STREAM HABITAT ENHANCEMENT EVALUATION WORKSHOP:

A SYNTHESIS OF VIEWS

Level I Workshop
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FOREWORD

This document is, in essence. a response by professionals active in stream habitat enhancement to a long-standing need for a consolidated approach to stream habitat enhancement evaluation programs and projects. This is, however, only a start. Prescriptive recommendations will be the product of a Level II Workshop [October. 1986] and subsequent endeavors. The Level I Workshop experts were charged with the complex task of sorting and identifying the "... best available scientific methodologies" and producing positivtive recommendations on stream habitat enhancement evaluation. We expected considerable divergence of opinion, but were pleasantly rewarded with significant agreement on many issues. The consenses presented herein represent the majority opinion; noteworthy alternative viewpoints on several issues were expressed. These alternative viewpoints are presented, for the most part, as Points of Agreement preceding the statement of Consensus. In addition to identifying and agreeing upon many areas of evaluation objectives, program design, and application of results, important informational and procedural shortcomings were identified such as limiting factors, effects of underseeding, acceptable risk, and the need for a hierarchical stratified classification system. Focusing and calling attention to these informational and procedural gaps is an important step and a major outcome of this workshop.

We sincerely thank all participants in the Level I Workshop for taking time to contribute - especially those who reviewed and commented on working drafts of this document. As further recognition, their names and affiliations appear on the following page. We also thank the many professionals who participated in scoping meetings and contributed written responses to preliminary framework questions during the planning phases. Through their input the substance of these Workshops was refined, resulting in a product we feel is, and will be, useful for enhancement professionals at all levels of experience.

Principal authorship is due Michael Parton for his insightful revisions of the working draft, incorporation of written and oral comments, and preparation of this manuscript. Paul Boehne and Chris Stainbrook are to be thanked for their roles in the development and conduct of the Level I Workshop and for preparation of the working draft of this document. Phyllis Goldberg processed innumerable revisions of the working draft and handled many details of the Level I Workshop.

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INTRODUCTION

Professional fish biologists, fisheries managers, and political entities have moved with increasing awareness to the great need to rehabilitate and enhance anadromous and resident salmonid habitat. This need is the result of over a century of degradation and neglect of watersheds and their streams as well as blockage of anadromous fish access to large portions of once productive basins. The results of enhancement have been as varied as the geographical locations in which the work was conducted - and our perception of results as varied as the evaluation methods applied.

The movement to rehabilitate and enhance salmonid habitat has stimulated many conferences, seminars, and meetings devoted in part or in whole to enhancement techniques. As the enhancement movement gathered momentum, the exchange of ideas, and particularly direct experience which resulted from these gatherings, was extremely important; it still is. In many cases, however, presentations have amounted to little more than "show and tell" sessions: case studies of boulder placements, log weirs, rock berms, side channel developments, riparian fencing, etc. While such presentations are interesting and important, especially to those still joining the ranks of enhancement-minded pofessionals, certain important aspects of the enhancement movement have been substantially ignored. As Dr. James Hall concluded at the Pacific Northwest Stream Habitat Management Workshop [October 1984, Humboldt State University]:

> "I would like to conclude <my presentation> by taking a college professor's prerogative to assign grades. In doing so I would emphasize that my judgement pertains to the program of evaluation of fish response to habitat enhancement projects, not the the effectiveness of structures per se. As to the evaluation program, then, my grade for Intentions is B-, for Performance, D. I would emphasize that these are class averages. There are some A students in the group . . . however, I conclude that there is much room for improvement. Progress has been slow and many problems remain to be overcome."

There is a paucity of detailed, refereed evaluations of stream habitat enhancement efforts, considering the rate of implementation and popularity of these efforts as restoration and mitigation measures. Hall and Baker (1982) conducted an exhaustive review of stream habitat enhancement evaluations and found a wide variety of approaches and rationales. Recent detailed evaluations of enhancement projects, such as Everest et al. (1989) House and Boehne (1985) and Petrosky and Holubetz (1985), still point up the need to consolidate professional thinking on rationales and procedures for evaluation. This need pervades the enhancement community and is coincident with efforts presently undertaken by Bonneville Power Administration (BPA) to evaluate progress of activities to mitigate and enhance anadromous fish runs in the Columbia River Basin [pursuant to Section 704(d) of

Northwest Power Planning Council's Fish and Wildlife Program). Perhaps the single most important need for defensible enhancement evaluation methodologies is in the area of accountability for expenditures. Almost universally now, fish biologists and managers are being asked to account, in terms of fish production, for monies spent and to project benefits for past and planned stream habitat enhancement efforts. "Accountability" has become a buzzword. The need for a consolidated approach is clear.

To begin the formal process of unifying evaluation methodology, Buell & Associates, in cooperation with BPA, brought together recognized experts to address the fundamental principals of stream habitat enhancement evaluation. This initial "Level I" Workshop [March 1986, Hood River, Oregon1 was exploratory and descriptive in nature. The purpose was to elucidate defensible, rational approaches and techniques fundamental to any evaluation program or project, and to provide the basis for continued discussion and presentation of prescriptive information at the Level II Workshop [October 21-23, 1986 in Portland, Oregon).

This document and the Level II Workshop are important steps in an ongoing process to refine and prescribe methodologies for stream enhancement evaluation. To this end, the Following document presents philosophies and approaches for the design and conduct of enhancement evaluation programs and projects. It is our sincere hope that these Workshops and documents will provide a sound framework for fish biologists, managers, and other allied professionals who are, or will be, evaluating stream habitat enhancement efforts.

WORKSHOP AND DOCUMENT FORMAT

Critical framework questions for the Level I Workshop (Appendix A) were developed via a planning and review process that involved meetings and written input from enhancement professionals throughout the Pacific Northwest. Level I Workshop participants were divided into small work groups to identify informational and procedural needs by discussing and arriving, if possible, at consenses of opinion on framework questions. Potential solutions and approaches were explored to formulate a rational, broad-scale evaluation program. Participants were instructed to leave policy and politics aside and concentrate on the technical aspects of evaluating stream habitat enhancement efforts.

Group leaders maintained running accounts of discussions and diagrams-that were combined with notes taken by Buell and Associates staff to form the basis for working and final drafts of this document. In addition, notes submitted by workshop participants and responses from absentee contributors were incorporated. A working draft was circulated to participants for critical review in July 1986. Comments received by late August 1986 were incorporated into this final document.

This document consists of structured responses subordinate to three questions generally agreed to be fundamental to any evaluation effort:

1. What are the fundamental onjectives of enhancement project evaluation? [What questions should we be asking?]

2. What constitutes good evaluation program design?

3. How should we apply what we learn?

Answers to these questions are presented as responses to a series of subordinate questions (24 in total). This document consists of a compilation of major schools of thought and, frequently, consenses. In the few cases where opinions were divergent, we provide a narrative. In the course of the Level I Workshop several areas of particular concern were identified [limiting factors, acceptable risk, effects of under-seeding, and a hierarchical stratified classification system). These Issues of Particular Concern are presented in a separate section following responses to questions.

The objective of the Level I Workshop and document was to provide a basis for discussion and presentation of evaluation methodologies at the Level II Technical/Training Workshop. Sufficient editorial license was exercised to provide the essence of the discussions in a tractable format, rather than providing a lengthy transcript of all proceedings. While necessarily exploratory and descriptive in nature, we expect that this synthesis of views will provide a useful philosophical and technical framework for evaluating or planning stream habitat enhancement programs or projects.

1.0 WHAT ARE THE FUNDMENTAL OBJECTIVES OF ENHANCEMENT PROJECT EVALUATION? WHAT QUESTIONS SHOULD WE BE ASKING?

Direct responses to this question were not solicited. Some work groups and absentee contributors did, however, choose to discuss it. Discussions from other questions and areas of particular concern are used to provide the following synthesis.

The Fundamental objectives of any enhancement evaluation program [or project) are necessarily unique to that program but must be:

1. To establish a record of mitigation for adults Cas with BPA's current efforts).

2. To account for enhancement costs,

3. To acquire new knowledge about the physical and/or biological effects and interactions of stream enhancement measures.

Bear in mind, these objectives are not necessarily mutually exclusive. An evaluation program consists of a series of evaluation projects that should be balanced to achieve one or more of these overall program objectives. Evaluation project objectives are enhancement project Cor measure1 specific. They are closely tied to the objectives(s) of the original enhancement project, and ask, depending on the intensity of the evaluation effort (see Question 1.23, "if" or “why and how” a particular enhancement did or did not achieve its intended objective.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIUES OF EUALUATION?

1.1 SHOULD WE BE DOING SCIENCE/RESEARCH OR GATHERING JUST ENOUGH INFORMATION FOR PLANNING/MANAGEMENT PURPOSES?

Points of Agreement

1. The distinction between 'science/research' and "planning/management" approaches is artificial; all evaluation efforts should be based on sound scientific methodologies, preferably tested in a rigorous research framework.

2. Too much "information" has been gathered that has not provided useful answers Cusually for planning and accounting purposes).

3. Expenditures for project implementation are far ahead of our knowledge of the end result, i.e. total fish produced.

4. There are not enough long-term, “intensive” evaluations (see question 1.2) being done.

5. Short-term, "general" evaluations are of limited utility (also see 1.21.

CONSENSUS

An applied research approach to enhancement evaluation programs should be used. The shorter term planning requirements should be accomodated in the evalubtion program to facilitate the continued implementation of enhancement projects - management can use information right now and can not have too much. A feed-back loop exists between intensive "research" evaluations and well grounded, reduced risk, management decisions to plan and implement certain enhancement projects or measures.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIVES OF EVALUATION?

1.1.1 WHAT FIRE THE RESPECTIVE PITFALLS AND TRASEOFFS OF THE TWO APPROACHES? (see Question 1.1)

This question grades into question 1.2 which eliminates the distinction between science/research and planning/management approaches by considering the "intensity" of evaluation projects.

Points of Agreement

The following pitfalls and tradeoffs were identified:

Science/Research

- High cost.
- Longer time frame when answers to planning and management questions are needed quickly.
- Not always directly applicable to planning and management.
- Cost and time limit the number of projects/streams that can be evaluated, which in turn may limit the ability to extrapolate results.

Planning/Management

- Cheaper; but is it a wise use of monies?
- Shorter time frame but falls short of information needs; real questions about mechanisms not answered.
- Complexity and interaction of variables preclude identification of cause and effect.
- Nay not evaluate most appropriate time period or life stage.
- Lack of definitiveness limits extrapolation of data.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIUES OF EVALUATION?

1.2 WHAT IS MEANT BY "GENERAL" AND "INTENSIUE" PROJECT EVALUATIONS? ARE BOTH IMPORTANT?

Points of Agreement

1. "General" may be a better term than “extensive”, which has been used in the past. "General" evaluation suggests more streams/drainages, broader scope, preferably pre- and post treatment, looking at limited number of physical and biological variables over a shorter time period Cless than one life cycle of the target species].

2. "General" evaluations are deductive only. Models developed and validated through intensive evaluations are employed.

3. "General" evaluations are important components of an integrated evaluation program; due to larger scope, they provide much of the data from which extrapolations may be made.

4. "Intensive" evaluations are project specific and look at a greater number of variables for fewer projects over a longer period of time (preferably at least one life cycle). Pre- and post-treatment data are required. Observed changes are put in perspective.

5 "Intensive" evaluations have an inductive element. Models are built and/or validated. The framework for "general" evaluations is developed through these “intensive” evaluations.

CONSENSUS

A continuum of intensity exists between general and intensive evaluations. Both types of evaluation are important. The framework for general evaluations [i.e. specific variables1 should be based on intensive evaluations. In turn, general evaluations aid in the formulation of hypotheses about mechanisms, interaction of variables, and effectiveness of enhancement measures to be investigated within intensive evaluations. A feed-back loop exists. General and intensive evaluations should, therefore, be integrated to comprise a sound overall evaluation program.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIVES OF EVALUATION?

1.3 WHAT IS THE ULTIMATE TARGET OF AN EVALUATION PROGRAM? HABITAT CAPABILITY CWHETHER THE FISH ARE THERE OR NOT)? PRESMOLTS? SMOLTS? ADULTS?

Points of Agreement

1. Depends on the questions(s) to be answered. Habitat managers are interested in habitat - fish managers in fish. Both are important.

2. Genetic preservation. The ultimate enhancement target is wild adults; the ultimater intensive evaluation target is the production end-point of the enhanced system, namely, smolts Cor in the case of resident fish, adults].

3. It is difficult to correlate easily-measured summer stock Juveniles with smolts. More work is needed in this area.

4. Four questions should be answered:

   a. Did the enhancement effort do what was wanted?

   b. Whatever happened, did the enhancement effort make more fish?

   C. Was the enhancement effort cost effective?

   d. If the evaluation is intensive, why was or wasn’t the enhancement effort successful?

5. Naturally reproducing fish that are linked to habitat. Habitat capability (productive capacity1 may not be an ultimate target but is an important piece of the puzzle, especially in under-seeded streams Csee Effects of underseeding, page 45).

CONSENSUS

Specifically, evaluations should determine if the project increases the number or biomass of smolts Cor resident fish adults1 - the end product of the enhanced production system. participants recognized that much more work is needed to be able to correlate easily-measured juveniles with smolts. Further, in streams with significant downstream emigration of Juveniles to rear and smolt in higher order streams Cthe "early-out" situation common to many streams in the upper Columbia River system and other semi-arid basins), pre-smolts may have to be the target. More work is also needed to correlate early-out juveniles with smolts.

Question 1.3

Adult anadromous fish, while demanded by the public, are not a feasible measure of project success due to multiple, and variable, sources of mortality. Escapement should, however, be integrated into the evaluation program as an "index" of enhancement efforts. Assumptions will have to be made and substantiated about survival rates and other factors, as it is generally held that further correlations are needed.

1.0 WHAT ARE THE FUNDAMENTAL-OBJECTIVES OF EVALUATION?

1.4 WITH REGARD TO INDIUIDUAL PROJECT ELEMENTS, SHOULD WE BE MORE INTERESTED IN "WHY" AND "HOW" THEY WORK, OR "IF" THEY WORK COR DON'T WORK)?

Points of Agreement

1. This is a restatement of question 1.2 Cthe general-to-intensive evaluation continuuml.
2. Both ore important. "Why" and “how”, as well as "if", are answered in intensive evaluations; "if" is answered for more projects in general evaluations.
3. Again, general evaluations must be based on intensive evaluation methodologies and results.
4. A temporal sequence is suggested. Ask "if" first, then "how" and "why". It may be possible to answer “how” and "why" early with good overall program design.

CONSENSUS

The first question asked is "if" the project worked. For obvious reasons, management needs to know this. Enhancement professionals can not apply knowledge if certain mechanisms ("why" and "how") are not known. Research/intensive evaluations are needed. It was generally agreed this was a reiteration of the general-to-intensive continuum discussion [question 1.21 and that the previously discussed feed-back loop exists.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIUES OF EUALUATION?

