	Y	2001	Fourth of July Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SWC-01 ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Williams Creek	Upper Salmon R.	SALR	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SWC-02 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Williams Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SWC-03 ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Williams Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SWC-04 ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Williams Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion SWSC-017/ ; Screen Infiltration; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	Williams Creek	Upper Salmon R.	SALR	
BPA	Idaho Fish Screen Improvement	Diversion USGC-01 (p) ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1999	Gold Creek	Upper Salmon R.	SALR	
?	Upper Salmon diversion	fish ladder	Upper Salmon	Fish Passage Improvement	Y	N	1981	Salmon River below confluence with Alturas Lake and Pole Creeks	Upper Salmon R.	SALR	
BLM		Anderson Ranch Riparian exclosure fence; excluded grazing from 2 miles of stream. Fence is connected to Forest Service exclosure; 4 miles of stream excluded from grazing.	Upper Salmon	Restore Riparian Function	Y	Y	1990	Road Creek, tributary to East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Ingram Ranch	The Gary Ingram fence was constructed in the East Fork in May. About .85 miles of f riparian corridor fence were constructed along the East Fork of the Salmon River. Protection of 1.3 miles of the river. As the riparian zone recovers, more shade will be created thus lowering stream temperatures. Eventually there will be input of large woody debris	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1996	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Doug Baker Ranch	.66 mile corridor fence	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Abatti Ranch	A project was completed on the Abatti Ranch to convert 308 acres to sprinkler irrigation. This project also resulted in the elimination of SEF-1 and SEF-2.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Sherwood Project	rock barbs and .75 mile of corridor fencing	Upper Salmon	Riparian Fencing/Grazing Management; Habitat Features	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2002	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-01 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-01 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-01 ; Screen Pump Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-01 (p)8/ ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-02 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-02 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SEF-02 ; Screen Pump Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-02 (p) ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-03 Anderson Ditch; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1995	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-05 Leuzinger Ditch #1; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1995	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEF-06 Leuzinger Ditch #2; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEFAP ; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	East Fork Salmon River	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
BPA	Idaho Fish Screen Improvement	Diversion SEFP-6.8 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	2000	East Fork Salmon River @ RM 6.8	E. Fk. Salmon R. & Herd Cr.	SALREF	HERDC
Shoshone-Bannock Tribes	Big Boulder Dam.	Passage restoration – remove 15' high dam formerly used for hydroelectric purposes for nearby mining	Upper Salmon	Barrier Removal	Y	N	1991	Big Boulder Creek, trib to East Fork Salmon River	E. Fk. Salmon R.	SALREF	
		Diversion consolidation	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	N	1996	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Wayne Baker Ranch	a sprinkler system was installed on the Wayne Baker Ranch to eliminate an irrigation diversion on Pine Creek. This project left 4 cfs in Pine Creek and provided habitat connectivity.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	N	N	1998	Pine Creek	E. Fk. Salmon R.	SALREF	
