August 1992

SUPLEMENTATION IN THE COLUMBIA BASIN Part III

Rasp Sumary Report Series Planning Guidelines

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SUPLEMENTATION IN THE COLUMBIA BASIN

Part III

Rasp Summary Report Series

Planning Guidelines

Prepared For

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NOTE ON THE USE OF THESE GUIDELINES

The planning guidelines presented in this report are not rules to be followed in every detail. Their purpose is to guide the development of supplementation plans by stimulating the manager to think about the structure and function of the ecosystem to be manipulated through artificial propagation. Hopefully this will suggest new approaches and strategies and increase the probability of success. Managers axe encouraged to adapt the forms and procedures presented here to the specific conditions of their stream/stock system. In addition to these guidelines, Chapter C of the Integrated System Plan (ISP) (CBPWA 1991) also provides helpful information for managers planning a supplementation project.

The process described in this report was developed to be consistent with the Northwest Power Planning Council's policy of adaptive management. All the detailed information called for in the guidelines does not need to be in hand before a project is implemented. The manager should do the best he/she can with the existing information. Through carefully designed monitoring and evaluation, the information gaps will be filled in and the uncertainties resolved. While adaptive management allows projects to be implemented with information gaps and uncertainty, it also means that planning and evaluation are not a one time activity. Planning becomes an iterative process. New information is used to update the plan until the uncertainties are resolved.

As new information is gained through the implementation and evaluation of supplementation, these guidelines and those contained in the ISP are expected to change.

RASP CONTRIBUTORS

Scientists with expertise and interest in supplementation have contributed to this report, among them are: Tom Backman, Ed Bowles, Craig Busack, Rich Carmichael, Duane Fickeisen, Larry Lestelle, Jim Lichatowich, Rich Lincoln, Lars Mobrand, Willa Nehlsen, Rich Turner, Tom Vogel, and Bruce Watson. Numerous constructive and insightful comments to previous drafts were also received from the Scientific Review Group.

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INTRODUCTION

The purpose of this progress report is to describe a set of guidelines to be used by managers to design supplementation projects, and by reviewers to evaluate supplementation proposals. Topics included in this document are: a brief review of supplementation in the Columbia Basin, planning guidelines comprised of eight specific steps, a discussion of risk analysis, and guidelines for the design of monitoring and evaluation: Since this is a progress report, the ideas herein will be subject to revision, particularly when supplementation research and experience produces new information.

This is the third in a series of four summary reports. Our goal is to make findings from the Regional Assessment of Supplementation Project (RASP) more accessible by grouping related topics into brief reports on important aspects of supplementation. RASP is planning or has already published the following reports under the general title Supplementation in the Columbia River Basin: Part I, Background, Description, Performance Measures, Uncertainty and Theory (completed); Part II, Theoretical Framework and Models (in preparation); Part III, Planning Guidelines; and Part IV, Regional Coordination of Research and Monitoring.

Supplementation is a major element of the program to increase salmon and steelhead production in the Columbia Basin. The Fish and Wildlife Program of the Northwest Power Planning Council (NPPC) uses three approaches to protect and enhance salmon and steelhead in the Columbia Basin: 1) improve fish production; 3) improve passage in the mainstem; and 3) improve harvest management to support the rebuilding of fish runs (NPPC 1987). The fish production segment calls for a three-part approach: natural production, hatchery production and supplementation. The ISP (CBFWA 1991) indicates that the fish management agencies and tribes expect supplement&on to provide over half of the total production increases (Table 1).

Table 1. Percent of total production increases attributable to supplementation in the ISP. Computed from System Planning Model output[a] (Duane Anderson, NPPC, personal communication).

SPECIES/STOCK	COLUMBIA RIVER REGION LOWER	MID	SNAKE	UPPER	ALL
LATE COHO	97.7%	-	-	-	97.7%
EARLY COHO	100.0%	100.0%	-	-	100.0%
FALL CHINOOK	0.0%	37.4%	51.2%	0.0%	8.6%
SPRING CHINOOK	88.4%	64.0%	74.3%	34.7%	65.4%
SUMMER CHINOOK	-	6.3%	66.0%	38.496	43.5%
SUMMER STEELHEAD A	100.0%	25.6%	95.5%	73.9%	71.8%
SUMMER STEELHEAD B	-	-	72.0%	-	72.0%
WINTER STEELHEAD	48.0%	100.0%	-	-	60.2%
ALL	45.4%	47.5%	78.2%	34.5%	52.4%

[a]The Integrated System Plan addressed other stocks that were not modelled and are not included in Table 1.

In August 1990, the NPPC gave conditional approval to proceed with the final design phase of the Yakima and Klickitat Production Project. The Council called on the Bonneville Power Administration (BPA) to "fund immediately a supplementation assessment to reevaluate, prioritize and coordinate all existing and planned supplementation monitoring and evaluation activities in the basin... Provid[ing] for the participation of the fishery agencies and tribes and others having expertise in this area." RASP was initiated as a result of that request by the NPPC. Coordination of supplementation research was also recommended by the Supplementation Technical Work Group.

RASP addresses four principal objectives:

- provide an overview of ongoing and planned supplementation activities and identify critical uncertainties associated with Supplementation
- construct a conceptual framework and spreadsheet model which estimates the potential benefits and risks of supplementation and ranks the importance of uncertainties based on their projected effects on the risks and benefits of a project
- provide guidelines for the development of supplementation projects
- develop a plan for regional coordination of research and monitoring.

RASP has further divided the four broad objectives into technical topics:

- defmilion of supplementation
- description of the diversity of supplementation projects
- objectives and performance standards
- identification of uncertainties
- supplementation theory
- development of a conceptual model of supplemented populations
- development of a spreadsheet model of risks and benefits of supplementation
- classification of stocks, streams, and supplementation strategies
- regional design of supplementation evaluation and, monitoring
- guidelines for planning supplementation projects
- application of the spreadsheet model to supplementation planning
- experimental design and decision making with uncertainty.

Progress in each topic area has been presented in regular progress reports which are available from the Bonneville Power Administration.

BACKGROUND

This section defines supplementation and gives an overview of uncertainties related to supplementation, theoretical considerations, and relevant policies and statutes.

Definition

RASP's working definition of supplementation is: *Supplementation is the use of artificial propagation in an attempt to maintain or increase natural production while maintaining the long term fitness of the target population, and keeping the ecological and genetic impacts on nontarget populations within specified biological limits.*

The purpose of supplementation is to increase or maintain natural production[1] and that objective must be achieved without a loss of long term fitness in the target population. Each supplementation project must hold the genetic and ecological impacts on nontarget populations to specified limits. Supplementation is clearly a departure from conventional hatchery programs and it reflects, a changing management, paradigm (for a historical perspective on the change see Part I of this series).

Supplementation presents managers with a new challenge: to integrate natural and artificial production systems in the Columbia Basin in a way that yields sustainable increases in total and natural production. This will call for new ideas in the physical design and operation of hatcheries as well as a better technical understanding of genetics, behavior, competition and predation — fields that were not strongly emphasized in the domain of artificial propagation until recently.

Supplementation Uncertainties

Supplementation as defined above is a nascent management strategy (CBFWA 1991). Since we have only limited management experience and research results, supplementation must be implemented with substantial uncertainty. An important purpose of planning is to identify and manage the critical uncertainties — those. uncertainties for which the choice of assumption in the supplementation plan can determine success or failure of the project.

[1] Natural production - production resulting from naturally produced progeny that have spent their entire life in their natural habitat.

Supplementation uncertainties are a product of three factors: 1) ecological factors that determine productivity in the stream ecosystem, or our perception of them, 2) supplementation strategies, and 3) objectives of the project. The presence of uncertainty automatically presents the manager with risk — risk of failure, risk of unintended impacts (genetic or ecological), and risk of future surprise outcomes. Uncertainty and risk are inseparable elements in fisheries programs. Where you find one you will always find the other (Figure 1).

Risk can be estimated and assessed through models that substitute assumptions for the critical uncertainties or by listing the uncertainties and reviewing the relevant literature. The critical uncertainties must be "managed" to reduce or contain the risks of project failure. One step to reduce risk to acceptable levels is to monitor the appropriate parameters in a way that gives early warning of a problem. RASP calls this "risk containment monitoring." Research carried out within an adaptive management framework is an additional way to manage uncertainties and reduce risk. (For a detailed discussion of uncertainties see Part I of this series of reports.)