1.4.1 ON A BROADER SCALE, WHAT IS THE APPROPRIATE RATIO OF EUALUATIONS DESIGNED TO DETERMINE "HOW" ENHANCEMENT PROJECTS WORK TO THOSE DESIGNED TO DETERMINE "IF" THEY WORK?

Points of Agreement

1. Quantification of intensive (How and Why) evaluations is dependent on geology Cand many other factors1 and the definition of a "subbasin".

2. Some kind of classification system is needed first - then one can answer the ratio question Csee Hierarchical Stratified Classification System, page 43). Do regional site studies first; plan with geography/geology/basin concept in mind.

3. Can not answer this question without more specifics. For example: What confidence do managers need to make implementation decisions? What are the enhancement project objectives?

CONSENSUS

It is difficult to answer the ratio question. A definitive land classification system, or some basin wide approach, is needed to assess heterogeneity of stream types. The number of intensive evaluations will depend on the heterogeneity within the basin Cor subbasinl. Again, a feed-back loop exists.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIVES OF EVALUATION?

1.5 TO WHAT EXTENT SHOULD EUALUATION REQUIREMENTS DRIVE THE DESIGN AND PLANNING PROCESS?

Points of Agreement

1. When we have solid supportable data that show that a certain enhancement strategy solves a problem, then we can let evaluation become a major influence on the design and planning process. We should' however, continue to identify the original couse(s) of the problem and try to correct it.

2. Intensive evaluation requirements probably should drive, or at least be integrated in, the planning and development process, but should not drive it completely. They are one of several factors. Some projects should be designated for evaluation, but evaluation costs or experimental constraints should not kill a "good" project.

3. Evaluation results can influence the planning and development of future projects.

CONSENSUS

Evaluation is part of a closed loop:

Planning and Design ------> Implsmsntation ---

---------------------- **Evaluation** <---------------

In this context, evaluation does not drive the process; it is part of the overall enhancement program. Concern was expressed that costs or other factors of enhancement evaluation should not stop or preclude the implementation of projects. Some projects are good and we know it "a priori". These enhancement projects should still be done even if no evaluation can be conducted.

Evaluation becomes increasingly important for projects where problems and solutions are uncertain (i.e. subtle limiting factors, multiple species interactions and habitat requirements). Many habitat/production problems may still be lessened through projects based on past experience and evaluations [regardless of scope and intensity].

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIUES OF EUALUATION?

1.6 HOW MUCH BASELINE DATA IS NECESSARY BEFORE STARTING AN ENHANCEMENT PROJECT?

Points of Agreement

1. The absolute minimum should be sufficient data to identify/assess factors limiting fish production,

2. Dependent upon the anticipated degree of among-year variation in physical and biological factors. The more variation the more data is needed. Thus, two to three years is the minimum. (For statistical inference, the practical minimum may be four years.1

3. Also dependent upon the degree of expected change in habitat or production. The greater the expected change, as when working in severely degraded systems, the less data required.

4. Depends on the a priori selection of the accuracy/-confidence level. Greater accuracy Cless risk of erroneous conclusion3 requires more data. Moreover, it is driven by the preselection of the intensity of the evaluation (whether or not the evaluation involves inferential statistics).

5. Some physical attributes (i.e. stream width3 could be done in one year; other attributes Ci.e. bedload movemens, substrate composition1 may be as variable as biological (population/density) factors.

Note: No clear consensus was reached on “how much” data is needed before starting an enhancement project. A continuum is apparent between data requirements for determining limiting factors and those for an “intensive” evaluation. Physical data needs were considered to be less than biological data needs. The continuum is expressed above in the points of agreement.

1.0 WHAT ARE THE FUNDAMENTAL'OBJECTIUES OF EUALUATION?

1.7 WHEN IN THE LIFE OF A SINGLE EVALUATION PROGRAM, OR A GROUP OF CONCURRENT PROGRAMS, CAN WE BEGIN USING THE RESULTS FOR DECISION-MAKING?

Points of Agreement

1. Use evaluation results as they become available - but, preliminary results should be treated as such. Early results can be used to help guide the rate of future investments Cimplementationl.

2. If it [the enhancement1 works, use it.

3. Closely parallels Question 1.5.

4. Depends on the type of project and the objectives. Some changes, usually physical, are obvious immediately. Biological changes are usually more subtle; there is a lag time.

CONSENSUS

Be careful with the use of preliminary [short-term1 evaluation results. Biological responses may take some time to detect. Physical changes will be more readily apparent. Most changes are subtle. Preliminary evaluations may be used with caution to guide planning and implementation of future projects.

1.0 WHAT ARE THE FUNDAMENTAL OBJECTIVES OF EUALUATION?

1.8 WHAT IS THE ROLE OF INNOVATION? WHEN SHOULD DECISION-MAKING GO BEYOND THE RESULTS OF AN EVALUATION PROGRAM? HOW FAR?

Points of Agreement

1. The higher the degree of innovation, the higher the degree of risk. Learning is enhanced by proper design and evaluation.
2. Innovative enhancement projects should not be stifled. We should, however, continue with techniques and experiences we already have. Keep risk low.
3. If you innovate, evaluate. Use an intensive approach. Get the results out to the rest of the enhancement community.
4. Do innovative projects after the obvious ones [using conventional approaches).

CONSENSUS

There is room for innovation in enhancement Cand evaluation] techniques, but only after immediate and obvious projects have been implemented using conventional approaches. If some innovative approach is tried it should be a high priority for intensive evaluation.

[Note: No participants or absentee contributors really dealt with the additional questions of when decision-making should go beyond the results of the evaluation program and how for?)

2.0 WHAT CONSTITUTES GOOD EVALUATION PROGRAM DESIGN?

2.1 HOW IMPORTANT IS IT TO IDENTIFY HABITAT FACTORS PRESENTLY LIMITING FISH PRODUCTION? HOW DO WE IDENTIFY LIMITING FACTORS?

Points of Agreement

1. Identifying limiting factors is the most important feature in planning and evaluating any enhancement effort.

2. Many projects have been prematurely implemented - better analysis of limiting factors was needed.

3. Consider two stages to identifying limiting factors. First, look at obvious factors affecting the system - dams (also seasonal stage/discharge management), grazing, clear cutting, water quality etc. Next, look at the finer levels of pool:riffle ratio, instream "structure" etc. and compare with each [target) species habitat requirements.

4. Limiting factor analysis is a good opportunity for intensive studies [probably very wise use of time and resources since correct identification of the limiting factor(s) is the keystone of the enhancement effort).

5. In some cases the problem of limiting factors is obvious. If so, these projects should be high priority.

6. Look at the basin or subbasin level. Do a “mass balance" analysis by looking at smolts Cin the case of anadromous fish3 and correlate back to "habitat types". Habitat types are determined by the habitat requirements of each life stage of each species.

7. It is important to quantify habitat types within the system of concern. Given some assumptions Cfrom experience in the system or literature sources1 about the capacity of each habitat type to support a given life stage and species, that in least supply is a likely candidate for the limiting factor.

8. State and document all assumptions.

9. Use a "pristine" stream, or one that is known to be relatively productive, as a standard for comparison of certain physical and biological variables. Differences are indicative of limiting factors. [See Hierarchical Stratified Classification System, page 43.1

10. Use a checklist of factors that are known to limit production. Look at each factor for each species and target life stage.

2.0 WHAT CONSTITUTES GOOD EVALUATION PROGRAM DESIGN?

Question 2.1

CONSENSUS

Careful analysis of limiting factor(s) is the most important aspect of any enhancement pproject or program. A structured, defensible analysis of limiting factors should consider gross factors (dams, water quality etc.1 operating at the subbasin or basin level [outside the project reach3 as well as the availability of habitat types specific for each life history stage of each species. Obtain as much information as possible, document all assumptions, minimize reliance on professional judgement.

Note: A considerable amount of discussion was devoted to limiting factor analysis. See page 38 for *a* more complete presentation of techniques. References that are cited closely follow the methods suggested by workshop participants and are not intended to be a complete review of methodologies to date.

2.0 WHAT CONSTITUTES GOOD EVALUATION PROGRAM DESIGN?

2.2 WHICH ASSUMPTIONS ARE WE ENTITLED TO MAKE? WHICH NOT?

Points of Agreement

1. Fish production from the enhanced system Cand controls3 will vary from year to year.
2. Do not assume habitat equals fish.
3. Important physical and biological variables should not be considered constant - natural events can eliminate healthy populations even in "pristine" streams.
4. Do not assume limiting factors for which a defensible rationale cannot be readily provided.
5. Do not assume full seeding, especially by adults.
6. Assumptions may be made based on previously conducted intensive evaluations or a testable hypothesis.
7. State and document all assumptions up front. Specify assumptions for each species and life stage of concern.
8. Can not assume limiting factors are constant, especially when limiting factor(s) are not readily apparent.

CONSENSUS

Rational, defensible assumptions may be made based on applicable intensive evaluations. Some assumptions are unavoidable, e.g. survival rates. Be objective - use formal, scientific defense and documentation of methods and thought processes. Do not assume full seeding by any life stage. Host importantly, participants felt that assuming more habitat translates to more fish was dangerous and somewhat naive.

2.0 WHAT CONSTITUTES GOOD EUALUATION PROGRAM DESIGN?

2.3 TO WHAT LEUEL OF DETAIL SHOULD ASSUMPTIONS AND RATIONALES BE SPECIFIED AND DOCUMENTED IN THE EUALUATION PROCESS? WHAT CATEGORIES SHOULD ALWAYS BE SPECIFIED?

Points of Agreement

1. Express assumptions and rationales in the greatest detail possible. No assumption or rationcle should be unreferenced or undefensible.

2. Always specify:

   a. survival coefficients (rates),

   b. limiting factors, and known or perceived interactions thereof,

   c. methods employed in the limiting factor analysis,

   d. level of seeding,

   e. physical and biological extrapolations,

   f. variables that will be important in future extrapolations/use of evaluation results,

   g. rationale for site selection,

   h. objectives of the habitat enhancement measure.

CONSENSUS

A consensus is evident in the points of agreement, above. Specification and documentation of all assumptions in any phase of enhancement planning or evaluation should be the standard procedure for any professional.

2.0 WHAT CONSTITUTES GOOD EUALUATION PROGRAM DESIGN?

2.4 HOW DOES ONE SELECT A SAMPLE SIZE EITHER WITHIN A PROJECT OR AMONG PROJECTS?

Points of Agreement

1. Cost will often be a major determinant of sample size.

2. Consider intensity of evaluation effort and whether questions are being asked about physical or biological phenomena. General or less intensive evaluations considering predominantly physical variables will require a smaller sample size.

3. Dependent upon the confidence/significance level determined by management - the greater the acceptable risk the smaller the required sample. [See Acceptable Risk, page 41.)

4. Dependent upon experimental design. A stratified sampling design often requires a smaller sample and results in smaller variance. Be clever in designing the experiment. The evaluator may want to consult a statistician.

CONSENSUS

No clear consensus was apparent. Participants represented a continuum of statistical backgrounds and therefore recommended a variety of approaches from consulting a statistician to applying sensitivity analyses Csee Lichatowich and Cramer 13791 for the determination of sample size. It was generally agreed that questions of sample size and even the application of inferential statistics is dependent on the nature of the questions being asked. For instance, barrier/passage enhancement projects require little in the way of sampling design or inferential statistics to determine effectiveness. Host importantly it was recognized that acceptable risk should be determined by management and will be a significant determinant of sample size Cand other sampling/statistical considerationsl.

Confidence intervals were addressed in passing in the course of general discussions on the application of statistics to fisheries studies. It was suggested that the use of statistics implies the calculation and statement of confidence intervals. It is important to understand that the 95 percent confidence level is a common convention. It is not law. The data Cand cost3 requirements to obtain statistical significance at the 95 percent confidence level can be extreme, especially considering the variability of data in most fisheries studies. The Washington Department of Fisheries conducted a study of the data requirements at the 95 percent confidence level and found the 70-75 percent to be acceptable for most management decisions (Jack Howerton, pers. comm., Level I Workshop, March, 1986). The cost of obtaining data beyond the 70-75 percent confidence level increased exponentially. Managers and other decision-makers should consider the realities of time and expense when interpreting data and planning evaluation programs. When considering acceptable risk,managers should consider something less than the 95 percent confidence in their decisions. At the 75 percent confidence level this is still a reasonable probability of implementing an enhancement measure that will work. In gambling terms,the three out of four chance of winning Cat the 75 percent confidence level) would be very attractive.

2.5 TO WHAT EXTENT SHOULD WE EUALUATE DESIGN CRITERIA AND PHYSICAL HABITAT OBJECTIUES (HYDRAULICS, SCOUR, COVER, ETC.?)

Points of Agreement

1. Look at physical habitat objectives at some level for all kinds of studies.

2. In general evaluations this may be the only criteria evaluated.

3. Should evaluate all design criteria and physical habitat objectives in intensive project evaluations.

4. Should evaluate all innovative techniques (new/untried) with respect to physical variables; these projects should be intensively evaluated.

5. It is important to evaluate the physical response of the stream to the enhancement structures(s) - especially after the first bankfull event and one year following implementation.

6. Evaluation of the physical habitat objectives is very important during the first year. Photographs and sketches Cas well as pertinent measurements] should be made during the following site visits:

   a. first bankfull event,

   b. peak flow that the structure was designed to accomodate,

   c. first low flow period after implementation.

CONSENSUS

Interestingly, not all work groups responded with suggestions for field techniques and time frames. Participants generally agreed that intensive evaluation should involve thorough treatment of physical variables and that involvement of a qualified hydrologist is advisable. New and innovative projects should probably be intensively studied with respect to physical variables. General evaluations may be composed exclusively of physical habitat objectives. Overall, first year physical evaluations over a range of flows were considered to be a quick return of useful information and an indication of project success [given some understanding of fish/habitat relationshipsl.

2.6 TO WHAT EXTENT CAN ONE EUALUATION TARGET [E.G. HABITAT ELEMENT3 BE AN INDEX OF ANOTHER (E.G. SMOLT)?

Points of Agreement

1. To the extent that the Habitat:fish life-stage correlation has been verified by some intensive evaluation or monitoring study, or verified by literature results.

2. Be careful about inter-basin extrapolation, particularly when indexing biological factors from physical data.

3. There is not enough data available to relate habitat element(s) with smolts Cor other life-stage) produced. Research Cand intensive evaluations1 may eventually provide necessary habitat:fish correlations. In the interim, we (participants) are not comfortable using this approach Csee question).

4. There is considerable variability in the excent that one physical element can index another (either physical or biologicall.

5. The extent is dependent on fish life-stage and geographic factors Cin the comparison or index). The easiest index is at the treatment level Cthe stream1 with fry. As fish age increases and the comparable geographic unit becomes removed from the data source, the index becomes less accurate.