Sawtooth NRA	Washington Basin Trail.	Habitat and watershed restoration – relocate several deteriorating segments of the trail, many in or adjacent to headwater tributaries. Enhance trail drainage throughout.	Upper Salmon	Reduce Sediment Load	N	N	1990	Fourth of July and Washington Lake Creeks	E. Fk. Salmon R.	SALREF	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Sawtooth NRA	Little Boulder Burn.	Habitat maintenance – prescribed burn treating portions of the Little Boulder and Wickiup Creek drainages.	Upper Salmon	Restore Riparian Function	Y	Y	1990	Little Boulder, trib to East Fork	E. Fk. Salmon R.	SALREF	
BLM		Installation of fish screen near Indian Cave with IDFG to reduce fish mortality	Upper Salmon	Fish Passage Improvement	Y	Y	1992	East Fork Salmon River near confluence of Fox Creek	E. Fk. Salmon R.	SALREF	
BLM		Installation of fish screen near Big Boulder Creek (Baker Ditch) with IDFG to reduce fish mortality	Upper Salmon	Fish Passage Improvement	Y	Y	1992	East Fork Salmon River near Big Boulder Creek	E. Fk. Salmon R.	SALREF	
Sawtooth NRA	Insinger Diversion.	Habitat maintenance – modify EF21 diversion intake to prevent further deterioration of habitat conditions	Upper Salmon	Restore Riparian Function	Y	Y	1992	East Fork Salmon River, trib to Salmon River	E. Fk. Salmon R.	SALREF	
		Instream LWD placement; bank stabilization	Upper Salmon	Habitat Features; Streambank Stabilization	Y	Y	1993	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
Sawtooth NRA	Castle Divide Trail.	Habitat and watershed restoration – relocate several deteriorating segments of the trail, many in or adjacent to headwater tributaries. Enhance trail drainage throughout.	Upper Salmon	Reduce Sediment Load	Y	Y	1994	Little Boulder Creek, trib to East Fork Salmon River	E. Fk. Salmon R.	SALREF	
Shoshone-Bannock Tribes	Big Boulder Restoration.	Habitat restoration – Repair and restore extensively damaged segment of Big Boulder Creek.	Upper Salmon	Restore Riparian Function	Y	Y	1994	Big Boulder Creek, trib to East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BLM		Installation of fish screen on Salmon River with IDFG to reduce fish mortality	Upper Salmon	Fish Passage Improvement	Y	Y	1996	East Fork Salmon River near Fox Creek	E. Fk. Salmon R.	SALREF	
Landowner	Junior Baker	43 rock barbs, 1 rock vortex weir, 3 root wads, 37 tree revetments and tree plantings; exclusion fencing	Upper Salmon	Habitat Features; Riparian Fencing/Grazing Management	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Baker Ranch	1.4 miles corridor fence	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Lyle Guffy	.3 mile corridor fence	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1998	East Fork Salmon River	E. Fk. Salmon R.	SALREF	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Landowner		Installation of 9 rock barbs, willow plantings	Upper Salmon	Streambank Stabilization; Riparian Re-vegetation; Reduce Sediment Load	Y	Y	1998	East Fork Salmon River, Lyle Guffy Property	E. Fk. Salmon R.	SALREF	
BPA	Leuzinger Ranch (Syd Dowton)	.33 mile corridor fence at the mouth of West Pass Creek	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Wayne Baker Ranch	1.2 miles corridor fence on East Fork Salmon River, .35 mile of corridor fence constructed to attach to .57 mile fence constructed by operator on Pine Creek.	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	1999	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2000	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
Sawtooth NRA	Big Boulder Trailhead Restoration.	Streamside restoration – Define trailhead boundaries and restore damaged conditions in closed dispersed campsites surrounding the trailhead adjacent to Big Boulder Creek.	Upper Salmon	Restore Riparian Function	Y	Y	2001	Big Boulder, trib to East Fork Salmon River	E. Fk. Salmon R.	SALREF	
		Vegetation planting	Upper Salmon	Riparian Re-vegetation	Y	Y	2001	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Salmon River Habitat Enhancement M & E	Vertical banks in a cutoff channel in Big Boulder Creek were sloped, the stream was diverted away from high cutbanks, returned to a more natural meander pattern within .5 km of affected floodplain, eliminating the cutoff channel of BBC as sediment source.	Upper Salmon	Streambank Stabilization; Reduce Sediment Load; Habitat Features	Y	Y	2001	Big Boulder Creek	E. Fk. Salmon R.	SALREF	