Supplementation Theory

The expectation that we can increase natural production by adding artificially propagated fish to natural habitats is based on our understanding of the artificial and natural production systems. Realizing the expected increases in production depends on how well the artificial and natural systems are integrated. Supplementation theory is an attempt to generalize our understanding of natural and artificial production and to establish guidelines for integrating the two.

Supplementation theory rests on three concepts: 1) capacity – each stream/stock system has a capacity to produce salmon and steelhead determined by the interaction of abiotic and biotic factors operating throughthe stock's life history, 2) performance – performance of a stream/stock is that part of the capacity realized in any given time interval, and 3) stock-~ – there is a relationship between the quality and quantity of a spawning population and recruitment of the adult progeny. The elements of a supplementation theory are discussed in more detail in Parts I and II of this series.

For planning purposes, the concepts of capacity and performance and stock-recruitment models are embedded in a broader "clinical" model of the target stream and stock. The basic elements of the "clinical" model are: template – the healthy stream/stock system, patient – the current condition of the stream/stock system in need of restoration, diagnosis – the comparison of template and patient that leads to

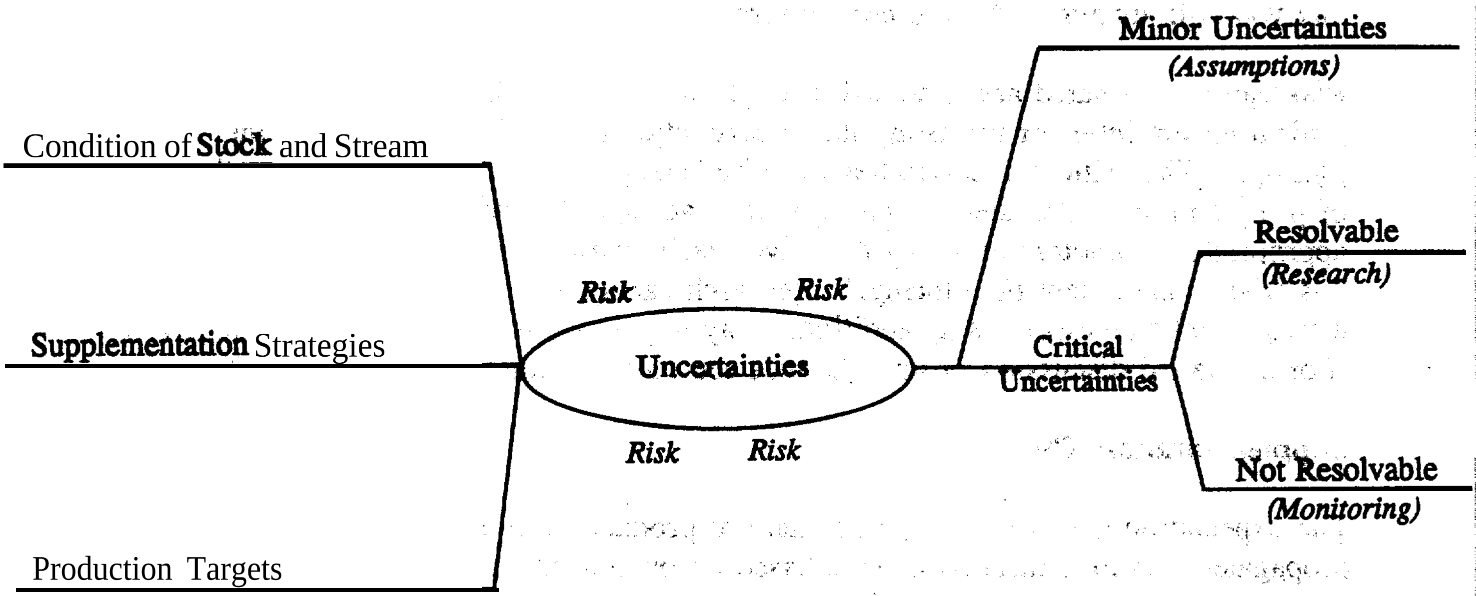


Figure 1. Schematic representation of the origin and treatment of supplementation uncertainties.

identification of limiting factors, and treatment -- the specific strategies to remove or circumvent the limiting factors.

Policies and Statutes

In addition to the guidelines given in this report, the manager planning a supplementation project must take into account appropriate state, federal and tribal policies and statutes and the policy guidelines in the Council's Fish and Wildlife Plan (NPPC 1987). For example, see Oregon's Natural Production and Wild Fish Management Rules (Oregon Administrative Rules 635-07-501 through 529 and 635-07-800 through 815) and Idaho's Anadromous Fishery Management Plan (Idaho Department of Fish and Game 1991). An Environmental Impact Statement under the National Environmental Policy Act of 1971 might be required for supplementation projects.

A manager planning a supplementation project should coordinate his/her proposed activities with other management activities in the subbasin an&in proximate subbasins.

PLANNING GUIDELINES

Detailed planning guidelines recommended by RASP are presented in this section.

Rationale and Approach

The planning guidelines are comprised of 9 steps (Figure 2) which are described within the context of a clinical model. In the first step goals are established,. steps 2 to 4 are fact-finding and descriptive; steps. 6 and 7 involve, analysis of risks and benefits, and in steps 8 and 9 an evaluation is conducted The steps are:

1. Identify Management Objectives. The objectives describe the desired future condition of the stream/stock system (expected benefits).
2. Describe Template. The template describes the healthy stream/stock system.
3. Describe Patient. The patient describes the current condition of the stream/stock system.
4. Make Diagnosis. The diagnosis identifies limiting factors that prevent the patient from reaching the objective;

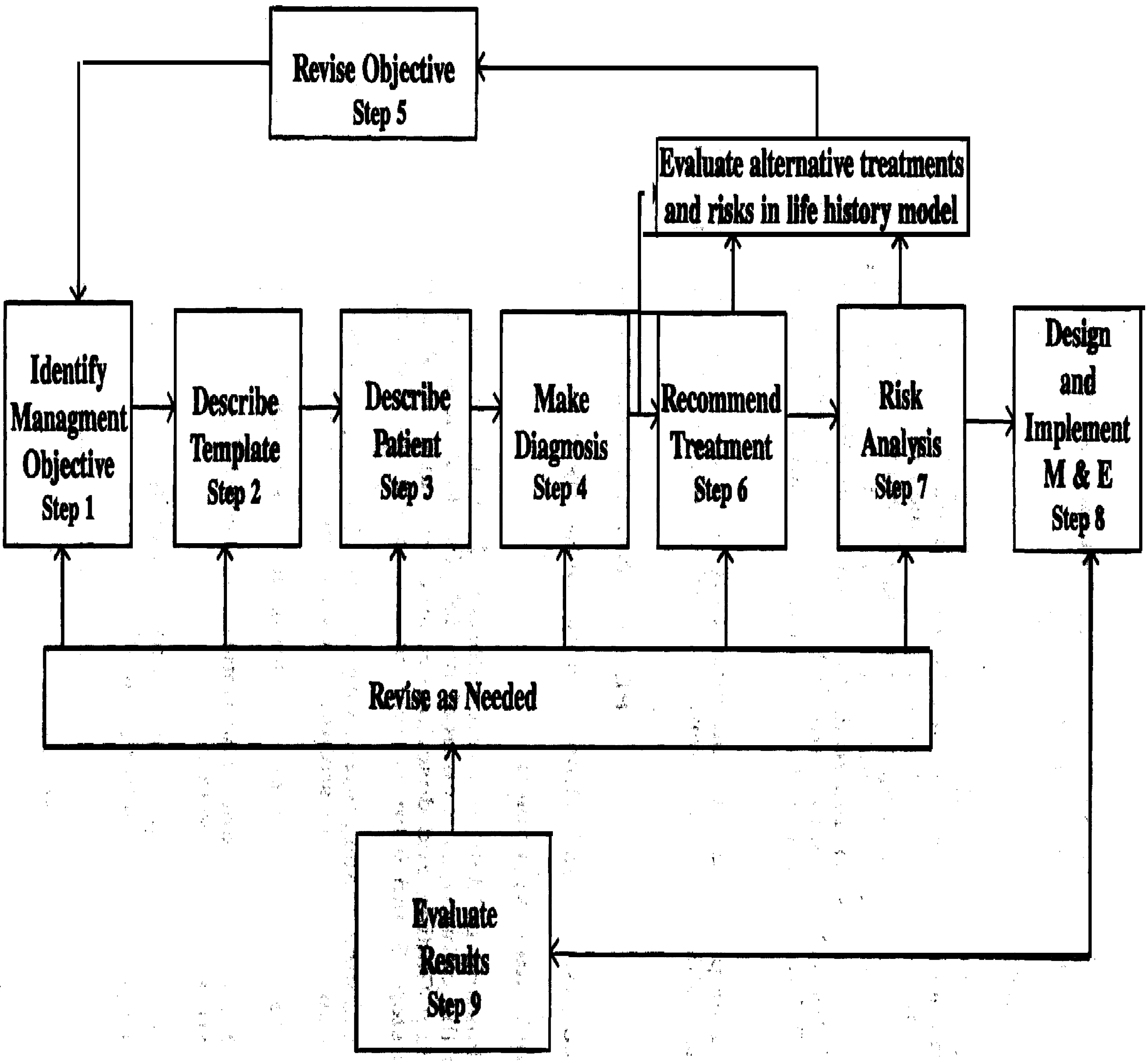


Figure 2. A Sequence of Planning Steps for Supplementation Projects.