CONSENSUS

We absolutely cannot assume that habitat (existing or potential1 will translate to fish production. Many stream- or system-specific correlations need to be verified through further intensive evaluations and/or research. The physical/biological mechanisms are not understood well enough yet.

2.7 HOW IMPORTANT ARE SEASONAL CONSIDERATIONS IN AN EVALUATION PROGRAM? UNDER WHAT CIRCUMSTANCES?

Points of Agreement

1. Uery important - under all circumstances.

2. Seasonal considerations are important to understand the ecological characteristics of selected species and stocks.

3. Seasonal considerations are very important when determining Cassessingl limiting Factors,

4. Little is known about winter habitat requirements. We are presently waiting for research results. Much needed knowledge can be made available from evaluations that cover all seasons.

5. See discussion of Question 2.1 Cand Limiting Factors, page 38).

CONSENSUS

Seasonal considerations are important in all evaluations, especially in determining limiting factors during the planning of an enhancement project or during post-implementation analysisi Cor re-analysis1 of limiting factors. Little is known about winter habitat requirements - and winter is increasingly being pointed to as a period limiting production. Participants often referred to Question 2.1 [pages 16-17) in discussion of this question.

2.0 WHAT CONSTITUTES GOOD EVALUATION PROGRAM DESIGN-?

2.8 HOW DOES ONE DEAL WITH THE PROBLEM OF INCOMPLETE SEEDING CUNDER-SEEDED HABITAT)?

Definition: Under-seeding is the condition in a stream where available habitat is not being fully utilized at a time when some limiting factor or factors could be limiting the stream's capacity to produce fish are exerting their greatest influence. In the context of stream habitat enhancement, additional habitat may not produce more fish. In an evaluation context, fish populations will not be reliable indices of increased productive capacity.

Points of Agreement

1. Underseeding is a problem that complicates detection of changes in biomass or density of fish attributable to habitat enhancement efforts.

2. Under-seeding complicates the process of limiting factor analysis; instead of habitat limiting fish, external factors [harvest, passage, etc.1 limit the population.

3. Dealing with problems of underseeded streams involves appealing to the potential production/carrying capacity of the stream or system. Some knowledge of potential carrying/production capacity is required for enhancement of under-seeded streams. It may be possible to infer productive capacity Cand habitat enhancement objectives) from nearby similar streams.

4. It is reasonable to assume that fish will seek out and occupy the most preferred habitats. Under-seeded streams can provide valuable insights into fish/habitat relationships.

5. It is still possible to increase production potential in under-seeded streams in anticipation of run-building or some other seeding mechanism.

6. There are density dependent and density independent factors that operate on a system. At full seeding and high density, habitat quantity may limit carrying capacity. At any level of seeding, habitat quality which directly limits survival rates (e.g. percent fines in spawning gravels1 from one life stage to the next will work to determine the number of fish produced by a stream.

Question 2.8

7. In severely under-seeded streams, for example the Upper Columbia River Basin, artificial seeding may be used before and after enhancement implementation to detect any change in carrying capacity.

6. The use of hatchery stocks as outplants in enhancement project evaluation may bias results due to differences in behavior, migration timing, survival, etc. Ideally, the endemic Cwildl stock would be artificially reared and outplanted to reduce the influence of these variables.

Note: No clear consensus was reached on how to deal with under-seeding. Some participants did not consider it a problem; others felt underseeding was common and subtle in its influence, especially when evaluation efforts attempt to use population levels as an index of success of the enhancement. Limiting factor analysis/assessment is also confounded. Interestingly, it was suggested that under-seeded streams provide an excellent opportunity to determine habitat preference/utilization based on the premise that with habitat and "excess" living space, only the most preferred habitat will be utilized by fish.

It was generally recognized that enhancement projects in under-seeded streams will require more complex and intensive evaluations. Artificial seeding, before and after implementation, may be required to index habitat suitability. Hatchery fish commonly emigrate earlier and have different behaviors than endemic stocks. Therefore, some participants felt that artificially propagated endemic stocks should be used for outplanting.

A commonly held view that under-seeded streams should not be enhanced was not widely adhered to by participants. Rather, it was suggested that the least under-seeded stream in the drainage of concern receive the highest priority for enhancement and intensive evaluation. Just because some systems are waiting for "external" limiting factors to be remedied does not mean enhancement should not proceed.

2.0 WHAT CONSTITUTES GOOD EUALUATION PROGRAM DESIGN?

2.9 TO WHAT EXTENT SHOULD WE CAND CAN WE) DESIGN EVALUATION PROCEDURES TO MINIMIZE THE INFLUENCE OF AMONG-YEAR UARIATION ON THE EVALUATION RESULTS?

Points of Agreement

1. A stratified design with replication may give sufficient data to reduce error in short term studies. A statistician should be consulted for the sampling design.

2. The evaluation goal should be clearly spelled out.

3. See Question 2.4 The experimental design should include good controls in the study and nearby Cand similar1 streams. Physical and biological covariables must be taken into account, i.e. flow, sediment load, temperature, Interspecific competition, seeding level, and harvest.

4. The study design depends on the confidence level desired. The influence of year-to-year variability Cof any factor1 can be lessened by longer term evaluations. It may be desirable to have one (or morel intensive studies with a paired control stream design in the evaluation program.

CONSENSUS

Stream habitat enhancement evaluations should have clearly stated goals. Paired controls within and between streams should be used. Accounting for physical and biological covariables [point 3, above1 will aid in explaining year-to-year variability. Stratified sampling designs, with replication, were suggested for shorter term studies. A statistician should be consulted for any sampling design. The number of strata and replicutes necessary to achieve a certain level of confidence will probably be unique to each evaluation program or project.

2.0 WHAT CONSTITUTES GOOD EUALUATION PROGRAM DESIGN?

2.10 HOW LONG SHOULD EUALUATION PROGRAMS LAST? WHAT IS THE BEST WAY TO DETERMINE PROJECT DETERIORATION/FAILURE RATE?

Points of Agreement

1. The time frame of an evaluation program or project depends on the "intensity" of the evaluation. General evaluations would not last as long as intensive evaluations. For physical evaluations, the design life [engineering term) of the structure may determine the length of the evaluation period as well as be an indication of structure life.

2. It depends on the questions being asked [mechanisms or performance]. Biological studies should encompass at least one life cycle of the fish species. Riparian regeneration will require a longer term study, regardless of intensity of the evaluation.

CONSENSUS

It was generally agreed that the duration of the evaluation depends on the questions being asked and, therefore, the intensity of the evaluation. General evaluations are often designed to answer questions about physical effects and will be of shorter duration. Physical evaluations might consider the designed Cor assumed1 "designed life" of the structure.

Intensive evaluations will be of longer term, No general agreements were reached about the duration of intensive evaluations, except that each program will be unique. Most participants agreed that one full life cycle of the species of concern should be the minimum evaluation period, Others felt that two full life cycles, or longer, should be the minimum. Again, the duration of the evaluation will depend on the questions asked and the type of enhancement project. General determinants of the length of an evaluation program that surfaced in the course of discussions were:

- Nature of the evaluation program [general-intensive, biological or physical, etc.);
- Life history of the target species;
- Flow history (see Question 2.51;
- For enhancement projects that involve run-building, the evaluation should continue until the asymptotic peak of escapement is apparent.

Question 2.10

It was also suggested that the frequency of on-site evaluations should be more frequent during the first few years Csee Question 2.53 and may change in subsequent years.

Regarding project deterioration/failure rate, there was little discussion and few specifics offered. It was apparent that failure rate is to be determined empirically. Therefore, evaluation programs should be integrated to include both intensive and general evaluations. All projects should be inspected at least once a year (see Question 2.5, page 223.

DO WE APPLY WHRT WE -LEARN?

3.1 TO WHAT EXTENT CAN WE EXTRAPOLATE RESULTS? WITHIN A MAJOR SUBBASIN? AMONG SUBBASINS?

Points of Agreement

1. Physical results are better understood and easier (more confidently3 extrapolated.

2. We can only extrapolate to similar types of (habitat/enhancement) problems assuming experienced professionals are involved.

3. Confidence in extrapolation decreases with increasing dissimilarity of streams or basins Can inverse relationship exists). That is, reasonableness of the extrapolation depends on the similarity of streams, biogeoclimatic regime, and other factors involved Csee Hierarchical Stratified Classification Scheme, page 58).

4. Variability, even within a subbasin, of physical and biological factors increases risk of extrapolation Cnot getting expected results based on the extrapolationl.

5. Use a list of similarities between an intensively studied stream Cor other unit1 and the target unit of the extrapolation to indicate validity of the extrapolation. Go ahead and extrapolate but clearly state your confidence in your conclusion. Have the manager decide whether the "fit" is tight enough. (See Acceptable Risk, page 55, and Hierarchical Stratified Classification System, page 58.3

CONSENSUS

Extrapolation from one stream, subbasin, or basin to another must be done with careful consideration of often highly variable physical and biological factors. Some statement of confidence about the results used in the extrapolation and the conclusion of the extrapolation should be provided to the decision-maker(s).

The validity of the extrapolation will depend on the physical and biological similarity of the units of consideration. This can only be determined with some type of classification scheme (see page 58) Preferably, evaluation results used in extrapolations will be from intensive project or program evaluations.

3.0 HOW DO WE APPLY WHAT WE LEARN?

3.2 SHOULD WE BE CONCENTRATING ON INDIVIDUAL PROJECT ELEMENTS, PROJECTS AS A WHOLE, OR BASIN-WIDE APPROACHES?

Points of Agreement

1. This depends on the goals and objectives of the evaluation.

2. Look at all three approaches in the context of an intensive to general evaluation continuum. We must consider a framework of an orderly, methodical study plan.

3. Use a basin-wide approach. It will probably be necessary to look at the subbasin or finer level as part of an integrated evaluation program.

CONSENSUS

This question asks, again, about the design of the evaluation program. The substance of the evaluation program will depend first of all on clearly stated objectives, secondly on the heterogeneity of stream types within a basin, and finally on the degree of intensity of evaluation that management and/or funding dictate. (see Questions 1.2, 1.3, and Acceptable Risk.1

It was agreed by some that a basin-wide perspective is needed. After all, we dealing with fish production systems. A single stream or project is not an isolated independent unit. An evaluation framework should consist of a balance of intensive and general evaluations probably encompassing several subbasins, depending on the heterogeneity of stream types as determined by some type of classification system Csee page 58). The specific answer to questions about the geographic scale of approach will be unique to each evaluation program or project.

3.0 HOW DO WE APPLY WHAT WE LEARN?

3.3 WHAT KINDS OF RESULTS ARE MORE AMENABLE TO EXTRAPOLATION, E.G. PHYSICAL CSCOUR ELEMENT PERFORMANCE, RATE OF RIPARIAN RECOVERY, ETC.1 VERSUS BIOLOGICAL (NUMBERS OF PRESMOLTS OR SMOLTS PRODUCED, SPAWNER USE, ETC.37

Points of Agreement

1. Physical results are more easily (confidently) extrapolated given certain similar classes of watersheds.

2. The presmolt to smolt extrapolation, or spawner use extrapolations are the hardest.

3. Extrapolation of physical and/or biological results depends on the available data base. All results could be extrapolated if the data are there and the units (stream, subbasin, etc.1 are "comparable". Similarity of streams based on a classification system is critical.

4. Certain types of physical evaluations (e.g. bedload and sediment transport1 require long-term studies for valid results. Predictive models are ball-park at best. It may not be advisable to use preliminary data.

5. Do not be trapped by assuming physical results are easily extrapolated and that (again) habitat = fish.

6. Physical results cannot be used in lieu of biological results until the linkage between the two are better understood.

CONSENSUS

Physical results are more amenable to extrapolation given similor stream/subbasin types as determined from a classification system. Biological results are much more difficult to extrapolate. Again, the key to the validity of the extrapolation is the similarity of the stream types.

Certain physical results, particularly bedload/dediment transport results, require long-term studies often including paired stream controls. The data may not be immediately usable. More general results on local scour, structure performance, etc. may be more immediately extrapolated given a thorough understanding of the respective hydrology and seasonal flow patterns.

It wos generally agreed that certain elements Cor perhaps all) of evaluation results may be extrapolated given a sufficient data base, statements of assumption and confidence about the evaluation results, and similarity of stream types. Both general and intensive evaluations must be integrated to establish this data base, particularly to establish correlations of presmolt to smolt production ond spawner use.

3.0 HOW DO WE APPLY WHAT WE LEARN'?

Question 3.3

Biological results were generally considered to be the least amenable to extrapolation. It was reiterated that specific relationships between habitat types and fish production Cor use) are highly variable and will require more research in this area. Again, do vnot assume habitat fish.

3.0 HOW DO WE APPLY WHAT WE LEARN?

3.9 WHAT IS MEANT BY "REPRESENTATIVE"? DO WE LOOK AT IT ON THE LEVEL OF PROJECT, STREAM OR A SUBBASIN?

Points of Agreement

1. Representative would be the condition or characteristic that allows for reasonable extrapolation to a similar element [presumably a habitat or stream type) with a reasonable degree of accuracy. The term can be applied to projects, streams, or subbasins depending on the homogeneity of the system. The use of results for decision-making must be considered (see Acceptable Risk, page 55).

2. Variability, even within a stream, limits our ability to collect sufficient data to infer "representativeness' such that the concept is applicable only at the stream/project level.

3. See discussions of Question 3.2.

4. Representative is highly dependent on the variability of evaluation factors in the stream or basin of concern, the objectives and geographic scope of the evaluation program, and the intended use of the results.

S. There are problems with the concept of 'representative". It depends on what we are trying to look at Ci.e. instream structure performance, riparian vegetation, smolt output, subbasin smolt output).

6. The concept of "representative" is only applicable at the project and stream levels.

CONSENSUS

The concept of "representative" in the context of stream habitat enhancement evaluation is unique to the objectives, homogeneity of the subbasin Cor other geographic unit), and the variability of physical and biological factors. Participants evidently chose not to deal directly with the statistical-connotations of representativeness except to acknowledge that variability of physical and biological factors beyond the project or stream level increases and may not even be understood (more general evaluations and/or stream classification are thus warrentedl. Also acknowledged were the constraints by decision-makers (funding and Acceptable Risk, although not specifically stated1 which can define "representative".

Question 3.4

Some participants felt the concept of "representative" is applicable only at the project or stream level. Still others felt that if a subbasin were somewhat homogenous with respect to stream types, evaluations of physical and biological factors may be representative of the entire subbasin.

Participants strongly agreed that representativeness depends on the evaluation objectives. If the evaluation program is design to investigate general effects or trends, representative data are obtainable. If the evaluation is designed to investigate specific biological or physical mechanisms the "representative" is specific to the project or stream. These results may or may not be representative of factors and conditions operating in streams even in the same subbasin.