		Exclusion fencing	Upper Salmon	Riparian Fencing/Grazing Management	Y	Y	2002	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-07 GOSSI-SHINDURLIN; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R.	SALREF	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SEF-07/08 GOSSI-SHINDURLIN; Screen ; Dam Improved	Upper Salmon	Diversion Screening	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-07/08 GOSSI-SHINDURLIN; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-08 GOSSI-SHINDURLIN; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-09 ; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1995	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-09 ; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1996	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-12 Pedrini-Yacomella; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1995	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-16 EDDY BAKER-01; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1997	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-18A BOB ENSINGER; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	2000	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEF-21 GARDNER RIVER; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	East Fork Salmon River	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEFBBC-01 EDDY BAKER-01; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	2001	Big Boulder Creek	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEFBBC-02 EDDY BAKER-02; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	2001	Big Boulder Creek	E. Fk. Salmon R.	SALREF	
BPA	Idaho Fish Screen Improvement	Diversion SEFGC-01 OLIVE DITCH-05; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	Germania Creek	E. Fk. Salmon R.	SALREF	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SEFP-10.5 ; Screen Passive; Dam	Upper Salmon	Diversion Screening	Y	Y	2000	East Fork Salmon River @ RM 10.5	E. Fk. Salmon R.	SALREF	
Sawtooth NRA		Stanley Creek Culvert. Passage Restoration – Enlarge culvert and facilitate passage where formerly prevented at perched culvert outlet.	Upper Salmon	Barrier Removal	Y	N	1996	Stanley Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Dry Creek Roads.	Watershed and channel restoration – 3.1 miles of road in the bottom of two drainages obliterated and watershed and channel conditions rehabilitated.	Upper Salmon	Habitat Features	N	N	2001	Dry and Park Creeks, tribs to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Dry Creek Roads.	Watershed and channel restoration – 3.1 miles of road in the bottom of two drainages obliterated and watershed and channel conditions rehabilitated.	Upper Salmon	Road Obliteration	N	N	2001	Dry and Park Creeks, tribs to Valley Creek	Valley Cr.	VALEYC	
BLM-Salmon Field Office		Remove / Consolidate S-29 (Laverty), S-26 (Hammond/Leaton) and Chester Pump diversions into S-28 (Gini) canal.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	N	N	1997	Dry and Park Creeks	Valley Cr.	VALEYC	
Sawtooth NRA	Dry Creek Prescribed Burn	Watershed restoration – 100 acre prescribed fire for restoration and maintenance of open, seasonally wet, meadow habitats.	Upper Salmon	Reduce Sediment Load	N	N	2002	Dry Creek trib. Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Dry Creek Roads.	Watershed and channel restoration – 3.1 miles of road in the bottom of two drainages obliterated and watershed and channel conditions rehabilitated.	Upper Salmon	Habitat Features	N	N	2001	Dry and Park Creeks, tribs to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Dry Creek Roads.	Watershed and channel restoration – 3.1 miles of road in the bottom of two drainages obliterated and watershed and channel conditions rehabilitated.	Upper Salmon	Road Obliteration	N	N	2001	Dry and Park Creeks, tribs to Valley Creek	Valley Cr.	VALEYC	
BLM-Salmon Field Office		Remove / Consolidate S-29 (Laverty), S-26 (Hammond/Leaton) and Chester Pump diversions into S-28 (Gini) canal.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	N	N	1997	Dry and Park Creeks	Valley Cr.	VALEYC	
Sawtooth NRA	Stanley Lake Old Highway Wetland Restoration.	Wetland restoration – 2 acres of abandoned road fill removed and former wetland function rehabilitated.	Upper Salmon	Restore Riparian Function	N	N	2001	Stanley Lake Creek, trib to Valley Creek	Valley Cr.	VALEYC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