5. Revise Objective. At this point the original objective should be reviewed and revised if appropriate.

6. Recommend Treatment. The treatment describes the supplementation strategies expected to realize the benefits set forth in the objective.

7. Risk Analysis. Risk analysis describes the uncertainties associated with the recommended treatments.

8. Design and Implement Monitoring and Evaluation. Monitoring and evaluation (M&B) presents general guidelines for the design of M&E.

9. Evaluate Results. The results are evaluated as the project plan is implemented and the plan is revised as needed.

Chapter C of the ISP (CBPWA 1991) discusses several topics relevant to supplementation planning. Those topics are in general agreement with the RASP guidelines. However, the ISP gives greater emphasis to implementation (description of supplementation technology and treatment guidelines). In another report that emphasized genetic conservation, Kapuscinski et al. (1991) listed five steps in the development of a supplementation plan:

1. State the goal of the proposed supplementation.

2. Define the current status of the populations targeted for supplementation and those that are inadvertently affected.

3. Determine the feasibility of improving the status of the targeted population, while not negatively impacting adjacent populations, and considering problems imposed by passage around dams, habitat loss, and fishery harvest (Riggs 1990, appendix VII).

4. Identify options available for each step in propagation.

5. Evaluate genetic risks associated with each option for a given step in propagation, based on an understanding of genetic processes involved.

These steps are also in general agreement with the eight steps in the RASP planning guidelines.

Supplementation is the attempt to increase natural production in a stream/stock system whose performance is consistently below capacity and where the ecological processes that determine the yield of salmon are still largely functioning or are repairable. Supplementation might be used to increase natural production in a system where a. production bottleneck created by a natural or a man-made disturbance has been removed. In that case, the natural rate of recovery is accelerated through the use of appropriate supplementation strategies. Depressed natural production might be increased through supplementation if a major cause of the decline is an artificial source of density-independent or depensatory mortality (mainstem passage, for example). In addition, a population depleted by over-harvest might be unable to recover naturally even if harvest is reduced if the population has been forced into a stable equilibrium at a lower density. This condition might result from competition or predation following a shift in species dominance brought on by the original depletion. Peterman (1977) described the theoretical basis for multiple stability regions in salmon production functions. Supplementation might be needed to build up numbers of the target population so it can "break out" of the lower stability region and reestablish a higher stable equilibrium. The restoration of extirpated stocks is another purpose of supplementation.

Successful ecological restoration is the acid teat of our understanding: of how. the elements of an ecosystem function (Bradshaw 1990). Restoration, measured as an increase in natural production and accomplished through the use of supplementation, is a test of our understanding of the relationships among the life history of the target stock, its habitat, and artificial propagation. This understand@ is developed and demonstrated through the completion of steps 2 - 6 in the planning process (template, patient, diagnosis, revise objectives, and treatment). The. guidelines proposed by RASP ask the manager planning a supplementation project to first look back in time at the stream/stock system before degradation occurred and then to describe how the original system functioned. This is an essential step because it focuses attention on ecological relationships early in the planning process.

When using supplementation as a management tool, the manager should avoid the traditional approach of focusing exclusively on production numbers — hatchery sizing, feed programming, release targets, and contribution goals, A focus on rebuilding numbers while ignoring the restoration of habitat and life history diversity and important ecological relationships will not yield sustainable results. Restoration must attempt to set things straight rather than preserve what we have disturbed (Vrijenhoek 1989). Accordingly, RASP has emphasized the relationship between habitat and life histories and the comparative analysis of the historic and current status of those , relationships.

Stocks, as defined by Ricker (1972), are the basic management units upon which the conservation of the species depends (Rich 1938). It is the diversity contained within and between stocks that must be conserved if the fisheries arc to be managed sustainably in the face of natural and manmade changes in the environment. When defining the boundaries around stocks the manager must take into account the tradeoff between the risk of a loss of diversity within and between stocks — the types 2 and 3 genetic risks of Busack (1990). Drawing a widegeographic circle around a stock could precipitate management activities that reduces between-stock diversity if the circle inadvertently included more that one distinct stock. Conversely, a small circle might exclude a legitimate part of a stock and contribute to loss of within-stock diversity.

The planning guidelines presuppose that the physical boundary of the target population has been &fined and its genetic characterization completed, The process of setting stock boundaries is currently the subject of a debate, however, it is a debate that cannot be resolved with our present level of knowledge. The type of stock designation (broad or narrow) effects treatment options, risk assessment and risk management in a supplementation project. For example, a narrow stock designation manages risk by restricting treatment strategies. A broader stock designation allows greater management flexibility, but it requires extensive monitoring and evaluation to manage risks.

Establish Supplementation Expectations

This section describes-steps 1 - 6 of the recommended planning process in detail. These steps help establish expectations for supplementation and lead to development of a proposed approach for the supplementation project.

Identify Existing Management Objectives (Step 1)

Every major subbasin in the Columbia River has at least generalized objectives contained in statewide management plans (for example, see Oregon's Species Management Plans and Idaho's Anadromous Fishery Management Plan). In addition, management objectives for specific subbasins are found in subbasin planning documents,hatchery master plans, and in individual regional, district or tribal planning document% Management objectives might be inferred from harvest regulations, stocking programs, and agency comments on forest practice applications, environmental impact statements, and proposed water quality and land use regulations.

since all of these sources shape management objectives, they should be reviewed and incorporated into the initial description ofobjectives.

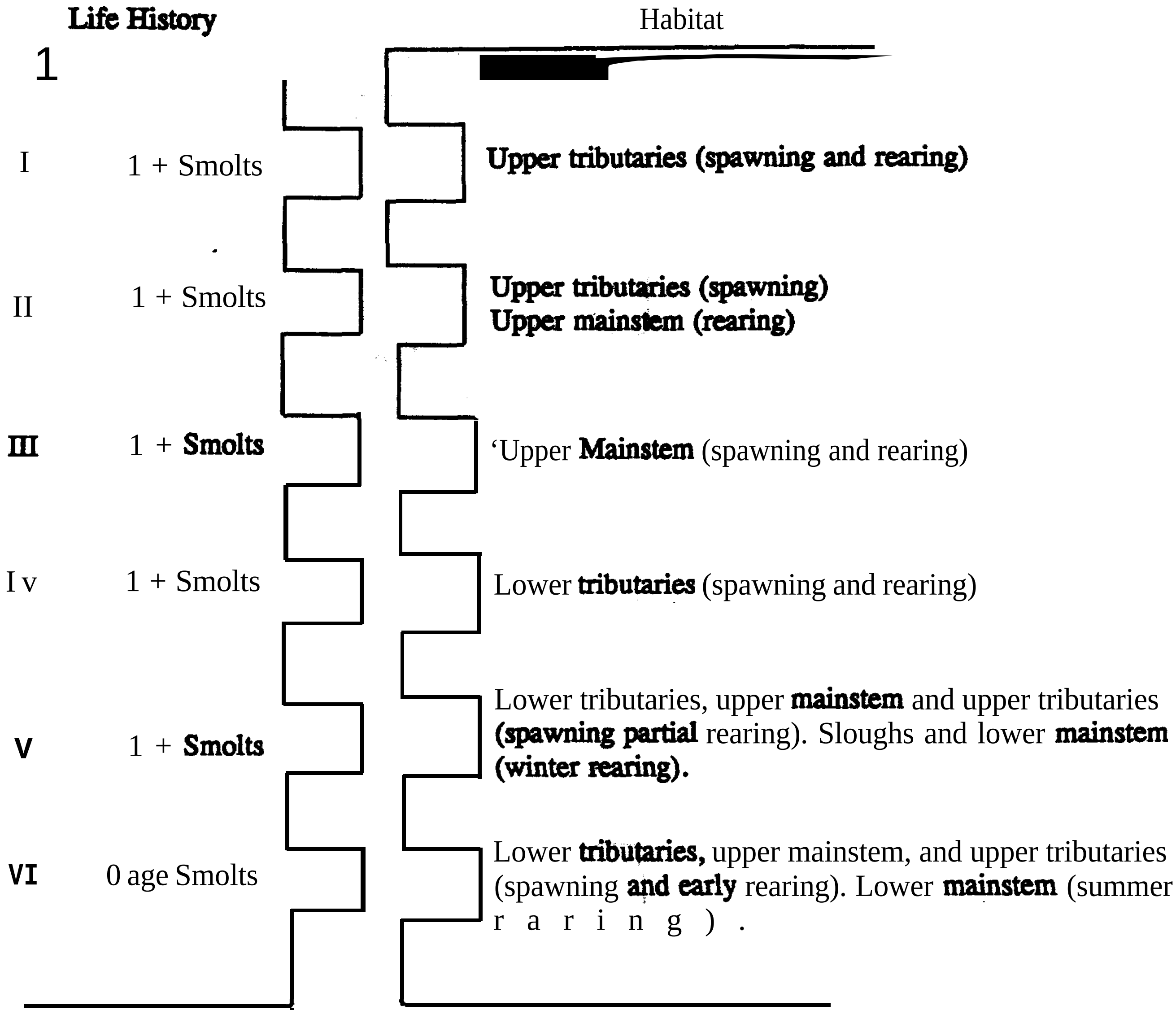
Describe the Template (Step 2)