The unifying concept of integrating general and intensive evaluations was again suggested. It was also evident that most concepts underlying "representative" were discussed in the context of the use of evaluation results in extrapolation (Question 3.11 and in the scope of extrapolation (Question 3.21. The concept of representative begs many statistical questions about confidence and significance that are dependent upon management and budgetary realities couched in the term "reasonable" in the definition offered by one participant:

> "Representative is the condition or characteristic Cof the evaluation1 that allows extrapolation to a similar unit with a reasonable degree of accuracy."

3.0 HOW DO WE APPLY WHAT WE LEARN?

3.5 WAHT ABOUT FACTORS THAT BECOME LIMITING AFTER PROJECT IMPLEMENTATION?

Points of Agreement

1. The stream enhancement project or program should correct all limiting factors in order or all of them at once Csee Limiting Factors, page 51).

2. Assuming the project is well-planned, and there has been a thorough analysis of potential limiting factors, post-implementation limiting factors are usually Cmay be) of secondary importance and may not be cost-effective to deal with.

3. The evaluation should consider the second-most limiting factor. See Question 2.1.

CONSENSUS

Participants did not discuss this question in great detail. However, it was generally agreed that, given some hierarchical analysis of limiting factors (see Buell 1985) and correction of the habitat problem by the enhancement measure, the second-most limiting factor should be considered. Year-to-year variability of limiting factors might also be considered. Participants often referred to their treatment of Question 2.1.

3.0 HOW DO WE APPLY WHAT WE LEARN'?

3.6 HOW CAN THE EFFECTIUE LIFE OF AN ENHANCEMENT PROJECT BE EXTRACTED FROM AN EUALUATION PROGRAM?

Points of Agreement

1. Through appropriate planned, identification of goals and specific objectives, and proper evaluation design.

2. Extrapolate evaluation results from enhancement projects that have been in place for some time.

3. Hydrology is critical to determining the life of an enhancement project. Evaluation efforts should include monitoring of the frequency, duration, and magnitude of flow events. Some type of stream gage should be installed.

4. Continue evaluating enhancement projects, and not Just on an annual basis. (See Question 2.5, points 5 and 6, page 29).

S. The first three years are the most critical in the life of an enhancement structure. Flow event magnitude coupled with bedload transport will significantly affect the life of in-channel projects.

CONSENSUS

Hydrology and related hydraulic and fluvial processes were considered to be the factors limiting the effective life of an enhancement project (specifically, in-channel structures). Above all we must continue to evaluate enhancement projects. It was evident that most participants considered project life expectancy to be based on empirical data. We are not yet at the predictive stage, if ever we will be due to the highly variable nature of the stream environment. It was suggested that evaluation data could used to plot curves from which life expectancy could be estimated. As many physical variables as possible should be used, although flow history was considered to be crucial. Data on flow events should be compiled through the installation of stream gages, particularly in intensive evaluations. It may also be advisable to involve a hydrologist trained in stream mechanics and fluvial processes in the evaluation, data compilation, or data interpretation.

Extrapolation of evaluation results for the purpose of estimating effective project life should consider, again, the similarity of the streams or subbasins. Particular emphasis should be given the aforementioned hydrologic and fluvial processes.

ISSUES OF PARTICULAR CONCERN

Limiting Factors

The need for a careful analysis of factors limiting fish production in planning and evaluating is very clear. The Fish Creek example in Oregon [Everest et al. 1985) bears this out. The task is complicated enough to defy streamside cogitation, and enhancement practicioners have, in general, not taken the time and effort to develop and engage in formal procedures themselves. In lieu of a formal stepwise procedure, enhancement objectives are all too often based on professional judement or assumptions about results from other streams deemed "similar".

The identification of limiting factors is, in essence, a comparison of the known, or assumed, ecological requirements of each of the specie life history stages to the existing seasonally available habitat in the stream or system of concern. Outwardly this may seem simple; in practice it is a difficult and complex task. Early in the enhancement movement biologists concentrated on improving low flow habitat conditions, assuming that more water/habitat during this period translated to more fish. As we are learning, this is not always true. In fact, Workshop participants generally agreed that assuming habitat equals fish is dangerous. Unfortunately, it is generally agreed that we know too little about the specific habitat requirements of various salmonid life stages, particularly during the winter. Refinement of procedures for assessing limiting factors, and thereby increasing assurance of some measure of project success, will continue to depend on further basic ecological research in this area. Intensive evaluation programs are an excellent opportunity to provide this much needed knowledge as well and should therefore be balanced with general evaluations in the overall program. Workshop participants often cautioned against development of prescriptive evaluation methodologies without better knowledge of life stage-specific habitat requirements.

Participants proposed a checklist, not itself a formal procedure, for initial investigations into factors limiting production of the freshwater life stages of salmonids. Also suggested was a "probing" method that looks for significant production responses from o given enhancement measure directed at a suspected limiting factor. Presumably, professional judgement or some other method is the basis for suspecting the limiting factor. Data requirements would be relatively great pre- and post-treatment physical and biological investigations.

A third method proposed minimizes pre-treatment data collection by inferring a limiting factor from comparison with a proximal, highly productive stream. It was agreed that this method has merit for severely degraded streams if there is a nearby "model" stream, but may be ambiguous when considering less degraded streams where some subtle differences in habitat characteristics may make discrimination difficult. Criteria for selecting a model stream (i.e species composition, hydrology, habitat composition) should be strict. Development and application of a stratified hierarchical classification scheme may have considerable utility in such problems of determining comparability.

Formal procedures for investigating possible limiting factors have been proposed by Nickelson (1985), Anderson (1985), Everest and Seddell (1984), and Buell (1986), These references are included as Appendix B. Fundamental to these procedures and the checklist suggested by Workshop participants are two necessities:

1. Some quantitative knowledge of the habitat types in the stream or system of concern. This may be as basic as the pool:riffle ratio, or as detailed as the intensive habitat surveys suggested by Anderson (1985) and Everest and Seddell (1984). Participants felt the more intense, the better.

2. Knowledge of habitat requirements of each life history stage of each species present. Habitat types are thus defined by the life stages of the species of concern.

An extremely important approach to limiting factor analyses is the consideration of lower ranking or seemingly less important limiting factors. One factor considered in the first analysis to be limiting may be superseded by another the next season. The factors limiting production may be several, and subtle. Considering only the top-ranked limiting factor can be dangerous (see Buell (1986) for a procedure that considers ranking potential limiting factors). Lesser-ranked factors may be equal, or close, in importance and there is always the possibility that we are wrong in our selection of the top-ranking limiting factors. In short, do not put all the eggs in one basket. The prudent approach is to consider several potential limiting factors and expect interaction between them. This is strong support for considering several limiting factors in enhancement planning and evaluation. Elucidating the limiting factor is a difficult task at best; interactions between limiting factors complicates both enhancement planning and evaluation. Enhancement planning for several potentially interacting limiting factors may solve several production problems at once for the same level of effort that would be directed toward only one limiting factor. Moreover, several problems may be solved for the same cost with an increased probability of success.

Limiting Factors

Naturally, the approach to enhancement should be reflected in the evaluation effort. Questions asked about mechanisms Chow and why a particular enhancement effort worked, or did not) should consider not only the limiting factor identified during the enhancement plonning, but independent assessments and most importantly, the next ranked or apparently limiting factors.

Acceptable Risk

In any system which requires decisions to be made based results of test cases - that is, where inference is involved - there is an element of risk that the decision will be wrong. In the case of a habitat enhancement program, decisions to proceed with a certain direction or with a certain level of commitment may well be based on an associated program of evaluations of enhancement efforts that have gone before. In such a program, however, a manager or decision-maker must be aware that available information, no matter how good it is, may lead to making a wrong decision. The risk of making a wrong decision can be reduced by engaging in more and intensive evaluations.

Acceptable risk is the risk a manager or decision-maker is willing to take when making a decision about enhancement project or measure implementation. It may be that the supporting evaluation data are misleading (i.e. the null hypothesis was incorrectly rejected). In statistical jargon, it is the probability of a Type I error. In everyday parlance, it is the risk of being misled into believing a cause-and-effect relationship exists when it does not.

It is the evaluator's role to do the best possible job of information-gathering and to report the results with whatever confidence and significance levels are indicated by the data. It is the decision-maker's role to decide if evaluation results warrent continued implementation of the enhancement measure(s) Interaction between those making implementation decisions and those evaluating stream habitat enhancement is very important. The acceptance of a given level of risk by a manager has direct influence on the design of the evaluation program. For instance, the sample size, replicates, and, possibly, the number of variables required for determining effectiveness at the 70 percent significance level is considerably less than the requirements for the 95 percent significance level. There is no scientific canon that dictates the use of the 95 percent confidence level; it is merely a convention.

The Washington Department of Game found that 70-75 percent significance levels are acceptable for management decisions [Jack Howerton, Level I Workshop, March 19861. They also found that the costs of acquiring data which would result in more confidence in management decisions increase exponentially from the 70-75 percent significance levels to the 95 percent region. Careful consideration of time, costs, and benefits of high significance levels is important.

Acceptable risk has a statistical bearing on the structure and intensity of an evaluation program or project in the following way. If management is willing to accept risks greater than the conventional 95 percent confidence or significance level, experimental design may be simplified, sample sizes reduced, and overall costs will be much lower. The question must be asked: How much confidence does the decision-maker have to have before commiting the dollars to enhancement? This is the sole province of management. Again, the evaluator(s) must report evaluation results with whatever confidence levels the data dictate.

Mierarchical Stratified Classification System

Participants in the Level I Workshop and others in the fishery and hydrological communities have repeatedly pointed to the clear need for a classification system around which an evaluation program for stream habitat enhancement projects can be structured. The approach suggested in the Level I Workshop was a hierarchical stratification system. Such a system was considered to be the only acceptable way to extrapolate evaluation results from one project/stream to another with some rational basis. The system also would provide a basis for determining the proportion of intensive and general evaluation projects within the overall evaluation program by indicating the heterogeneity of stream/habitat types within a subbasin or basin.

It was generally agreed by participants that a hierarchical stratification system should have the following principal strata:

1. Fish species composition.

2. Hydrology of the basin.

3. Geology and geomorphology of the basin.

4. Climatic conditions.

S. Major land uses in the basin,

6. Limiting factors addressed by the enhancement project.

These are only the minimum components. The suggested hierarchy here is general in utility. Each basin and extrapolation problem will probably require careful consideration of this hierarchy of importance of each factor to ultimately determine the "goodness of fit" of the streams or basins of consideration. It was generally felt that a multi-disciplinary team approach should be used to classify each basin or sub-basin. Additional components should be refinements of those listed above, such as: soil types, vegetative communities, source of streamflow, etc. Another component, not directly addressed by participants was water management [withdrawals, return flows, stage fluctuations from hydropower operations, etc). These will undoubtedly be significant factors to be considered in most large systems, particularly with the recent increase in small hydroelectric projects.

Fortunately, much of the information necessary to construct a hierarchical stratification system is already compiled or being compiled, particularly in the Columbia Basin. The Soil Conservation Service has mapped most of the Columbia Basin using a system of soil types, climate, vegetation, available water resources, predominant land use, and agricultural types. In addition, a large portion of Federal lands under the jurisdiction of the U.S. Forest Service or Bureau of Land Management that support timber harvesting or grazing have been mapped with respect to soil types and important vegetative communities. Much information may also be obtained from interpretation of aerial photographs maintained by these, and other, agencies. The Northwest Power Planning Council is presently developing a fisheries data base that will identify the presence or absence of anadromous salmonids by river reach. This data base is organized using the Environmental Protection Agency stream classification and mapping system.

Clearly, a considerable amount of this information already exists; it Just has not been put together. Participants felt it should b ‘one soon, and with a high priority, but not to the hinderance of enhancement or evaluation projects. tlomentum is important As we proceed with the development and implementation of stream enhancement evaluation programs and projects, we should do so intelligently and with an aye to potential and existing data collecitons, that can be incorporated into a classification system. High priority should be given to the development of a hierarchical stratified classification system.

The Effects of Under-seeding

The problem of habitat enhancement in under-seeded screams, especially in the context of evaluation, is an important and complex one. For purposes of this discussion, under-seeding is the condition in a stream where available habitat is not being fully utilized at a time when factors limiting the stream's capacity to produce fish are exerting their greatest influence on the system. In an enhancement effort context, the problem is that adding more habitat or 'productive capacity' to a stream may not result in the production of more fish, since there are not enough fish to fill the available habitat under pre-enhancement conditions. In an evaluation context one will be unable to turn to fish population studies as reliable indices of increase in habitat until such time as populations build to the point of fully seeding the stream.

It is important to note that many Cbut not all) participants felt that habitat enhancement efforts should proceed even in under-seeded anadromous streams in anticipation of run-building and especially in anticipation of amelioration of mainstem migration, predator, and overharvest problems. These problems are seen as being largely responsible for the under-seeded conditions of many upper watershed streams in large river basins.

These methods of dealing with problems in evaluating habitat enhancement in under-seeded streams were identified by the workshop participants. The first approach identified is to fully seed the stream segment being evaluated with an appropricate life stage (e.g. fry). This approach would allow the responses of fish to habitat manipulation to be studied, and any effects of enhancement on fish populations to be determined, in the same way as in a fully seeded stream. A control stream segment would have to be artificially seeded in the same way. A significant drawback to this approach is that behavioral characteristics and survival rates of hatchery stock Juveniles are often significantly different from wild counterparts. Conclusions regarding the effectiveness of enhancement efforts based on artificial seeding with fish of hatchery origin could be seriously biased. This drawback can be substantially overcome by culturing fry of known wild stock origin for artificial seeding in evaluation of enhancement in underseeded streams. This was the original concept behind 'hatchery reprogramming" in the Northwest Power Planning Council’s Fish and Wildlife Program Cfor the Columbia Basin).

A second approach to evaluating enhancement in under-seeded streams is to perform less intensive evaluations looking primarily at habitat elements rather than fish populations. Increases in productive capacity due to enhancement efforts would have to be inferred from more intensive evaluations conducted on nearby, similar Csee Hierarchical Stratified Classification System, page 43), fully seeded or artificially seeded streams.

The Effects of Undsr-seeding

If all reasonable candidates for intensive evaluation in a basin or subbasin are under-seeded, a third approach is to select the least under-seeded stream for study, or at least make this characteristic a high priority for selection. This stream would serve as the intensively evaluated benchmark for the basin or subbasin to which other less intensive evaluation efforts could be compared. Results could be adjusted over time if full seeding is approached.

It is incumbent on an evaluator to determine whether a stream is under-seeded in the first place and, to some extent, the degree of under-seeding. Several indicators are available. The most obvious is an appeal to the historical record for the stream in question Cif one exists). If the stream historically supported a much greater population of fish and the condition of the watershed is relatively unchanged, the stream is very likely under-seeded.