IDFG	Stanley Lake Creek, trib to Valley Creek	Stanley Lake Diversion Screen. Passage restoration – install prefabricated screen on existing diversion.	Upper Salmon	Fish Passage Improvement	N	N	1999	Stanley Lake Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Stanley Lake Creek, trib to Valley Creek	Stanley Lake Trail (lower). Habitat restoration – reconstruct with french-drained turnpike ¼ mile of badly deteriorating trail through wet meadows and 3 fords adjacent to Stanley Lake Creek.	Upper Salmon	Reduce Sediment Load	N	N	1999	Stanley Lake Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Stanley Lake Trail (upper). Habitat restoration – relocate ½ mile of trail through wet meadows and 2 fords to upland route requiring no stream crossings. Rehabilitate former route.	Upper Salmon	Restore Riparian Function; Reduce Sediment Load	N	N	1998	Stanley Lake Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Stanley Lake Road. Habitat restoration – Relocate 1 mile of main travel route, and associated dispersed campsites, adjacent to Stanley Lake Creek to upland route. Rehabilitate former route and campsites.	Upper Salmon	Reduce Sediment Load	N	N	1997	Stanley Lake Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Trap Creek, trib to Valley Creek	Trap Creek Diversion. Habitat restoration – rehabilitate ½ mile of main supply ditch and ½ mile of facility access road located adjacent to Trap Creek.	Upper Salmon	Restore Riparian Function	N	N	1999	Trap Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Trap Creek Diversion. Habitat restoration – discontinue irrigation withdrawals. Modify TRC1 diversion to facilitate consistent passage.	Upper Salmon	Restore Instream Flows	N	N	1992	Trap Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Valley and Hanna Creeks	Valley Creek 5/6 Diversions. Habitat and passage restoration – consolidate two diversions at one new location. Return ½ mile of previously captured Hanna Creek to it's historic channel. Remove and rehabilitate former diversion facilities and ditches.	Upper Salmon	Fish Passage Improvement; Restore Riparian Function	N	N	1999	Valley and Hanna Creeks	Valley Cr.	VALEYC	
Stanley Sewer Association	Stanley Sewer Lagoons Restoration.	Floodplain/wetland restoration – remove and rehabilitate 2 sewer cells occupying 10 acres of floodplain and wetland adjacent to Valley Creek.	Upper Salmon	Restore Riparian Function	N	N	2001	Valley Creek	Valley Cr.	VALEYC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Valley Creek Diversion	A memorandum of understanding was established with the Valley Creek Diversion X6 (VC-6) water users. Constructed flow control consisting of a large rock deflector was constructed to split the stream flow at the VC-6 diversion which previously left the channel of Valley Creek dry. Two rock weir and sill structures were constructed to assure proper flow was in each channel. These flow control structures now allow salmon access to the upper nine miles of Valley Creek. Spring chinook salmon were observed above the diversion by IDFC surveyors during late spawning in Valley Creek August.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	1988	Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Stanley Basin C&H Stanley Creek Pastures. Habitat maintenance – Construct 4 miles of riparian fence around 7 riparian pastures along the Stanley Creek to tightly control livestock use of riparian bottom.	Upper Salmon	Restore Riparian Function	Y	Y	1992	Stanley Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Valley Creek Boulders. Habitat enhancement - boulder cluster placement to increase rearing habitat complexity (e.g. pocket pools)	Upper Salmon	Restore Stream Complexity	Y	Y	1992	Valley Creek, trib to Salmon River	Valley Cr.	VALEYC	
Sawtooth NRA	Park, Elk and Trap Creek Meadows Grazing.	Habitat restoration – discontinue livestock grazing west of Highway 20 including Elk Meadows.	Upper Salmon	Restore Riparian Function	Y	Y	1993	Elk Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA		Stanley Basin C&H Valley Creek Fence. Habitat maintenance – Construct 1 ½ mile of riparian fence along the Valley Creek to preclude livestock access.	Upper Salmon	Restore Riparian Function	Y	Y	1994	Valley Creek, trib to Salmon River	Valley Cr.	VALEYC	
Sawtooth NRA		Stanley Creek Historic Channel. Habitat restoration – Restore flow to ½ mile of high quality habitat abandoned earlier when captured by entrenched placer dredge channel.	Upper Salmon	Restore Stream Complexity	Y	Y	1996	Stanley Creek, trib to Valley Creek	Valley Cr.	VALEYC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
Sawtooth NRA and American Hiking Society	Elk Meadows Trail.	Habitat restoration – relocate 1 mile of trail and two fords adjacent to Elk Creek to upland location requiring no stream crossings. Rehabilitate the former route.	Upper Salmon	Reduce Sediment Load	Y	Y	1997	Elk Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Valley and Hanna Creeks	Valley Creek 5/6 Diversions. Habitat and passage restoration – consolidate two diversions at one new location. Return ½ mile of previously captured Hanna Creek to it's historic channel. Remove and rehabilitate former diversion facilities and ditches.	Upper Salmon	Fish Passage Improvement; Restore Riparian Function	Y	Y	1999	Valley and Hanna Creeks	Valley Cr.	VALEYC	