The template analysis attempts to describe the system's historical performance through an evaluation of life history and habitat. The template is a pattern against which the present condition (patient) and proposed future condition (objective) are compared to identify limiting factors and reasonable expectations for increased natural production. The template analysis makes use of historical and contemporary information from within the stream/stock to be supplemented, and, when necessary, it uses inferences drawn from the literature on stocks outside the target subbasin. These guidelines, and the template analysis in particular, are based on the premise that the harmonious interaction between life history and habitat is an important determinant of natural production.

The template should not be confused with the objective. The template describes the historical performance of the stream/stock system and the objective describes that part of the template that management activities will attempt to restore. In few cases the template and objective will be the same, in very few cases the objective might exceed the template, although in most cases the objective will represent a part of the original performance.

The template analysis attempts to describe three elements important to the life history-habitat relationship of the target stock geography, time, and biology. The salmon's life history invokes important biological functions such as spawning, migration, feeding, and escaping predators which are carried out in a series of geographically and seasonally connected places (Thompson 1959). There are several possible approaches to the template analysis.

Figures 3, 4 and 5 show a schematic representation of the life history-habitat relationship in a stream/stock system proposed for supplementation. The figures are intended to illustrate the template/patient analysis for a typical spring chinook population from a mid-Columbia subbasin. Correspondence between habitat and life history is represented by tongues and grooves; and, in the template population, all of the habit&s and life histories are present (Figure 3). The patient illustration shows that two life history patterns and their associated habitats are missing. The remaining life history* show diminished performance (Figure 4). In this hypothetical example, the objectives of the supplementation project are to restore two life history patterns and their associated habitats (Figure 5).



Fiie 3. Hypothetical life histories and their associated habitats for a spring chinook population in a mid-Columbia subbasin. The combined **life histories** and **habitat constitute** the **template.**

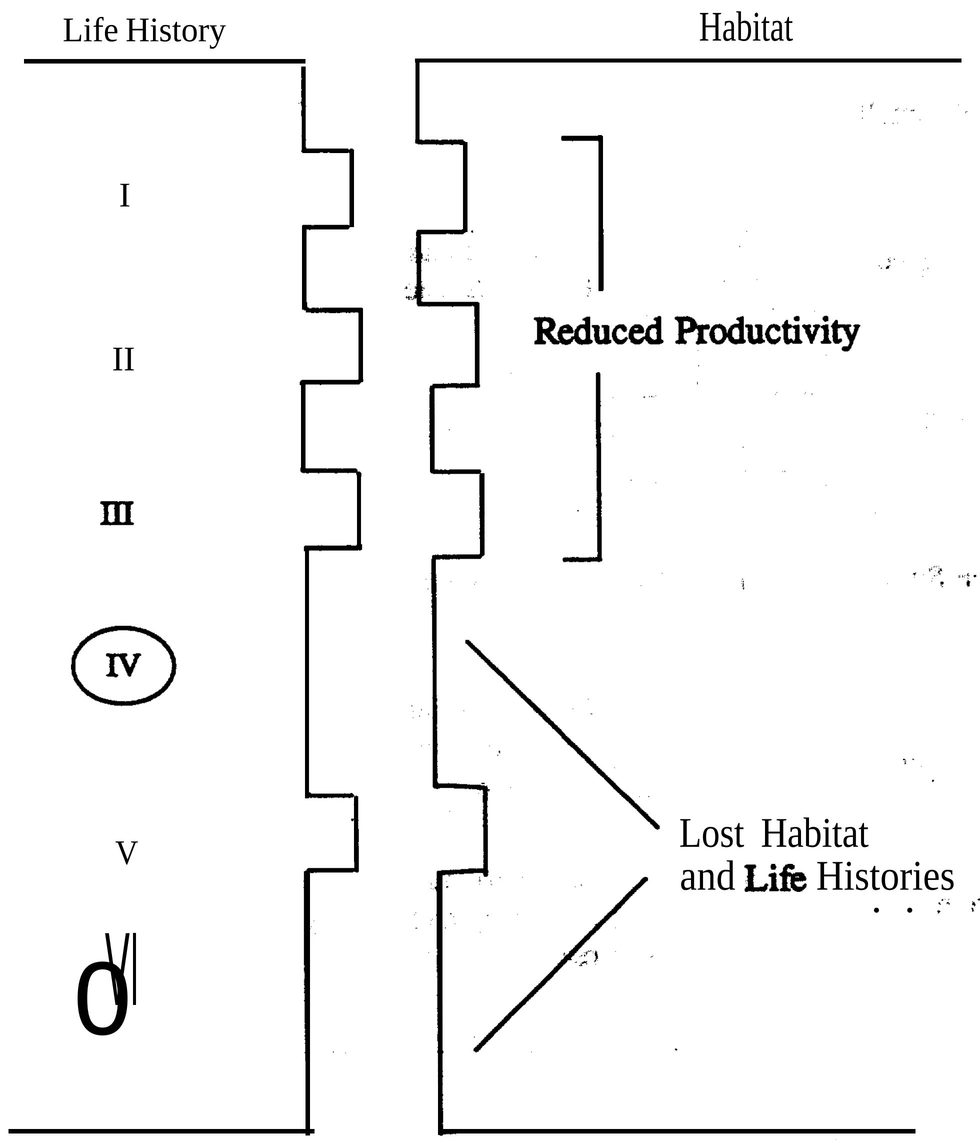


Figure 4. The patient from Figure 3 showing the current condition of the life histories and habitat of a hypothetical spring chinook population. Two life histories and their associated habitats have been lost. The remaining habitats and life histories have diminished productivity.