Another indicator of under-seeding is great among-year variation in fish populations (e.g. smolts for anadromous fish3 which cannot be explained by corresponding changes in meteorology or suspected limiting factors. In the case of anadromous fish smolts or juveniles, some attempt should be made to correlate these variations with corresponding changes in parent populations.

A third indicator of under-seeding is a comparison with other streams of 0 similar type. It is acknowledged that the ability to distinguish between seeded and underseeded is reduced as full seeding is approached, but the importance of the distinction is also diminished. It was generally acknowledged that fish population responses to habitat enhancement would become much easier to detect as full seeding was approached.

There is another aspect of the under-seeding problem. There are cases where fish populations increase in response to habitat enhancement, in spite of substantial underutilization of a stream's productive capacity at pre-enhancement conditions. This is a very important point. The best examples are those which deal with survival rates of specific life stages. If the rate of survival from deposited egg to emergent fry can be increased through improvement of spawning habitat quality from e.g. 10% to 40% four times as many Juvenile fish will be available to seed available rearing habitat from the same number of spawners as would be available under pre-enhancement conditions. This response to enhancement of spawning habitat quality would occur whether or not the productive capacity of the stream was fully utilized either before or after enhancement. There would be a positive response of fish populations to enhancement efforts in spite of under-seeding. Two other examples of survival rate limiting factors that are independent of population levels are turbine-related mortality of downstream migrants through hydroelectric facilities and, to a certain extent, predator related mortality.

The Effects of Under-seeding

This aspect of the under-seeding problem brings out an important distinction in the types of population limiting factors which operate in stream systems. One type is related to habitat quantity and controls the number of organisms a system can support. These are density-dependent limiting factors. Another type is related to habitat quality and controls the rate of survival from one life stage to the next, independent of seeding, Those are density-independent limiting factors. The "bottleneck" concept relating to limiting factors applies to density-dependent, but not to density-independent, limiting factors. In an evaluation context, the relative success of enhancement efforts can be measured directly by fish population studies far those targeted on density-independent limiting factors (habitat quality3 but not for those targeted on density-dependent limiting factors (habitat quality).

Finally, when population building Cin the case of anadromous fish) in underseeded watersheds is the goal of enhancement, it is especially important to focus on density-independent factors, that is habitat quality factors. This is due in part to the practice of discounting enhancement benefits over time. Benefits received early in the lifetime of an enhancement program are worth much more than later benefits. In this respect, population-building in under-seeded watersheds is one of the most important approaches which can be incorporated into a large enhancement program, and evaluation of these efforts is of correspondingly great importance.

SUMMARY

Participants in the Level I Workshop, March 1936, Hood River, Oregon discussed a series of framework questions pertaining to the fundamental objectives of evaluating stream habitat enhancement, the elements of a good evaluation program, and the application of evaluation results. These discussions and written answers submitted by absentee contributors were synthesized to provide the Points of Agreement and Consenses presented in this document. Workshop participants agreed on many aspects of philosophy, approach, and techniques for evaluating stream habitat enhancement. Alternative points of view were also expressed and are, hopefully, represented in the Points of Agreement and discussion following the Consenses. Participants brought to the Workshop a broad range of experience in different stream systems and different political arenas. Politics and vested interest were left out of most discussions. The common goal of the participants was to concentrate on the technical and apolitical administrative aspects of stream habitat enhancement evaluation programs and projects.

Participants also identified the following areas of particular concern: Limiting Factors, Acceptable Risk, Heirarchical Stratified Classification System, and the Effects of Underseeding. A separate section of this document is devoted to these issues. Many significant points of agreement surfaced in the course of discussions. Many informational and procedural needs also were identified and became recurrent themes of the Level I Workshop. These informational and procedural needs are:

1. It is not safe, in any case, to assume that the creation or restoration of habitat will result in fish production.
2. More research is needed on the habitat requirements of all salmonid life stages.
3. The goals and objectives of any evaluation program or project must be clearly stated.
4. Assumptions are part of the real world and must be clearly stated.
5. Extrapolation of evaluation results must be done with care and between "similar" streams.
6. A stream classification system is needed as the basis for extrapolation of evaluation results.

7. Management/decision-makers need to decide the acceptable risk of implementing an enhancement measure based on the best data the evaluators can supply.
8. Limitings factors must be identified, preferably using some objective hierarchical analysis.

The emphasis of the Level I Workshop was to discuss each topic and, to some extent, the inter-relationships of the framework questions. There was no effort to produce a set of prescriptive recommendations. This will be the function of the Level II Workshop to be held October 21-23 in Portland, Oregon. Rather, the basic components of an evaluation program, stream or system-specific elements of the evaluation effort, and feed-back loops of planning/design-implementation-evaluation were discussed.

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APPENDIX A

Framework Questions:

Level I Workshop, March, 1986

WORKSHOP FRAMEWORK

The following questions will provide the foundation for the Stream Habitat Enhancement Evaluation Workshop. Along with their respective answers, they will in turn serve as the basis of the workshop product: post tive recommendations and defended position statements on stream habitat enhancement evaluation techniques and philosophy.

I What are the fundamental objectives of enhancement project evaluation? What questions should we be asking?

1. Should we be doing or gathering just enough information for planning/management purposes? What are the respective pitfalls and trade-offs of the two approaches?

2. What is meant by "general" and "intensive" project evaluation? Are both Important?

3. What is the ultimate target of an evaluation program? Habitat capability (whether the fish are there or not)? Presmolts? Smol ts? Adults? If there are multiple targets, how are they related?

4. With regard to individual project elements, should we be more interested in why and how they work, or if they work (or don't work)? On a broader scale, what is the appropriate ratio of evaluations designed to determine how enhancement projects work to those designed to determine if they work?

5. To what extent should evaluation requirements drive the design end planning process?

6. How much baseline data is necessary before starting an enhancement project?

7. When in the life of a single evaluation program or a group of concurrent programs, can we begin using the results for decision-making?

8. What is the role of innovation? When should decision-making on enhancement implementation go beyond the results of an evaluation program? How far?

WORKSHOP FRAMEWORK (continued)

II. **What constitutes aood evaluation program desing?**

1 How important is it to Identify habitat factors presently limiting fish production? How do we identify limiting factors?

2. which assumptions are weentitledto make? Which not?

3 To what level of detail should assumptions and rationales be specified and documented in the evaluation process? What categories should always be specified?

4 How does one select a sample size -either within a project oramong projects? Are statistical confidence intervals necessary or useful? Under what circumstances?

5 To what extent should we evaluate design criteria and physical habitat objectives (hydraulics, scour, cover, etc.)?

6 To what extent can one evaluation target (e.g. habitat element) be an index of another (e.g. smolt)?

7 How important are seasonal considerations in an evaluat ion program? Under what ci rcumstances?

8 How does one deal with the problem of incomplete seeding (under-seeded habitat)?

9 To what extent should we (and can we) design evaluation procedures to minimize the influence of among-year variation on the evaluation results?

10 How long should evaluation programs last? What is the best way to determine project deterioration/failure rate?

WORKSHOP FRAMEWORK (Continued)

III. How should we apply what we learn?

1. To what extent can we extrapolate results? within a major subbasin? Among subbas ins?

2. Should we be concentrating on individual project elements, projects as a whole or basin-wade approaches?

3. What kind of results are more amenable to extrapolation, e.g. physical (scour element performance, rate of riparian recovery, etc.) versus biological (numbers of presmolts or smolts produced, spawner use, etc.)?

4 What is meant by "representative"? Do we look at it on the level of a project, a stream or a sub-basin?

5 What about factors which will become limiting after project implementation?

6 How can the effective life an an enhancement project be extracted from an evaluation program?

APPENDIX B

Selected References

A MODEL FOR DETERMINING FACTORS LIMITING ABUNDANCE, AND THEREBY ESTIMATING CARRYING CAPACITY OF FISHES IN STREAM SYSTEMS

The following model was developed for the purpose of determining factors limiting abundance of stram-dwelling fishes. The model is based on the concepts of specific habitat requirements for a given species at different stages of its freshwater life history and a habitat "bottleneck" limiting the number of individuals at some stage of the species that a stream can support. A simplified explanation of the model is that it specifies the "ideal" amount of different types of habitat needed to support a cohort of a species throughout Its freshwater life history. When employing the model on a particular stream, that habitat type that is least abundant relative to the "ideal", compared to the other habitat types, is the cause of a "bottleneck" and is the limiting factor. The population supported by the limiting habitat (after adjustment for density-independent mortality) is the carrying capacity of the stream.

Definition of limiting factors

Limiting factors of a stream system are species-specific and are defined as the habitat required to support a particular life history stage that is in shortest supply relative to the habitats required to support other life history stages, and thus results in a numerical or biomass "bottleneck" for the population. The classical limiting factors of Fry (1947) such as temperature and oxygen are included in the definitions of each habitat type.

For the purpose of this discussion, the definition of limiting factors is restricted to a numerical "bottleneck" and does not address the possibility of a biomass "bottleneck" (i.e. few large fish as opposed to many small fish). We assume that a population of anadromous fish will be regulated such that it will not produce smolts that are too small to survive in the marine environment. Thus, before the population allows itself to become so abundant relative to its habitat that individual size is reduced below this hypothetical "minimum", inherent mechanisms of regulation (such as territoriality and dominance heirarchy) will reduce the population's number. This is, admittedly, an over-simplification of the processes of population regulation and would not apply to resident species such as trout, whitefish, or bass whose multiple cohorts would require the use of a biomass "bottleneck" in the definition.

Definition of Carrying Capacity

The freshwater carrying capacity of a stream system is defined as the number of <u>wild</u> smolts (or other product of interest such as legal size trout or bass) that result from the population during the freshwater life history stage restricted by the least available type of habitat.

This is where a biomass "bottleneck" causes problems. A biomass of X at some stage can consist of an infinite number of combinations of fish numbers and fish size. Thus, it is impossible to relate a biomass value to a number of smolts produced or spawners needed to fully seed the available habitat.

When anadromous salmonid smolts are the product of interest, the carrying capacity is the population resulting from the “bottleneck” in the habitat, minus losses due to density-independent processes between the time of the “bottleneck” and the time the fish leave the stream. Once a “bottleneck” in the habitat restricts a cohort, subsequent mortality should be density- independent only, since the habitat required by subsequent freshwater life history stages would, by definition, be in surplus. It is assumed that the abundance of subsequent cohorts will not result in density-dependent mortality of the first cohort. This assumption is probably valid for most anadromous salmonids since usually only one or two cohorts are present in a stream at the same time, and differences between the size of fish in each cohort dictate different habitat needs.

The issue is more complex for resident species since the product of interest is usually comprised of fish from more than one cohort. In this case, the product of interest needs to be defined within a time frame such as: legal size trout on opening day of trout season. The carrying capacity would then be the population resulting from the “bottleneck” in the habitat, minus losses due to density-independent processes between the time of the “bottleneck” and the time defined by the product of interest. Again it is assumed that the abundance of subsequent cohorts will not result in density-dependent mortality of the cohorts comprising the product of interest.

A basic assumption of this definition is that food is seldom limiting in stream systems. Differences in abundance of food between streams is viewed as inherent to the productivity of the streams. Thus, a very productive stream will support more rearing individuals at each life stage than an unproductive stream. A classification system that accounts for the intrinsic productivity of a stream is needed to adjust the “ideal” habitat ratios and the estimates of carrying capacity.

Definition of Habitat Types and Capacities

Habitat types are species-specific and are determined by the life history of each species. A habitat type must be defined each time the habitat requirements of the species changes (usually as the result of growth or environmental changes such as temperature and flow). Each stage at which the habitat requirements change will be termed a life stage.

Each habitat type has associated with it the number of fish that it can support (its capacity). At some life stages, a variety of habitats that have differing capacities may be used. The capacity of each variety of habitat would then be stated in terms of best habitat equivalencies. For example, 2 units of type B summer habitat or 5 units of type C summer habitat might be equivalent to 1 unit of type A summer habitat (the best). The capacities of the various habitat types would vary by stream productivity class (as defined by stream classification).

An example of habitat types for coho salmon (these need further refinement)

Spawning Habitat: Stream areas of gravel l-13 cm in diameter, with a depth of >13 cm, and a velocity of 21-70 cm/sec (based on data from Oregon streams).

First Spring Habitat: Undefined at this time.

Summer Habitat: Pools in low gradient streams (<3%) with velocities <30 cm/s, depths of >30 cm (preferred), temperatures of <18 degrees C and dissolved oxygen levels ≥ 8.0 ppm (based on data from Oregon streams).

Winter Habitat: Deep pools, side channels, tnd backwaters having velocities <30 cm/s, extensive cover, usually in the form of large woody debris, temperatures of > 0 degrees C and dissolved oxygen levels ≥ 8.0 ppm (based on data from British Columbia; data from Oregon are very limited).

Downstream Migration Habitat: Rivers and estuaries having temperatures during spring of <18 degrees C and dissolved oxygen levels of ≥ 8.0 ppm.

Determining the Limiting Habitat Type

The habitat influencing the freshwater production of anadromous salmonids usually can be placed in five groups: (1) those that influence spawning success (i.e. survival from egg to fry); (2) those that influence survival during the first spring following emergence; (3) those that influence survival during summer; (4) those that influence survival during winter, and (5) those which influence survival during downstream migration. Typically, habitat in the first four groups determine the carrying capacity of a stream system for anadromous salmonids. The exceptions usually result from the presence of obstructions, such as dams or major predators, in the downstream migration habitat. To determine which of these habitat types is limiting in a particular stream system, we must know the ratio of the habitat types needed to support the species of interest, and how much of each habitat type is available in the stream.

To determine the ratio of habitat types needed for a particular species, we need to know the number of offspring from a pair of spawners that will be living at the beginning of each life stage having a different habitat requirement, given that habitat is unlimited (i.e. we need to know the density-independent survival rate for each life stage). We also need to know the number of individuals the habitat associated with each life stage will support. We can calculate the quantity of each habitat type needed to support the offspring from a single spawning pair by dividing the number of individuals expected to be present at the beginning of each life stage by the number of individuals each habitat will support. The ratio of habitat types can then be calculated by dividing each quantity by the smallest quantity.

The next step is to survey the stream system of interest to determine the quantity of each habitat present. The boundary of a stream system should be determined by the movement of the population among stream reaches and should include all areas used by the population. For example, the stream system for most populations of coastal fall chinook would include everything from the tributary stream where they spawn, downstream to the estuary where they rear. On the other extreme, the stream system for a population of resident cutthroat trout may include only the reach of a tributary above a waterfall. Ideally, the stream system should be surveyed during each time of the year when the habitat is different (e.g. winter, spring, and summer) to accurately estimate the quantities of each habitat type.

The limiting habitat is determined by comparing the ratio of the habitat observed in the stream of interest to the "ideal" ratio of the model. Each value of the stream's observed ratio is divided by the respective value of the ideal ratio and the smallest quotient identifies the limiting habitat.