Sawtooth NRA	Elk Creek, trib to Valley Creek	Elk Meadows Trailhead. Habitat restoration – relocate deteriorating and expanding trailhead adjacent to Elk Creek to upland location. Rehabilitate the former location and ¼ mile of road.	Upper Salmon	Reduce Sediment Load	Y	Y	1999	Elk Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Crooked Creek, trib to Valley Creek	Crooked Creek Diversions. Habitat restoration – discontinue irrigation withdrawals. Remove and rehabilitate diversion facilities and associated ditches.	Upper Salmon	Restore Riparian Function	Y	Y	1999	Crooked Creek, trib to Valley Creek	Valley Cr.	VALEYC	
BPA	Lower Valley Creek diversions	IDFG and NRCS completed a project consolidating four diversions and replacing the screens and headgates in lower Valley Creek in 2000.	Upper Salmon	Fish Passage Improvement; Restore Instream Flows	Y	Y	2000	Lower Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Alpine Way Trail.	Habitat restoration – close and relocate ½ mile of badly eroding trail, located in headwater tributary requiring several stream crossing, to an upland location. Rehabilitate former route.	Upper Salmon	Restore Riparian Function	Y	Y	2000	Iron Creek, trib to Valley Creek	Valley Cr.	VALEYC	
IDFG	Iron Creek Fish Screens.	Passage restoration – consolidate and install fish screen on IC4 and 5 diversions, and install fish screens on IC 3 and 6.	Upper Salmon	Fish Passage Improvement	Y	Y	2001	Iron Creek, trib to Valley Creek	Valley Cr.	VALEYC	
Sawtooth NRA	Dispersed Campsite Rehab.	Streamside restoration – close and rehabilitate newly established dispersed campsite area in potentially damaging location adjacent to Elk Creek.	Upper Salmon	Restore Riparian Function	Y	Y	2002	Elk Creek, trib to Valley	Valley Cr.	VALEYC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SVC-01 SILVA DITCH; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-01 SILVA DITCH; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1999	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-02 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-02 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1997	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-02/03 PAUL FIELD DITCH; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1998	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-03 PAUL FIELD DITCH; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	1996	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-03 PAUL FIELD DITCH; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-04 TRIPPLE H RANCH; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-04 TRIPPLE H RANCH; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1998	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-05 ; Screen Eliminated; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-06 ; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1999	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVC-05/06 ; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1999	Valley Creek	Valley Cr.	VALEYC	

Sponsor Agency	Project Title	Project Summary	Subbasin	Model Action Type	FX chinook?	FX juv surv?	Year Started	Location	PIT Stock(s)	Stock 1	Stock 2
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-01 USFS/ YOUNG DITCH; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1997	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-01 USFS/ YOUNG DITCH; Screen ; Dam Headgates	Upper Salmon	Diversion Screening	Y	Y	1998	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-02 MM RANCH/MAHONEY; Screen Replaced; Dam	Upper Salmon	Diversion Screening	Y	Y	1990	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-02 MM RANCH/MAHONEY; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-02 MM RANCH/MAHONEY; Screen Screened; Dam	Upper Salmon	Diversion Screening	Y	Y	2001	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCEC-03 ; Screen ; Dam Eliminated	Upper Salmon	Diversion Screening	Y	Y	1998	Elk Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCP-0.2 ; Screen Passive; Dam	Upper Salmon	Diversion Screening	Y	Y	2002	Valley Creek	Valley Cr.	VALEYC	
BPA	Idaho Fish Screen Improvement	Diversion SVCP-4.5 ; Screen Complete; Dam	Upper Salmon	Diversion Screening	Y	Y	2002	Valley Creek	Valley Cr.	VALEYC	

Appendix 3
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