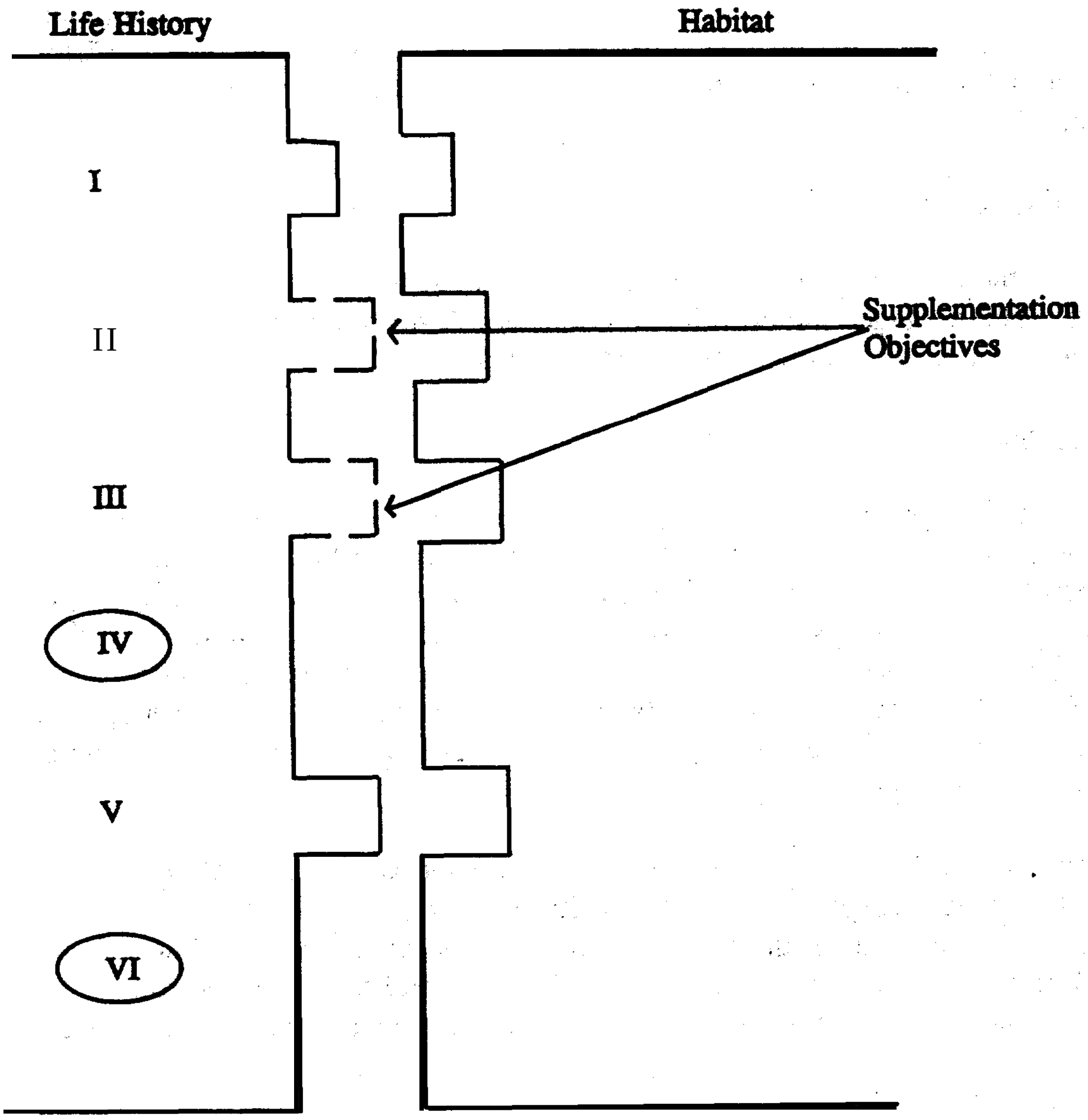


Figure 5. The patient population from Figure 4 showing the objectives of a restoration program which will employ supplementation.

Figures 3 - 5 were intentionally simplified to illustrate the concepts underlying the template/patient analysis. The actual analysis is more complicated and is based on the compilation of a substantial data base. RASP encourages the manager to adapt his/her approach to the characteristics of the specific stock/stream system to be supplemented. To assist the manager, RASP has prepared a set of tables which identify the life history and habitat information needed to complete a patient/template analysis (see Appendix A).

<u>Describe the Patient (Step 3)</u>

In this step, the existing status of the stock and habitat to be supplemented is described (Figure 4). The manager should refer to Appendix A for a description of the information needed to complete the patient description.

<u>Diagnosis (Step 4)</u>

The diagnosis is a comparison of the template and patient for the purpose of identifying the factors limiting natural production, selecting the appropriate management activity to correct or circumvent the limitation, and describing the life history-habitat relationships that management should attempt to rebuild or repair. The completed diagnosis should result in a clear problem statement — identification of that which prevents attainment of an objective. If Tables A.1 - A.3 in Appendix A were used to describe the template and patient, the questions in Table 2 will be useful in completing the diagnosis.

The questions in Table 2 are divided into three categories: those questions that describe the stream ecosystem and its capacity, questions that describe the performance (production) of the target population, and questions that describe the limiting factors. Answers to the questions in Table 2 lead to one of the four conclusions listed at the bottom of the table. The four conclusions are described below:

A recognition that there is not enough information to describe the putient sufficiently to determine appropriate enhancement measures and or management actions. **(A) Identification of the appropriate management action to increase natural production requires a minimal understanding of the Life history – habitat relationship in the stream/stock system. This is especially true where the integration of natural and hatchery production (supplementation) is being proposed. If basic information on life history, distribution and habitat quality is not available to complete the patient description, the chances of selecting strategies that will yield long-term success are**

Table 2. Diagnosis Procedure. This series of questions is intended to help diagnose the target stream/stock.

CAPACITY/ECOSYSTEM DESCRIPTION

1) Can the template/patient be described with sufficient detail to identify the factor(s) preventing the patient from achieving the objective7 if yes, continue. if no see Conclusion A.

2) Does the template/patient comparison suggest that current natural production is less than historic? if no, sea Conclusion B. If yes, continue.

3) a. Are the historic life history patterns present in the patient population?

b. Has the quality and quantity of abiotic and biodc habitat been altered?

c. is the difference between template and patient due to fishery management activities?

d. is the difference between template and patient due to factors outside the basin such as passage?

4) Describe the factors above (3a-3d) that contribute to the difference between template and patient. Proceed to the next set of questions.

PERFORMANCE OF THE TARGET POPULATION

5) a) Is the habitat fully seeded at each life history stage?

b) Are density, growth, survival, by life stage in the patient comparable to other populations reported in the literature?

c) Has the distribution of the target population within the subbasin been reduced7

d) Can the adult stock production function be described?

e) Is the population controlled by density independent or density dependent factors at each life stage?

6) Do the answers to 5a-5e suggest the potential to increase natural production? if no, see conclusion B. If yes, continue.

7) Do the answers to 5a-5e generally support the target population size contained in the objective? If no, see Conclusion C. if yes, continue.

POPULATION LIMITING FACTORS

8) a. Has the timing of life history events changed putting them out of synch with flow and temperature patterns?

b. Have flow and temperature changed in a way that is detrimental to the completion of template life history patterns?

c. Are there biotic interactions limiting production of the target population?

d. Are there full or partial migration blocks (juvenile and adult) that were not present in the template?

e. Can specific mortality factors be identified such as fine sediment in spawning gravels or improperly screened diversions?

f. Would the planting of hatchery fish create a bottleneck at a later life history stage/habitat?

g. Have fecundity, sex ratio, or reproductive success changed?

h. Are there genetic changes that might account for the differences in template and patient.

9) Are the limiting factors correctable? If yes, see Conclusion D. If no, see Conclusion C.

CONCLUSIONS

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

reduced. Under those circumstances, it may be prudent to delay supplementation until the data can be obtained.

A recognition that there is no problem, i. e. the performance of the system is at its natural production capacity.(B) The template and patient comparison might reveal that the performance of the stream/stock is comparable to historic production and it is not reasonable to assume additional capacity for natural production. In that case, any increase in total production would have to come from a well-planned conventional hatchery — a conventional hatchery that added to and did not replace natural production.. Such a program must be designed to minimize risk to the natural production system.

A recognition that the existing management objective needs revision.(C) The template/patient analysis might show that the management expectations for the target stream/stock are not consistent with its potential i.e., the target stock size in the objective is too high or too low. Assuming the manager has confidence in the analysis, the objective should be changed and the diagnosis repeated.

A recommend&ion to implement specific management activities to circumvent or correct the limitation in natural production.@) The diagnosis might lead to the conclusion that natural production can be increased through management action. The management activities might include supplementation, habitat improvement, water management, removal of barriers, harvest regulation, or some combination of the above. The manager must explain how the factors limiting production will be corrected by the chosen management activity. Supplementation is an appropriate strategy if the objective includes increases in natural production and the constraints on production can be circumvented through the use of artificial propagation.

The diagnosis should result in a clear problem statement and a recommendation for a management action to overcome the problem and achieve the goal. If supplementation is the management activity chosen, the objective will probably have to be revised.

Revise the Objective (Step 5)

At this point in the development of the supplementation plan, the manager should revisit the objective to determine if it is consistent with the template/patient analysis. The objective should describe what part of the template production can be reasonably obtained through supplementation. In general, management objectives are limited to numerical targets stated as the number of juveniles released from the hatchery and/or the expected number of adults in the catch and escapement. Numerical targets are importantmeasures of performance, however, RASP has identified additional performance standards that should be incorporated into supplementation objectives: post-release survival, reproductive success, long-term fitness, and ecological interactions. Once supplementation has been identified as an appropriate management activity, the objective should be reviewed and these new performance standards included.