Example : Determining Limiting Factors and Estimating Carrying Capacity for Coho Salmon

The following is a simplified example of determining the limiting factor and carrying capacity for coho salmon. Let us assume that: (1) 3 square meters of gravel are needed for a pair of spawning coho (2500/3 = 833 eggs per unit); (2) we would expect 1300 offspring to be present at the beginning of summer; (3) summer habitat for coho is pools and 1 cubic meter of summer pool will support 4 juvenile coho (4 per unit); (4) we would expect 1100 offspring to be present at the beginning of winter; and (5) winter habitat for coho is usually associated with woody debris and 1 cubic meter of debris will support 3 juvenile coho (3 per unit). Thus the habitat needed to support one pair of coho spawners would be 3 units of gravel, 1300/4 = 325 units of pool during summer and 1100/3 = 367 units of debris during winter, and the "ideal" habitat ratio would be 3:325:367 or 1: 108: 122:

Now, suppose we surveyed three stream systems during summer and winter and estimated the following spawning, summer, and winter habitats:

Habitat	Unit Measure	Stream A	Stream B	Stream C
Spawning	3 sq. m gravel	260 units	130 units	30 units
Summer	1 cu. m pool	260 units	507 units	6000 units
Winter	1 cu. m debris	728 units	195 units	5400 units

These data are then converted into ratios:

Habitat	Stream A	Stream B	Stream C
Spawning	1	1	1
Summer	1	3.9	200
Winter	2.8	1.5	180

The ratios are then compared to the "ideal" ratio of 1:108:122 by division, and the smallest quotient identifies the limiting habitat:

Habitat	Stream A	Stream B	Stream C
Spawning	l/l = 1	l/l = 1	l/l = 1
Summer	l/108 = 0.01	3.9/108 = 0.04	200/108 = 1.85
Winter	2.8/122 0.02	1.5/122 = 0.01	180/122 = 1.48

In this example, spawning habitat is limiting in stream C, summer habitat is limiting in stream A, and winter habitat is limiting in stream B.

To estimate the carrying capacity of these three stream systems, we expand the limiting habitat of each to the number of fish of the appropriate life stage supported by that habitat. We then apply a density-independent survival curve (used above to estimate population abundance at the beginning of summer and winter) to estimate the number of fish surviving from the time of the "bottleneck" until smolt migration. In this case:

Stream A: C.C. = 260 un. sum. hab. X 4 fish/un. X 0.43 s.r. = 468 smolts
Stream B C.C. = 195 un. win. hab. X 3 fish/un. X 0.53 s.r. = 310 smolts
Stream C C.C. = 30 un. sp. hab. X 833 eggs/un. X 0.23 s.r. = 5748 smolts

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A Method for Monitoring and Evaluating Salmonid Habitat Carrying Capacity of Natural and Enhanced Oregon Coastal Streams

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ABSTRACT

A model was developed for predicting the carrying capacity of stream habitat for coastal salmonids to provide fish numbers that can be used in developing benefit-cost ratio. The habitat was broken into types. Each type was assigned a range of carrying capacity (fish per square meter) by species at summer low flow. The predictor model was based on three hundred sixty-five field samples collected in the Salem and Coos Bay Districts of BLM. The usefulness of the method is demonstrated by applying it to three seperate stream habitat cases in the Coos Bay District.

INTRODUCTION

The Bureau of Land Management quantifies the benefit of stream enhancement and protection for salmonids in order to procure funds for projects. Measuring the value of stream habitat based on returning adults has become unreliable. Some reaches of stream are not used for spawning but are prime rearing habitat. Variables such as stocking of hatchery smolts and pre-smolts, volunteer enhancement hatchbox stocking, straying of adults from private aquaculture facilities, and over harvest of adultshave all worked to make it difficult to determine current natural production.

The Bureau, as a land management agency, has the responsibility for habitat management while the state regulates fish populations and their harvest. Bureau biologists can manipulate the quality of riparian and stream habitat to increase or decrease a species' carrying capacity. The Coos Bay District has been working to rehabilitate and enhance habitat for the last fifteen years. This work has improved the habitat but in many cases, due to outside factors, populations of salmon have declined. Variables listed in the previous paragraph have caused biologists to try to find a more reliable method of determining fish use of stream habitat on Bureau lands.

External variables such as overfishing and straying that are not related to the productivity of stream habitat lead to the development of a range of salmonid production numbers based on stream habitat carrying capacity. Whether the carrying capacity is ever filled does not change the fact that it still is available. This is the same approach that foresters and range managers use in the measurement of production. Foresters predict board feet production per acre and range conservationists estimate animal unit months (AUM's) per acre based on forage available. In a similar manner we can measure fish productivity, based on square meters of habitat by type, during the summer when flows are lowest in coastal streams. The habitat is classified by type and the estimate of potential range of carrying capacity for each type is developed.The connection between habitat and late summer salmonid populations can be integrated with existing empirical smolt and adult survival rates. Realistic benefit cost ratios can be developed from this data to analyze past and future stream management actions.

The standard value of fish per square meter of habitat has been used by researchers for many years. The breakdown of stream habitats into habitat types provided a means for biologists to quantify streams (Bisson et. al, 1980). The habitat type measured in square meters has made it possible to break the stream into individual types that have visually different characteristics, and in some cases, different production levels for a species. The three ma jor habitats are pool, riffle and glide. Pools and riffles are further broken into types (Table 2). We added several riffle types based on substrate and gradient to those described initially by Bisson.

METHODS

A format built around habitat type was developed into a two part form. The first part is used to record habitat type information. The second part provided sampling of the fish populations using the two-pass method (Carle and Strub 1978). The habitat type and the fish density by species were then compared.

A second form was developed to record habitat type data only. This form was used to extensively survey whole stream basins. This can provide an estimate of potential fish densities, basic data for enhancement or expansion of habitat and a measure of the effectiveness of existing management actions.

The intensive form was used by the Coos Bay and Salem District of the BLM. The habitat types were recorded and the fish populations were estimated using the electrofishing two-pass method for each habitat type. A large number of the samples were taken in stream enhancement reaches to monitor population response to artificial structures. Cont rol units were also designated for comparability . Only streams that were known to have adult coho and winter steelhead spawning the winter before were sampled. The data collection did not attempt to stratify samples in equal numbers by habitat type. An entire reach of connected habitat types was sampled thus the most common types were more heavily represented. Uncommon types were less well represented and in the case of cascades, none were found. All sampled habitat types were separated with seines to isolate populations within each habitat type.

Statistical analysis of the two districts combined 365 intensive habitat type samples to provide a greater statistical base. A statistical analysis of the data provides the means and range of population expected to occur at the .05

confidence limit. A Tukey test to determine the level of significance to the 10 level for population means between habitat types within the pool and riffle types was used (Table 1).

A transformation using the natural logarithm of y+.Ol provided satisfactory results and the listings reflect this transformation. Tukey tests, in which means for all habitat types within each habitat (pool and riffle) were tested against all the other habitat types within that habitat, were calculated for all habitats except coho pools and trout riffles, for which the overall analysis of variance indicated there were no significant differences.

Table 1. Listing of the habitats, habitat types tested against each other that showed a significant level equal to or greater than .10 by species resulting from Tukey test.

Species	Habitat	Habitat Type6	Sig. Level
Cutthroat	Pool	Secondary channel vs. plunge	.05
		Secondary channel vs. lateral scour	.01
		Trench vs. plunge	.05
		Trench vs. lateral scour	.01
		Plunge vs. dammed	.01
		Lateral scour vs. dammed	.01
	Riffle	Secondary channel vs. cobble	.01
		Gravel vs. cobble	.01
		Bedrock vs. cobble	.01
		Cobble vs. boulder	.01
Coho	Riffle	Secondary channel vs. gravel	.10
		Gravel vs. boulder	.10
Trout	Pool	Trench vs. plunge	.05
		Trench vs. lateral scour	.05
		Plunge vs. dammed	.10
		Lateral scour vs. dammed	.10
Steelhead	Pool	Plunge vs. dammed	.01
		Lateral scour vs. dammed	.01
		Secondary channel vs. backwater	.10
		Secondary channel vs. trench	.05
		Secondary channel vs. plunge	.01
		Secondary channel vs. lateral scour	.01
	Riffle	Secondary channel vs. cobble	.01
		Secondary channel vs. rapids	.05
		Gravel vs. bedrock	.01
		Gravel vs. cobble	.01
		Gravel vs. rapids	.01

Mean density and confidence intervals for each species by habitat type is shown in Table. 2. These data were used to model population carry capacity by stream habitats. It was recognized that population by species for some habitat types was not significantly different. For modeling purposes, habitat types are listed individually even though they are not significantly different.

Table 2. ___ Range of fish per area (m^2) at the .05 confidence limit.

Habitat Type	Low	Mean	High	Low	Mean	High
	Coho parr/(m^2)			Trout age 0/ (m^2)		
POOLS						
Secondary channel	0.26	0.53	0.80	0.00	0.28	0.60
Backwater	0.31	0.69	1.07	0.00	0.14	0.35
Trench	0.17	0.31	0.45	0.02	0.05	0.08
Plunge	0.36	0.47	0.58	0.14	0.22	0.31
Lateral scour	0.42	0.54	0.66	0.08	0.13	0.18
Dammed	0.18	0.27	0.36	0.02	0.05	0.08
RIFFLES						
Secondary channel	0.00	0.39	1.12	0.00	1.04	3.90
Low Gradient gravel	0.06	0.11	0.17	0.02	0.30	0.58
Low Gradient bedrock	0.03	0.09	0.15	0.16	0.29	0.42
Low Gradient cobble	0.04	0.08	0.13	0.18	0.32	0.46
Low Gradient boulder	0.001	0.06	0.15	0.11	0.19	0.27
Rapids	0.00	0.06	0.15	0.00	0.09	0.26
GLIDE	0.23	0.39	0.55	0.08	0.17	0.27
	Steelhead 1+/(m^2)			Cutthroat 1+/(m^2)		
POOLS						
Secondary channel	0.00	0.003	0.008	0.00	0.007	0.017
Backwater	0.00	0.030	0.064	0.00	0.021	0.053
Trench	0.009	0.032	0.055	0.002	0.017	0.032
Plunge	0.053	0.075	0.097	0.035	0.058	0.081
Lateral scour	0.035	0.057	0.079	0.029	0.046	0.063
Dammed	0.007	0.012	0.017	0.003	0.007	0.011
RIFFLES						
Secondary channel	0.00	0.024	0.081	0.00	0.000	0.00
Lo grad. gravel	0.001	0.015	0.029	0.00	0.004	0.009
Lo grad. bedrock	0.008	0.025	0.042	0.00	0.003	0.006
Lo grad. cobble	0.028	0.045	0.062	0.003	0.009	0.015
Lo grad. boulder	0.043	0.060	0.077	0.011	0.034	0.057
Rapids	0.041	0.139	0.237	0.00	0.019	0.045
GLIDE	0.017	0.029	0.041	0.010	0.022	0.035

MANAGEMENT APPLICATION

The usefulness of the carrying capacity model (method) is demonstrated by applying it to three management situation6 in the Coos Bay District.

Moore Creek is the first case where a 425 meter reach was enhanced with a series of wooden drop structures and blasted rearing pools. The stream reach was almost entirely a bedrock substrate with few pools for rearing and no gravel for spawning of coho or steelhead. The habitat changed after enhancement (Table 3). The number of square meters of habitat surface area decreased by 31% but the quality of the enhanced habitat increased dramatically to favor coho parr. A prediction of the population (Table 4a.) and the actual population estimates from electrofishing (Table 4b.) were compared. The prediction was developed using the data for habitat types (Table 2). The range of population estimates at the 0.5% level for both electrofishing and the predictor overlap in four out of six cases (Table 4a. and 4b.) with the exception of 1982 and 1983 coho parr. In two cases after enhancement, the population exceeded the predictor6 projection for a substantial increase.

Nearly all of the trout were age zero and the extensive bedrock riffles provided excellent habitat for them before enhancement. After enhancement the stream was converted to mostly pool habitat which reduced their numbers substantially.

Almost no cutthroat or steelhead l+ were present in 1981 due to lack of habitat and are therefore not included. Both species are now present since enhancement.

Table 3. ___ Moore Creek stream habitat surface area changes (m^2) before and after enhancement.

Habitat	Type	Before	After
Pools			
	Trench	242	27
	Plunge		299
	Lateral scour	-	37
	Dammed		763
Riffles			
	Bedrock	1,350	7
	Gravel	149	7
Glide			55
TOTAL		1,741	1,195

Table 4a.___ Moore Creek predictor estimate of Coho parr and trout age 0 before and after enhancement.

Species	Habitat	Type	Before Low	Before Mean	Before High	After Low	After Mean	After High
Coho	Pool							
		Trench	41	75	109	5	8	12
		Plunge				108	141	173
		Lateral scour	-	-	-	16	20	24
		Dammed	-	-	-	137	206	275
	Riffles							
		Bedrock	41	122	203		1	1
		Gravel	9	16	25		1	1
	Glide					13	21	30
	Total Coho Parr		91	213	337	279	398	516
Trout								
	Pool	Trench	5	12	19	1	1	2
		Plunge				42	66	93
		Lateral scour	-	-	-	3	5	7
		Dammed	-	-	-	15	38	61
	Riffle6							
		Bedrock	216	392	567	1	2	3
		Gravel	3	45	86		2	4
	Glide					4	9	15
	TOTAL TROUT		224	449	672	66	123	185

Table 4b.___ Moore Creek **two-pass** population estimate of coho parr and trout age zero per (m^{-2}) before and after enhancement.

Specie6	Pre-Construction 1981	Post Construction 1982	1983
Coho parr	83 ± 15	655 ± 28	714 ± 13
Trout age 0	596 ± 160	185 ± 16	117 ± 18

The second case is the "Gold Reach" of the West Fork of Smith River where a 300 meter reach was modified with approximately 200 meters of gabion structures. The purpose of the work was to create additional adult coho and winter steelhead spawning as well as juvenile rearing habitat. The total wetted stream surface area increased from approximately 3,347 to 4,249 square meters.

The gabion construction substantiallly changed the habitat and type (Table 5). The predictor for all four salmonid species was applied to the habitat and a range of estimates was developed to show the expected increased production created by the project (Table 6). The predictor would indicate a substantial increases in coho parr, steelhead and cutthroat, while only a minor decrease in age zero trout should occur. The increase in pool habitat contributes to the increase in coho, steelhead and cutthroat. Only a slight decrease in riffle habitat type occurred which prevented a decrease in trout population.

Table 5. West Fork Smith River Gold Reach surface area (m^2) by habitat type before and after enhancement.