The RASP definition of supplementation implies that the manager has some discretion when setting the criteria for post-release survival, ecological interactions,. and reproductive success. The definition also implies no discretion with regard to the goal of maintaining long-term fitness of the target stock ,

The follow& hypothetical scenario is discussed to illustrate setting quantitative objectives based on the four performance measures. The example uses codes to indicate fishes with different parental life histories:

> T_0 is the progeny of wild parents,
>
> T_1 is the progeny of one wild and one hatchery parent thatspawned naturally,
>
> T_2 is the progeny of hatchery parents, that spawned naturally,
>
> T_3 is a hatchery produced fish.

While recognizing that it may *currently* be impossible to monitor all the types described above, the concept of fish types has considerable value in planning, especially when using the RASP spreadsheet model as a planning tool. (See Part II in this report series.)

Consider an upper basin, summer steelhead pop&ion which is essentially wild (has never been supplemented) and is currently depressed. Some of the conditions that caused the initial depression have been eliminated (e.g., a tributary dam has been removed), and improvements in others (passage at mainstem dams) can be anticipated. Spawning and rearing habitat in the subbasin is excellent in quality and currently is utilized primarily by a large population of rainbow trout which supports a fishery of . some intensity.

In good years, abundance is maintained, but managers fear that three or four bad years in succession could result in critical depression or extinction. The managers' fundamental objective is to use supplementation to increase the abundance of the population rapidly and substantially, and to preserve as much as possible of the native gene pool. The managers decide, based on the template/patient analysis that-it is realistic to double spawning escapement by the third generation of supplementation:

$$(\sum N_i)_{after\ 2\ generations} = 2N_{0_{now}}$$

They. also have set the constraint that this escapement will be maintained with a terminal fishery that harvests an average of 20% of the returns; Therefore, they have set the objective that escapement *to the subbasin should* be *2.5 times the* current average. Secondarily, the managers would like to re-establish a terminal steelhead fishery, which has been closed for a number of years. The managers determine to accomplish these general objectives by sustained smolt supplementation utilizing local broodstock. In this example, the project objectives would include:

Post-release survival. Through modeling, it has been estimated that, given the number of smolts that can be produced, the objective can only be accomplished if the post-release survival (smolt -to-adult) of supplemented fish is at least 50% of the wild rate. The survival target of 50% of the wild rate becomes a part of the project's objective.

Reproductive success Model runs also indicate that targeted product& increases cannot be maintained unless egg-to-smolt survival of T_2 and T_1 fish is, respectively, 80 and 90 percent of the wild rate:

$$S_{egg/smolt,T_2} = .8S_{egg/smolt,T_0}$$

$$S_{egg/smolt,T_1} = .9S_{egg/smolt,T_0}$$

Equally necessary, on the basis of model runs, is the preservation of the pre-supplemented age distribution and mean fecundity in T_3 fish:

$$Fec_{T_3} = Fec_{T_0}$$

An additional management objective is that the "homing fidelity" of T_3 fish be at least 90% ofthewildrate, and that T_2s and T_1s home at rates equivalent to wild fish.

Those three criteria also become part of the project's objective.

Ecological interactions. The managers decide to accept a.5076 reduction in abundance of rainbow trout by the third generation, if necessary. They plan to implement acclimation and release strategies that might reduce this impact. The tradeoff between resident trout and steelhead should be specified in the objective.

Long-term fitness. Direct measures of long-term fitness are difficult if not impossible to obtain from a naturally reproducing population of salmon. Obviously, long-term fitness cannot be measured in the short term. However, measures of short-term fitness can be used to estimate long-term fitness. A reduction in long-term fitness might be measured indirectly as an unintended change in life history or demographic parameter such as migration or spawning timing, age structure, spawning distribution, or juvenile rearing patterns. Minimum viable population analysis and monitoring of the effective population size are other tools that can provide insight to long-term fitness. Additional evidence of a probable change in long-term fitness may be obtained from an analysis of biochemical genetic descriptors of the supplemented population measured over time. The specific parameters to be monitored for change must be specified in the objective before supplementation begins with sufficient lead time to obtain reliable baseline estimates.

Recommend Treatment (Step 6)

To reach. this step, the diagnosis should have indicated that supplementation alone or in combiion with another management action-such as habitat restoration is a candidate strategy to restore or increase natural production in a stream?stock system. In this step of the planning process, the manager develops and evaluates alternative supplementation strategies. The operative word is alternative. The RASP model, which- was developed as a tool for managers planning supplementation, (Figure 2) achieves its full value if it is used to compare the risks and benefits of reasonable alternativetreatmentsstrategies.

General guidelines for treatments selection. Kapuscinski et al. (1991) and Chapter C of the ISP (CBFWA 1991) discuss the selection of supplementation strategies and Reisenbichler and McIntyre (1986) give guidelines for integrating natural and artificial production of salmonids. Those reports offer imp&ant guidance for development of alternative supplementation strategies. The following discussion will draw heavily on the advice they contain.

The development of alternative treatments must consider genetic risks, habitat bottlenecks, natural life history patterns,. and the physical constraints of the hatchery facilities. Supplementation strategies are comprised of six basic elements: brood stock selection, mating protocols, escapement management, incubation and rearing practices, release variables, and project scale. In the discussion that follows, we present alternative approaches to each of these basic elements and, in some cases, recommend priorities for the alternative treatments. In specific situations the recommended priorities might be altered because of unique qualities or conditions in a stream/stock system. In those cases, the manager should justify the deviation from-the priorities given here.

Broodstock Selection When supplementation will increase natural production in an existing population, the best way to insure long-term fitness in the target stock is to select brood fish that are similar in genetic resources, life history, and originating environments (ecological similarity). Each of the three similarity factors is discussed below:,

Genetic Similarity. Analysis of the genetic structure of the donor and target population should be completed to determine if the stocks are phylogenetically similar. The manager should consult with a geneticist to obtain help in determining genetic similarity. Distance from the target stream may be used as a surrogate for genetic similarity if the habitats in the donor and target stream are similar. However, even streams that are close may support genetically different stocks. For example, Wade (1986) reported reduced resistance to the parasite *Ceratomyxa shasta* in the native stock the Nehalem River, Oregon. He attributed the change in resistance to the planting of nonresistant fish from the nearby Trask stock. It's important to avoid mixing ancestrally divergent populations even if they are in close proximity.

Life History Similarity. Comparable life history patterns between the donor and patient stock might reflect genetic similarity and also afford the best opportunity for the donor stock to adapt to the habitat and environmental conditions in the target stream.

Ecological Similarity. If a non-native stock is selected as the donor, ecological similarity can be evaluated through a template/patient analysis (Appendix A). In this case, the patient is the donor stock described in the context of its native stream and habitat which should then be compared to the target stream/stock. Human alteration of the donor and target habitats must be taken into account.

When selecting a brood source the target population should be the first priority;-. however, the number of brood fish removed should not create genetic risks for the donor stock (Busack 1990 and Ryman and Laikre 1991). The second priority is a neighboring population that has the greatest degree of similarity using the three criteria discussed above. The last priority is a hatchery stock that meets the similarity criteria. If the target stock is facing extinction, a different set of criteria should be used (for a discussion of those see Kapuscinski et al. (1991)).

If the priorities listed above have to be changed, the following overall constraints should guide the selection of a donor stock: maintain the gene& resources, life history patterns, and self-sustainability of the donor population; the candidate stocks should be evaluated against the three similarity factors; and-the effective population size of the hatchery population should be maximized.

Mating Protocols After the choice of broodstock, mating is the next most important activity that influences the hatchery gene pool. When selecting mating strategies the manager needs to consider life history and effective population size.

> Life History. All of the donor stock's life histories should be represented in the fish bred in the hatchery. To achieve this goal the broodstock should reflect the -following characteristics in the natural population: agestructure, time of spawning, spawning location, migration timing and, where possible, juvenile smolt migration.
>
> Effective Population Size. The effective population size of the fish bred in the hatchery should be maximized (See Kapuscinski et al. (1991) for a discussion of ways to maximize effective population size).

In addition, managers should review the seven spawning guidelines presented in the ISP (CBFWA 1991).

Escapement Management Once supplementation is underway:. the manager must decide how the broodstock will be selected from the mix of wild and hatchery fish returning to the target stream. The proportion of hatchery and wild fish in the hatchery broodstock and in natural spawning areas might be regulated by agency policies (the Oregon Wild Fish Policy, for example). In the absence of policy guidelines, the hatchery broodstock should be selected from returning adults according to the following in priority order:

- breed only naturally-produced adults in the hatchery
- breedamixtureofhatcheryandwildadults
- as a last priority, breed only hatchery fish.

Selecting the appropriate strategy will depend on a balance of genetic risks (Busack 1990) associated with the removal of naturally produced fish from a small population and the genetic effect from repeated use of hatchery fish in the broodstock. A genetic risk assessment should address uncertainty associated with each of the possible strategies for using returning adults.

Incubation and Rearing Practices Post-release survival may be heavily influenced by the rearing methodologies and physical habitat of the hatchery. Survival is dependent on fish health, and in general, the manager has to be concerned about two kinds of fish health:

- clinical health in the hatchery which is threatened by disease, poor nutrition that leads to physiological anomalies, and stress from crowding or chemical quality of the water
- ecological health which is threatened by lack of predator avoidance, inability to compete for food and space, and release to the stream at sizes, times and places that differ from the normal life history patterns of the stock.

The first concern has received a lot of attention and there are generally accepted procedures to ensure clinical health of a hatchery population. To maintain ecological health, the manager should attempt, to the extent possible, to incubate and rear the juveniles in ways that reflect natural conditions. Ultimately natural conditions for rearing should reduce random mortality while duplicating the natural selective mortality (Bowles and Leitzinger 1991). Recent research in this area should lead to the development of natural rearing-practices. For the present, the manager should consult Kapuscinski et al. (1991) for specific suggestions.

Release Variables The time, size, and place of release of hatchery-reared fish. can have important effects on life history, post-release survival and the genetic structure of the stock. The first priority should be to mimic natural life history. Hatchery practices that mimic natural life history have a better chance of achieving project objectives (Reimers 1979), particularly in areas with existing natural production. Sixes, times and places of release consistent with natural life history can be derived from the template/patient analysis (Appendix A).

Project Scale The number of fish released into a stream may be governed by policies that limit the proportion of hatchery and natural fish on the spawning grounds (see Oregon's Wild Fish Policy and Bowles and Leitzinger 1991). In the absence of specific policies, the number of fish released into the target stream should not exceed the natural stream's capacity. The manager can derive some guidance on stocking level, frequency and duration from a comparison of patient rearing densities with published densities (see Appendices A and C). In the absence of data on stocking densities, start at a conservative scale and gradually work up to the final release numbers based on monitoring information. The exception to this guideline is the target stream/stock locked into a stable equilibrium at a density lower than historic because of predation or competition (gee Part I of this series).

Use of captive broodstock for restoration of depleted stocks Restoration of depleted stocks of salmon and steelhead has become a regularly occurring challenge for fishery managers and it is likely that the number of salmon and steelhead stocks in need of restoration will increase. Planning and implementation of restoration programs are complicated, requiring knowledge and skills in many areas and a wide array of tools and strategies. Captive brood is an unconventional approach to brood@& management that has been used in commercial aquaculture and has had limited use in salmonid restoration projects.

Captive brood as used here refers to anadromous salmonids held in captivity through all or most of their life cycle in order to build a mature broodstock for artificial propagation. Captive broods may be reared entirely in fresh water or in a combination of fresh and salt water in a sequence that mimics the natural residence in those environments. The fish may be held in captivity from the egg through mature adult or wild juveniles may be captured and held to maturity. Captive brood has recently been applied to the recovery of the Red Fish Lake sockeye.

Captive brood technology has potential benefits and risks. Because the benefits and risks have not been evaluated through appropriate monitoring and evaluation, captive brood should be considered an experimental approach and used with caution and only in circumstances where there are no acceptable alternatives.

Model evaluation Once the alternative supplementation strategies have been devised, the manager should evaluate the risks and benefits of each treatment. There are several approaches to this analysis. RASP recommends that at least part of the evaluation of risks and benefits be completed though the use of a life-history model which was designed specifically to assist in evaluating alternative supplementation strategies. Part II of this series should be consulted for a detailed description of the model and its use.

RISK ANALYSIS

This section describes the critical role of risk analysis in planning a supplementation project (in the Background section) and the recommended process for accomplishing a risk analysis and assessment.

Background

Supplementation involves use of technology to increase natural production while limiting negative impacts on important natural attributes of the target and non-target stocks. Identifying and making provision to manage the risks of those impacts are important tasks in the planning of supplementation projects. Risk analysis is a form of technology assessment. According to Brooks (1973), technology assessment should attempt to reduce the gap in opposing values that often generates conflict regarding the use of technology, determine the appropriate scale for the application of a technology, and promote innovation and adaptation in a technology. A fourth purpose is to prevent surprise — failures or deviations from the expected results following the application of a technology (Timmerman 1986).

The use of supplementation technology to restore or enhance natural production in the Columbia Basin is controversial. The controversy is fueled by divergent values held by agencies and organizations that possess political influence in the basin. Those values conflict in part because of the uncertainty surrounding the potential success or the potential negative side effects of supplementation, and because supplementation is associated in positive and negative ways with the past performance of conventional hatcheries. The gap in values that fuels the controversy can be reduced through knowledge. Some of the uncertainties can be reduced through the application of existing knowledge while some will require new research. As new information and understanding reduce the uncertainties surrounding supplementation, the issues and debate will become more focused on specific questions and a smaller number of less divergent values should emerge (Brooks 1973). A risk analysis that results in a timely and efficient reduction of uncertainties and/or a plan for managing risks will help reduce the conflict that currently surrounds the use of supplementation in the Columbia Basin.

When setting the scale of 8 supplementation project, the manager must take into account life histories and habitat quality, potential straying and introgression with non-target populations, the genetically effective population size (Ryman and Laikre 1991), and economic efficiency (CBFWA 1991). The presence of-multiple stability regions within a stock's production functions would also influence project scale. The scale of a supplementation project is an important determinant of the nature and number of critical uncertainties and therefore is an important consideration in risk analysis.

Technologies with successful histories often slip into monocultures. Failure to recognize changing environments or public attitudes may lead to homogenous technologies, which are less innovative and adaptive (Brooks 1973). Because supplementation attempts to integrate two production systems (natural and artificial) to achieve a higher level of natural production, and because there are a number of uncertainties associated with supplementation, innovation and adaptation are essential elements in the overall program. In addition, the Council's policy of adaptive management requires flexibility in the design and implementation of management programs in the basin. However, large investments in fixed physical facilities may be an impediment to innovation and adaptation in supplementation. Risk analysis must consider the design of fixed facilities and the flexibility of those facilities to "adapt" to new information,

Surprise is defined as a major program failure or deviation from the expected and is often the product of too much reliance on unexamined assumptions regarding&e use of a technology. Although we should try to conduct management programs and supporting research and monitoring in ways that minimize surprise, it is also important that we learn enough to act appropriately when surprise occurs.

All of the purposes of technology assessment listed above are relevant to risk analysis and management for supplementation. Throughout this stage of the planning process, the manager should keep in mind the overall purposes of risk analysis — to reduce conflict, set the project scale, promote adaptation, and prevent or respond effectively to surprise.

Risk Assessment (Step 7)

Risk assessment is comprised of two tasks:

- Estimating risk. Risk may be estimated by a qualitative assessment of uncertainties or through a quantitative procedure that produces an estimate of the probability of success of the project.

- **Managing risk.** If the manager decides to complete the project plan, after reviewing the probability of success or its reciprocal, the risk of failure, he or she must develop a strategy to manage the risk associated with a project's critical uncertainties.

Estimating Risk Risks associated with a proposed supplementation project may be described qualitatively by listing the critical uncertainties and weighing their effect based on experience and a review of the literature. Another approach is to incorporate a subset of uncertainties into a model which. generates a numerical estimate of risk. We have labelled these two ways of estimating risk Type 1 and Type 2. They are not independent estimates. Type 1 risk assessment, which is based on a listing of critic& uncertainties; must be completed for each project. Since a Type 2 risk assessment requires the prior identification of critical uncertainties, it cannot be attempted until after the Type 1 assessment has been completed.

During project planning, all uncertainties are initially managed by making appropriate assumptions. An uncertainty is critical if the choice of assumption will determine success or failure of the project. The choice of assumptions for minor uncertainties will have small effects on the project outcome. For example, a project attempting to restore an extirpated stock might list among its critical uncertainties the quantity, quality and distribution of spawning and rearing habitat, especially if it is known that habitats have been degraded since extirpation of the native stock. Another critical uncertainty might be the choice of donor stock, especially if the habitat and life histories of the only available donor stock are not similar to those of the native stock Minor uncertainties might include appropriate temperature regimes for incubation and rearing, feed programming, broodstock capture and holding methods, preventative hygiene, pond density, and grading practices. Not all supplementation projects will necessarily have critical uncertainties associated with them. It is conceivable that some small scale projects may not identify critical uncertainties. Other projects may identify several critical uncertainties.