Habitat	Type	Before	After
POOL			
	Trench	211	732
	Plunge		518
	Lateral scour	352	316
	Dammed	362	1,494
	Backwater	94	
RIFFLES			
	Bedrock	191	120
	Gravel	1,089	1,069
GLIDE		1,048	
TOTAL		3,347	4,249

Table 6 West Fork Smith River Gold Reach estimated range of salmonid populations before and after enhancement.

Species	Before			After		
	Low	Mean	High	Low	Mean	High.
Coho parr	592	968	1,352	780	1,173	1,576
Steelhead l+	45	85	135	57	117	176
Cutthroat 1+	21	53	84	32	71	112
Trout 0	175	648	1,137	183	623	1,067

The third example is Camas Creek where all of the potential anadromous fish habitat was extensively inventoried to classify the habitat type and surface area. The total stream length is approximately sixteen kilometers and it has a total of 91,790 m^2 of summer habitat. The predictor for coho salmon was applied to the habitat types. A fish laddering project downstream from the mouth of Camas Creek will soon open this habitat for coho salmon. A range of estimates was developed for late summer coho parr (Table 7). The predicted population ranges were then combined with smolt to ocean survival data (Nicholson, 1984) to develop a survival matrix. A constant value of 0.35 survival from parr to smolt was used for the model (Cedarholm et. al, 1980). The resultant matrix provides a possible range of nine values that could be used in the benefit cost ratio for the project (Table 8).

Table 7. Camas Creek habitat types by area (m^2) and estimated range of coho parr carrying capacity.

Habitat Type		Area m^2	Coho Population Carrying Capacity Range Low	Mean	High
Pool					
	Secondary channel	348	100	184	278
	Backwater	1,495	463	1,032	1,600
	Trench	13,289	2,259	4,120	5,980
	Plunge	4,739	1,706	2,227	2,749
	Lateral scour	8,109	2,986	4,379	5,352
	Dammed	5,578	1,004	1,506	2,008
Riffles					
	Secondary channel	784	0	306	343
	Lo grad. gravel	2,514	151	277	427
	Lo grad. bedrock	5,639	169	508	846
	Lo grad. cobble	5,151	206	412	670
	Lo grad. boulder	373	0	22	56
	Rapids	7,527	0	452	1,129
	Cascade6	7,829	0	0	0
Glides		28,415	6,635	11,081	15,628
	TOTAL	91,790	15,579	26,506	37,066

Table 8. Matrix of catchable coho adults surviving from coho parr calculated by using a range of values for parr abundance and smolt to adult survival and by using a .35 parr to smolt survival rate for all Parr.

	Smolt to catchable adult survival rate .05	.lO	.15
Coho parr population			
Low (15,579)	273	545	818
Mean (26,506)	464	928	1,392
High (37,066)	649	1,297	1,946

DISCUSSION

The use of a predictor model based on field data collected from different habitats provides a range of population estimates. As additional samples are collected through the years, the data base will increase and the predictor should become more refined. The use of this method makes it possible to communicate a value for habitat to managers who must make decision6 concerning funding of projects and habitat protection. The method may also eventually be used to assess the value of habitat lost or created or the amount of mitigation necessary to compensate for habitat alteration.

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TECHNICAL MEMORANDUM

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To: File

From: J. W. Buell, Ph.D.

Date: October 1985

Subject: The Determination of limiting Factors for the Production of Anrdromous Salmonids in Streams

Introduction

Over the past few years a great deal of attention has been devoted to the need for increasing anadromous fish production in the Pacific Northwest, This need has formed the basis of the Northwest Power Planning Council's Fish and Wildlife Program, the STEP effort in Oregon, SEP in Canada, and several other programs in the Pacific Northwest and northern California. As a result of these programs, huge sums of money have been spent or earmarked for stream habitat improvement. These expenditures are based on the premise that purposeful manipulation of stream habitat will result in an increase in the production of anadromous fish.

Early in the enhancement movement, efforts to increase fish production in streams concentrated on "improving" the ratios of pools to riffles, adding certain kinds of cover (wood, boulders, etc.) stopping erosion by various means and stimulating recovery of riparian zones. Nearly all of these efforts were consciously directed at increasing the "carrying capacity" of streams during the summer low flow period or so-cal led "pinch period." It was generally reasoned that, since fish need water, when there isn't much water there can't be very many fish and we should therefore focus our habitat enhancement efforts on conditions prevailing during periods of low stream flow. Notable exceptions to this general thrust of habitat enhancement include some efforts to catch and hold spawning gravel in streams judged very deficient in this habitat type. In most cases, there was *no* organized, formal effort to determine just what was limiting the production of anadromous fish in the stream in the first place. This de facto hit-and-miss approach to enhancement scored some clear hits and some clear misses; most results (when efforts were made to find them out) were understandably ambiguous.

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This lack of attention to defining the problem before implementing the solution has not gone entirely unnoticed, however. Most often in conversation but occasionally in presentations at symposia, a few enhancement practitioners have discussed the great importance of the identification of limiting factors prior to design and implementation of stream habitat enhancement projects. Hall and Baker (1982) identified the need in their review paper on enhancement techniques. Hall (1984) elaborated on the “bottleneck” analogy to the limiting factor idea at the Pacific Northwest Stream Habitat Management Workshop in Arcata, California and again at the 1984 Annual Meeting of the Western Division, American Fisheries Society meetings in Victoria, B.C. Everest (1984) discussed limiting factors at length, stressed the importance of limiting factor analysis as well as its complexity, and lamented the lack of it in most enhancement projects. Everest again discussed the importance of limiting factors and their directing influence *on* enhancement projects at the 1985 annual meeting of the American Fisheries Society in Sun Valley, Idaho.

The need for a careful analysis of factors limiting anadromous fish production in planning individual habitat enhancement projects is very clear. The failure to perform the analysis in most projects is equally clear. *One* possible reason for the deficiency is the absence of a format process or procedure for identifying limiting factors. The task is complicated enough to defy streamside cogitation, and habitat enhancement practitioners have, in general, not taken the time and effort to develop and engage in formal procedures themselves. Rather, they have been content to do what others do and call it a good day’s work. It is the purpose of this Technical Memorandum to propose a formal procedure which, if followed carefully, will greatly assist enhancement practitioners in the identification of factors limiting anadromous fish production in streams. However, this stepwise procedure, like any other, is only as good as the information that is used in its execution. Care should be used in thinking through various assumptions the user will have to make.

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The Procedure

1. Choose the species of interest. If there is more than *one,* deal with each one separately, then merge the findings at the end.

2. Make a time line encompassing all of the life history stages during which the target species has a relationship with the stream segment under consideration. The time line may be more than two years long in some cases.

3. Enter all life history stages (subdivide if helpful) and all details of the relationship of the target species with the stream. These details should generally be in the form of habitat needs, but other kinds of entries may be appropriate.

4. Make a similar time line parallel to the first one for the stream. Enter all known characteristics of the stream, especially those which may change seasonally <flow, temperature and other water quality parameters, *cover,* etc.). Remember to include habitat elements and emphasize seasonal changes For example, pools are the most inhospitable places in a stream during period of peak flow. Include other environmental parameters such as food supply, predators <including fisherman), etc.

5. For each of the two time lines, where information is not known, find it out. This may mean consulting other biologists knowledgeable in certain details of life history and habitat requirements, consulting flow records of the target stream or a nearby stream interviewing land owners or others with first-hand knowledge of seasonal conditions and variability of the stream, etc. There is no substitute for first hand observation of the stream system under a variety of conditions. Every effort should be made to visit the stream and swim it or make other first hand observations under several sets of circumstances (seasons, flows, etc.). Where information is simply unobtainable, make rational assumptions and label them as such. This is an important step, since assumptions are likely to be tested in *any* evaluation program.

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6. Carefully compare the two time lines. Note any instances where the life history needs of the target species are not adequately met by the corresponding prevailing conditions in the stream. These instances will indicate "candidates" for limiting factors. Note also, if possible, the degree to which they are not met: the severity of the shortfall. Be sure and take into account the variability of conditions both within seasons (e.g. "flashiness" of the stream) and among years. The latter must be considered in any evaluation program which may be carried out. This step will require a good deal of professional judgment and careful thought.

7. Rank the instances where life history needs are not adequately met by the stream with the most constraining influence on the population given highest rank. This is *an* application of the "bottleneck" concept. The environmental characteristic of the stream system under consideration that most constrains the target species population is likely to be the most important limiting factor needing enhancement attention. It is extremely important to note, however, that *any* well-conceived habitat enhancement effort will take into account more than one potential constraining influence on the target population. There are several reasons for this. First, when dealing with systems as complex and interactive as anadromous fish streams, even the most rigorous analysis may not take all factors into account properly. Second, it is impossible to know everything about a stream and certain assumptions may be invalid. Third, the next-most-constraining influence on production may not be far behind the first: a large level of effort aimed at only the most important factor may produce only a very small population gain. Fourth, and perhaps most important, by actively considering several potential population constraints at once, an analyst is much more likely to develop insights into the system he is striving to improve and into specific approaches to accomplish that end.

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8. If more than *one* target species is under consideration, compare the results of limiting factor analysis for each. Look first for areas of conflict or incompatibility and try to resolve these in the approach to enhancement. Some hard choices may have to be made here. It may be that an important limiting factor for one target species is the presence, enhanced *or* otherwise, of the other one. Next look for areas where solutions to population constraints can be complementary. *Even* if different habitat elements *are* called for, a single prescription can often accomplish both ends at once. This step requires a relatively thorough knowledge of enhancement technology, how and why certain enhancement measures so what they do (both physically and biologically) and the reasons for past successes and failures.

At this point, the limiting factor analysis is relatively complete. It is now up to the enhancement practitioner to use his knowledge of enhancement technology and design in approach which will meet the needs of the target species. At all times during the planning process, however, it is important to continually challenge the assumptions in the limiting factor analysis and make adjustments whenever appropriate. If an evaluation program is to be part of the enhancement project, it is also important to design both the enhancement project and the evaluation effort to specifically test assumptions used in the limiting factor analysis, especially those made in lieu of hard data.

Evaluating Effectiveness of Stream Enhancement Projects

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Abstract

The need for improving stream habitats for salmonids has been recognized by resource agencies since the 1930s, and more recently through legislation passed by Congress. Successful evaluation of habitat enhancement is still difficult because planners often lack adequate biological knowledge of the habitat needs of salmonids, fail to put enhanced habitats in perspective with total salmonied production within stream subbasins, and lack economic knowledge of the value of salmonid fisheries Biological benefit6 must be put in a seasonal perspective within an entire stream subbasin to be meaningful, and marginal economic values associated with incremental increases in fish production must be used for, predicting economic benefits. When these components of the evaluations have been properly defined, a realistic analysis of benefits and costs can be made by use of existing procedures.

Introduction

Managers of aquatic habitat must be concerned simultaneously with protection, rehabilitation, and enhancement of aquatic resources. Fishery manager6 should strongly emphasize protect ion of existing aquatic habitat in the face of current intense competition for resources produced by public and private lands. There is ample opportunity for improvement of degraded habitats, but improvement is difficult and expensive; hence, the need for emphasizing protection rather than rehabilitation or enhancement. Jf managers are doing everything possible to protect aquatic resources, there is still a need for habitat improvement, especially salmonid habitat in streams.

Public agencies such as the USDA Forest Service have recognized the need for stream improvement for more than hal f a century. Stream improvement efforts by the Forest Service began in the 1930s with the stated intent of increasing production of salmonids in streams (Silcox 1936, Tarzwell 1938). Suggested projects included a variety of instream habitat structures. The habitat improvements actually made during those early years, however, were often of dubious value. Project planners generally lacked: (1) the biological knowledge necessary to identify factors limiting production of salmonids in streams, (2) the hydraulic engineering skillss needed to design structures that would accomplish enhancement objectives and survive the annual flow variations of western streams for several years, and (3) the biological and economic knowledge needed to place the costs of such projects in perspective with their economic benefits.

Degradation of natural habitats in salmonid streams of the west occurred at an alarming rate from the 1930s through the 1960s as rivers were dammed to produce hydropower, and management of forest, range, and agricultural land6 increased in intensity. Accumulated habitat losses and declining fisheries created an urgent need for rehabilitation and enhancement of stream habitats. The need to restore lost and damaged fish habitats was recognized by Congress with several important pieces of legislation during the past decade. Some of the legislation pertains specifically to the National Forests (e.g., P.L. 93-452; P.L. 94-588), whereas other laws (P.L. 96-501, for example) deal with problem6 of specific river basins, such as the Columbia Basin. The cumulative effect of these laws has been a steady increase in funding for restoration and enhancement of salmonid habitats during the past decade.

Although opportunities for habitat improvement have increased markedly, some of the problems that thwarted successful habitat work in the 1930s have not been fully resolved. Advance6 have been made in every area related to habitat improvement, but identification of limiting factors, design of instream structures, and analysis of project benefit6 are still problem areas.

Evaluation of cost-effectiveness can be the most difficult aspect of habitat improvement since the analysis depends on accurate definition of costs and of biological and economic benefits. Costs can be determined with relative ease and biological benefits can be assessed with some difficulty, but economic benefits associated with incremental increases in fish populations have proved difficult indeed to quantify.

It is the purpose of this paper to describe the kinds of planning, information, and technique6 required for effective analyses of benefits and costs of stream improvements and to identify some of the current limitations in these types of analyses.

Planning Habitat Improvements

Planning habitat improvement projects is a complicated generally underfunded process consequently , it is often given superficial treatment. Part of the problem is that habitat improvement funds are of ten designated for specific projects, and use of the funds for planning and evaluation is disallowed. Careful planning is essential, however, if a cost-effective program is to be developed. When managers desire to increase the population of salmonids in a stream, a broad-based analytical planning procedure is required to increase the odds of success. An essential first step in the procedure is identifying the desired product; for example, catchable rainbow trout, or steelhead smolts. Second, a manager must decide how much to increase the product in a given stream, or how much funding to commit to such a project. Once these goals are established, planning the habitat improvements needed to produce the desired product can begin.

The importance of identifying 'the correct product of habitat improvement (smolts when dealing with anadromous fish) cannot be overstated. An error here is fatal to correct assessment of project benefits and make6 benefit-cost analysis impossible. Most evaluations have failed in this critical area. For example , when projects are designed to enhance spawning habitat for anadromou6 salmonids, the temptation is to evaluate project success by the number of adult salmonids using the improved habitat. But, increased use of improved habitat often means decreased use on adjacent unimproved habitat; that is, a redistribution of spawning adults rather than an increase in total numbers. The real question is, what increase in smolts- from the subbasin can be attributed to production from the enhanced spawning habitat? The same problems hold true for enhanced rearing habitats. Evaluation usually focuses on the number of juvenile salmonids using the improved areas during the summer low-flow period. The assumption is that a given percentage of the increased number will survive the winter to smolt the next spring. Again, the real question is, what increase in smolts from the subbasin is actually attributable to the project? Only when the correct product6 of habitat improvement have been identified can project planning proceed to the next level.

A primary step in the planning process is identification of factors limiting production of the desired product. For the purpose of this paper the discussion will be restricted to identification of limiting factors in streams. Determining limiting factors is not an easy task. Consider that a given stream often produces three or more species of salmonids, and that each species has different habitat needs for different age classes and life history stages. Each age or life stage has different habitat needs during the day and night, during summer and winter, for spawning and migration, and for water quality and quantity. A matrix can be set up as in Table 1 to examine this complex of species needs within a given stream. Examination of Table 1 reveals a somewhat overwhelming number of factors (73) that could be limiting fish production in a stream containing steelhead (Salmo airdneri) and cutthroat trout (S. clarki) and coho (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha). Some categories could be further subdivided, and this would increase the potential number of limiting factors. Focusing on the structural aspects of rearing, spawning, and migration habitat, there are at least 38 potential limiting factors to consider. The point is that it requires a thorough understanding of the habitat requirements of the various life history stages of a species and a thorough knowledge of the habitat characteristics of the stream where habitat work is proposed before a well-conceived habitat project can be developed.

The problem of accurately identifying Limiting factors is compounded when we realize how little is known about some aspects of the habitat requirements of most salmonids. For example , Little is known about the winter habitat needs of most species, but lack of suitable winter habitat could limit production in any stream. Habitat needs of salmonids at night have been given scant attention, but work by Edmundson et al. (1968) revealed large shifts in locations occupied by juvenile steelhead trout and chinook salmon during day and night. Personal diving observations have shown that young steelhead move to the

Table 1. Potential factors limiting fish production in a hypothetical stream containing steelhead trout, cutthroat trout, coho salmon, and fall chinook salmon.

Species & life stage	Potential limiting factors							
	Water		Rearing habitat				Spawning habitat	Migration access
				Summer				
	Quality	Quantity	Food	Day	Right	Winter		
Steel-head								
Age 0	x		x	x	x	x		
Age I	x		x	x	x	x		
Age II	x		x	x	x	x		
Adult	x							
Cut-throat								
Age 0	x	x	x	x	x	x		
Age I	x	x	x	x	x	x		
Age II	x	x	x	x	x	x		x
Adult	x	x						x
Coho								
Age 0	x	x	x	x	x	x		
Age I	x	x	x	x	x	x		
Adult	x	x					x	
Chinook								
Age 0	x	x	x	x	x			x
Adult	x	x					x	x
	13	13	9	9	9	8	4	8
					73			
						38		

stream margins at night seeking interstitial spaces in quiet water. In one area of the Locha River in Idaho where suitable interstitial habitat was lacking, juvenile steelhead crowded into crayfish holes and discarded beverage cans at night. Because knowledge of winter or night habitat requirements is limited, it is difficult to know when, or if, these factors are Limiting production of salmonids.

Given that some aspects of the habitat requirements of most salmonids are unknown, can managers proceed 'with habitat improvement programs and still have a reasonable probability of success? In many cases the answer is yes Limiting factors might be obvious in cases where streams have been severely damaged by channelization or poorly controlled land management practices. In such cases restoration of habitat diversity and an increase in habitat complexity would probably be the best first step in improving fish production. Barriers that limit upstream access of anafromous salmonids, or streams almost totally devoid of spawning habitat, also are examples of easily identified Limiting factors.

Whether limiting factor6 are obvious or nebulous, habitat inventories can help to identify them. Potential limiting factors can be studied and systematically eliminated with good inventory information. If a manager know6 the amount of spawning and rearing habitat in a stream subbasin, an analysis can determine which might be Limiting a given fish population (Table 2). In this example from Fish Creek, the present spawning area can accommodate enough adults to fully seed available rearing habitat. Such an analysis is based on quantitative knowledge of available spawning and rearing habitat and published data on the spatial needs of spawning adults and rearing juveniles. Most published data on the needs of rearing juveniles

Table 2. Relationship between spawning and rearing habitat for steelhead in Fish Creek, Clackamas Basin, Oregon. Rearing habitat appears to be Limiting production of smolts.

Parameter	Number6
Spawning area required/pair	4.4 m^2
Spawning area in system	1348 m^2
♀s accommodated without redd superimposition	300
Eggs from 300 ♀'s (2,000/♀)	600,000
Emergent fry (30% survival)	198,000
Parr (20% survivaL/yr)	39,600
Smolts (50% survival/yr)	19,800
Rearing area required/smelt	20 m^2
Rearing area in system	308,000 m^2
Smolts accommodated in system	15,400

pertain to habitat preferences in summer, so this type of analysis usually relates spawning habitat to summer rearing habitat.

If the analysis points to lack of spawning habitat there are a number of sucessful documented enhancement techniques available to managers (Reeves and Roelofs 1982, Hall and Baker 1982). If rearing habitat is in short supply managers must decide whether production is Limited by seasonal or diel factors and then manipulate the habitat accordingly.

Managers must also decide where projects should be Located in a stream basin. Much habitat work, both passage improvement for anadromous fish and modification of instream habitat, has been conducted -in small headwater streams because small streams provide easy areas within which to work. Recent research that we have done on Knowles Creek, a 58 km^2 basin in the Oregon Coast Range, however, indicated that the greatest opportunity for increased fish production did not occur in headwater streams. The most productive habitats per cubic meter volume in Knowles Creek were in headwater tributaries, but the volume of these streams was only about 5 percent of the basin total. On an absolute basis more than 80 percent of the total number of coho in the system were reared in downstream mainstem waters of the middle and lower basin. The larger downstream waters were also the most devoid of habitat diversity and complexity. The greatest opportunity for significant increases in coho production appeared to be associated with large pools in lower Knowles Creek basin. We suspect this to be generally true of other stream systems where in all probability work in small streams will potentially produce small benefit6 whereas work in larger downstream waters will potentially produce larger benefits.

At this point we need to discuss the geographic scale of enhancement planning efforts. It is possible to plan project6 at the site or reach level, but the narrow perspective obtained from such restricted planning might lead to erroneous conclusions regarding limiting factors. For example, suppose a 5 km reach of stream is dominantly boulder riffle with essentially no spawning habitat. Would spawning habitat enhancement be just if ied in such an area? The question cannot be answered without looking more broadly within the stream basin. Abundant gravels might occur above or below the reach or in adjacent tributaries. Spawning in these areas might more than seed available rearing habitat within the gravel-poor area. It is far safer to use subbasins in the 20-50 km^2 range as the minimum units for enhancement planning. Areas of this size require an intensive, extensive, and expensive inventory of fish habitats and populations for enlightened enhancement planning, but the time and money invested will maximize the probability of cost-effective projects. Managers must realize that if successful cost-effective projects are the goal, funding this level of planning is even more important than funding the proposed habitat improvements.

Sampling efforts within subbasins must be thorough enough to estimate the total area of each major habitat type (riffles, pools, side channels, etc.) within the subbasin, and the fish populations and biomass associated with each habitat type (for more detail6 see Everest and

Sedell 1984). With this information managers can determine which habitat types are most abundant, which are in short supply, which are most productive for a given species; and they can estimate what changes in fish populations would occur with increases or decreases in each habitat typel It is questionable, however, whether data collected in a single year provides adquate information for effective planning. Natural variability in fish populations can exceed 100% per year so more than one year's data is desirable.

Once limiting factors have been identified and enhancement projects selected, effect6 of the projects on other species (salmonids or nonsalmonids) , or other age classes of the same species, must be carefully examined. For example , improving riffle habitat for age 1+ steelhead might reduce rearing habitat for age 0 steelhead, or converting riffles to pools to increase production of young coho salmon might result in a corresponding decrease in production of presmolt steelhead. Because of these interactions, the consequences of proposed projects to each species of fish i.n the subbaisn must be carefully studied. When studies of benefits and costs are conducted, production losses to one species must be deducted from gains to another.

Planning Evaluation of Habitat Improvements

Evaluations of habitat improvements can be conducted at several levels of intensity. At the most basic level managers could 'choose to assess only whether anticipated changes in physical habitat resulting from a project actually occurred. At the next level managers could determine whether expected changes in fish use or populations associated with habitat changes were actually realized. Finally, for a complete evaluation managers could conduct a benefit-cost analysis to determine if the project was cost-effective over its lifespan.

Efficient evaluations of habitat improvements follow naturally from well-planned enhancement projects. Comprehensive enhancement planning will mean that fish and habitat characteristics in the subbasin are already known and that any changes in habitat and fish populations resulting from projects can be put in perspective with pre-project conditions. Additional sampling will of course be required at specified time intervals in the future to document changes in habitat and fish populations. in some cases additional seeding through increased escapement might be necessary to achieve a full response to habitat changes.

Benefit-Cost Analysis

The first step in benefit-cost analysis is determining the costs of a proposed project. This is relatively easy since the costs of Labor, equipment , wood, concrete, steel, and other components are readily available. Unforeseen construction problems, however, can cause additional costs for construction. Actual costs must always be substituted for estimated costs in revised benefit-cost equations.

The next step is assessing project benef! ts. Based on information obtained during project planning, managers should be able to predict with some degree of accuracy what changes in habitat and fish populations will result from a project. Initial benefit-cost estimates are usually based on such predictions.

When good inventory information has been collected from the basin, such predictions can be accurate. For example, construction of 18 boulder berms on Fish Creek in the upper clackamas River basin of Oregon in 1983 eliminated about 5800 m^2 of riffle habitat while creating about 5900 m^2 of pool habitat (Everest and Sedell 1984). Based on fish population surveys in the basin, habitat change6 resulting from the berms were predicted to produce a modest net gain of 310 age l+ steelhead trout (about 155 smolts)--a loss of 865 age l+ trout in inundated riffles and a gain of 1175 age l+ trout in newly created pools (Sedell et al., in press). A resurvey of the berm6 in 1984 placed estimates of the actual net gain at 383 age l+ steelhead--very close to the original prediction. This estimate will likely change as the pools begin to fill with gravel and the project experiences some large winter discharges. In many cases the benefits and costs will not be known until after such discharge events. If all the berm pools filled with gravel there would be a net loss of age l+ steelhead rearing habitat but an increase in spawning habitat, and benefit6 would have to be adjusted accordingly. The payoff from a project may come Later or may be greatly reduced because of flood or wind events in a basin. Accurate prediction6 of increased fish production based an existing data, followed by sampling to document actual changes, should be standard procedure for benefit-cost analyses. Too often benefit-cost ratios are based only on optimistic predictions of change6 in fish production, with no subsequent verification.

How can the benefits of increased fish production be estimated? The following discussion is based on Everest and Talhelm (1982). Because benefits are measured by the willingness of people to pay for the change, the effects of each project on anglers, commercial fishers, and other6 must be estimated. Ideally, commercial f ishing benefit6 attributable to a project would be estimated by the resulting increase in commercial fishing revenue6 (landed value) minus the resulting increase in commercial fishing costs. Because precise estimates of these revenues, and particularly these costs, are usually not available, average revenues and costs may be substituted. These figures are generally available for major commercial species, and average values probably differ little in the long run from values attributable to the project. If the increase in production is great enough to lower prices, the effects on consumers and producer6 must be considered. Producer6 benefit because they harvest more fish with the same effort, and consumers benefit from lower prices at the partial expenses of producers. The net benefit may be approximated by multiplying the change in price by the average of total production before the change and total production after the change. Detailed econometric studies would be needed to estimate the benefit6 more precisely.

Accurate estimates of angling values in the United States are now possible but expensive, requiring highly sophisticated econometric studies of angler travel and expenditure patterns or of angler's responses to questions about hypothetical situations. An important caution is necessary here. Unless the study is specific to the project site or a similar site, the project values will probably differ from the estimated values. Project values can vary that much, even within a restricted geographic area. In fact, by far most econometric studies of angling values estimate the values of choices that drastically differ from any of the choices usually considered by improvement planners. Typically the studies estimate the all-or-none value of the fishery investigated-- the willingness of anglers to pay to have the present fishery rather than not have it. This is an extreme value, and it is generally higher than most project values because improvement projects generally represent relatively minor changes in the overall fishery. Economists estimate all-or-none values because they are academically interesting and because they represent a clearly identifiable social choice, even if it has practically no direct significance to the projects. More detailed explanations of principles and procedures are available in Clawson and Knetsch (1966), Gregory (1972), Talhelm (1973), Dwyer et al. (1977), and Freeman (1979).

This leaves managers with little information on which to estimate project benefits. Even the current values from the Forest anh Rangeland Renewable Resources Planning Act used by the Forest Service are based on estimates of all-or-none values. One good source of economic information that habitat improvement planners can use for anadromous salmonids in the Columbia Basin is Meyer 1982. Some of Meyer's recommended values might be cautiously applied over a wider geographic area of the west.

Once costs and benefits have been -estimated, managers can proceed with a benefit-cost analysis. Costs and benefits anticipated during the effective life of the project (often considered to be 20 years although longer or shorter lifespans might be justified) may be listed in a table and discounted back to a common time, usually the year of construction. Discounting is necessary because a dollar today is worth more than the prospect of a dollar at some future date, and discounting determines the present worth of costs and benefits that are incurred or realized in the future. The present worth (discounted value) of a cost incurred in the future is calculated by use of the single-payment, present-worth factor by the formula:

$$P = S \frac{1}{(1 + i)^n}$$

where: P = worth of the sum S, n years in the future at interest rate i. For example, the present worth of a $500 benefit expected 2 years in the future at 7% interest equals:

$$P = 500 \frac{1}{(1 + 0.07)^2} = \$437.$$

A planner should use this standard method of discounting and the appropriate current interest rate and project lifespan to estimate present worth of project costs and benefits.

A benefit-cost ratio is derived by dividing discounted benefits by discounted costs. If the ratio is greater than 1, the project is economically sound. For a more detailed discussion of benefit/cost analysis and an example from an actual project see Everest and Talhelm (1982).

Additional benefit-cost calculations on each project should be made as actual increases in biological production are monitored over the life of the project. Results of such evaluation6 are valuable in planning future projects to enhance habitat and for improving precision of future benefit-cost analyses.

Conclusions

Funds for enhancement of salmonid habitats in the west are increasing at a rapid rate. More than $100 million will be spent on enhancement in the next decade. Fishery biologists will be mainly responsible for the way this large sum is spent and will be accountable to produce commensurate, tangible, readily identifiable benefits. The credibility of the fisheries profession and availability of future funding for habitat improvement will depend on the success of habitat work completed within the next few years.

Much of the habitat improvement work in progress currently suffers from lack of adequate planning and evaluation. Fishery biologists must sharpen their skills and apply adequate funding to these activities if habitat is to be improved. Special care must be taken to identify factor6 limiting production of salmonids and to evaluate the correct products of habitat improvement.

Properly planned and executed projects can be subjected to benefit-cost analysis. Incremental increases in the value of fisheries associated with habitat improvements are difficult to determine, however, and they generally constitute the "weak link" in assessment of benefit6 and benefit-cost ratios.

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