The universe of uncertainties for a given project is the product of three factors: the condition of the stock and stream, or our perception of them; supplementation strategies applied to the system; and management expectations or objectives expressed as production targets (Figure 1). The combination of those factors will produce a unique set of uncertainties for a given project although' there will be some overlap among projects. RASP (in preparation) gives a hierarchial description of potential supplementation uncertainties and outlines approaches to their identification. The manager attempting to list uncertainties for a specific project should consult RASP (in preparation).

Type 1 risk is broadly defined as the sum of the critical uncertainties associated with a project. The assessment of those risks is the qualitative weighing and comparison of the critical Uncertainties for alternative treatments *including the no action alternative*. Critical uncertainties should be identified for all dimensions of the management objective including long-term fitness, reproductive success, ecological interactions, post-release survival, and the numerical production targets. Tables 3a - e are provided as work sheets to aid in estimating Type 1 risk and in completion of the risk analysis for each dimension of the objective. The worksheets call for a list of critical uncertainties (if there are any); their potential impact on the specific dimension of the objective, i.e. numerical production targets, post-release survival, reproductive success, ecological interactions and long-term fitness; the overall impact of the project; the initial (planning) assumptions; and a description of how the uncertainty (risk) will be managed through monitoring and evaluation. Tables 3a - e are a critical part of the planning process. In effect, they summarize the outcome of all the previous steps.

The following suggestions should help the manager attempting to complete Tables 3a - e: The treatment alternative should be described in terms of the six basic elements of the treatment listed on pages 22 - 25. Each critical uncertainty listed in the table should include its minimum acceptable value. For example, a target value for post-release survival will have been stated in the first section of Table 3b, and the ability to achieve that target might be a critical uncertainty. Assume, for example, that the target for post-release survival is 50% of the survival rate of the wild fish. In the example, at a **post-release survival of less than 50% but greater than 10% the project will be continued with a diminished benefit/cost ratio, however, at a post-release survival of less than 10% of the wild fish, the project will be terminated. The 10% survival level is the minimum acceptable value for this example. Under the column Welled "Potential Impact on Specific Dimension of the Objective," the range of observed values should be reported along with an estimate of the most probable impact. In the previous example, the range in post-release survivals from the literature should be reported. In the example given above, the overall impact on the project is termination if post-release survivals are below 10%. Where appropriate, the initial assumption for each of the six basic elements of the treatment should be described for** each critical **uncertainty.**

In a Type 2 risk assessment the manager analyzes critical uncertainties through a model and &rives a numerical estimate of the probability of success or failure of a supplementation project. This type of risk assessment will genera& focus on a subset of the critical uncertainties which are associated with a particular aspect of supplementation. For example, in the Treatment section above, we recommended that

Table 3a. Risk Analysis Numerical Targets Work Sheet

MANAGEMENT OBJECTIVE

Numerical Targets: ______________________________

Treatment Alternative: ______________________________

____

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Table 3b. Risk Analysis Post Release Survival Work Sheet

MANAGEMENT OBJECTIVE

Post Release Survival: ______________________________

Treatment Alternative: ______________________________

____

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Table 3c. Risk Analysis Reproductive Success Work Sheet

MANAGEMENT OBJECTIVE

Reproductive Success: ______________________________

Treatment Alternative: ______________________________

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Table 3d. Risk Analysis Ecological Interactions Work Sheet

MANAGEMENT OBJECTIVE

Ecological Interactive: ______________________________

Treatment Alternative: ______________________________

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

Table 3e. Risk Analysis Long Term Fitness Work Sheet

MANAGEMENT OBJECTIVE

Long Term Fitness: ____________________
Treatment Alternative: ____________________

Critical Uncertainty	Potential Impact on Specific Dimension of Objective	Overall Impact on Project	Initial Assumptions	M & E

the RASP life history model be used to identify and evaluate risks associated with specific supplementation strategies. The life history model allows the manager to assess the benefits and risks of various treatment alternatives. However the model -- cannot evaluate risk associated with all critical uncertainties and all dimensions of the objective. The RASP model can also be used to rank (prioritize) uncertainties according to their projected impact on production (see Part II in this report series).

Type 2 risk assessment may also employ less complex models. For example, at each life stage, we tight assign numerical probabilities of success conditioned by the specific supplementation treatment. The simple sum or product of the life stage probabilities gives a single numerical estimate of the chance of success and the reciprocal is an index of-risk.

Type 2 assessments reduce risk to a numerical estimate which is more convenient for decision makers than the Type 1, qualitative list of critical uncertainties. However, the numerical estimates may give a false sense of concreteness and mask the dynamics of the components of risk. The numerical estimates of Type 2 risk have variances which are a measure of the risk associated with their use. In some cases, high variances might render the numerical estimate of risk no more useful than the qualitative weighing of critical uncertainties (Type 1).

The purpose of risk assessment is to give the decision maker technical advice regarding the probability of achieving the management objectives by using supplementation. The assessment must include all dimensions of the management objective i.e., long-term fitness of the native stock, reproductive success, ecological interactions and post-release survival as well as the numerical targets for adult returns (Tables 3a - e).

Risk assessment is tied to decision making, however, there is a clear distinction between the two. Risks associated with the use of technology such as supplementation can be determined through an objective, scientific process. The consequences of alternative choices can described through analysis, but there is no scientific basis for making the final decision i.e., deciding how much risk to accept (Brooks 1973). While the final decision has to include consideration of the scientific analysis, it must also incorporate economic considerations, community values and political processes as well.

Managing Risk. By definition, critical uncertainties can bring about the failure of a supplementation project. Since they determine the success or failure of a project, the risk associated with the critical uncertainties must be "managed" to reduce their potential negative effect and improve the probability that the supplementation project will achieve its objective. Risk management is accomplished in three ways:

- Initially, the critical uncertainties listed in Tables 3a - e are managedthrough reasonable assumptions. The assumptions should be based on a review of the literature and they should be subjected to a review by qualified experts.
- The risks associated with some uncertainties can be removed or reduced by research. A brief outline of the research design is called for in Tables 3a - e. The next section (Monitoring and Evaluation) gives more information on the design of research on the critical uncertainties.
- Some uncertainties may not be amendable to research. The risks associated with those uncertainties are managed through monitoring designed to contain risk by giving early warning of an error in a assumption from Tables 3a - e.

The manager must show ho&each critical uncertainty will be addressed either through research or monitoring. In many cases, research and monitoring costs can be minimized through cooperative efforts among supplementation projects through global, design (see Part IV of this series).

MONITORING AND EVALUATION

This section describes the purpose of monitoring and evaluation and suggests elements to consider in designing and implementing a monitoring and evaluation program.

Background

The objectives of project-level monitoring ' and evaluation (M&E) are to reduce or remove the critical uncertainties identified in Tables 3a - e and thereby improve the probability of a project's success (risk management), to monitor population variables that give warning of an error in planning assumptions (risk containment monitoring), and to document the return on project investment (accountability). M&E is a pivotal step in the planning process and it is linked to all of the previously described steps (Figure 2) through the Council's policy of adaptive. management (NPPC 1987).

Few stream/stock systems being proposed for supplementation will have sufficient information to complete all the steps described in the previous sections of this report; particularly Tables A.1 - A.3 in Appendix A. However, under adaptive management, all the steps need not be completed before implementation. We encourage managers to address all the steps with existing information, whether that information is qualitative or quantitative. Adaptive management permits projects to proceed to the implementation stage with a degree of caution commensurate with the number of critical uncertainties (Tables 3a - e) and the degree of risk. For example, projects with a large number of critical uncertainties and high risk may initially be implemented with temporary facilities and at a scale no larger than that dictated by the needs of the M&E program.

M&E in an adaptive management context permits the manager to "learn by doing." Under adaptive management, planning for projects that contain critical uncertainties assumes a different role. The planning steps described in this report become an iterative process driven by information obtained through M&E. Key elements in the process i.e., template/patient analysis, diagnosis, and risk analysis are repeated at regular intends to incorporate the new information. The objective of an iterative planning process is to eventually reduce or eliminate the critical uncertainties. In this context, planning is not a one-time activity but it becomes an important part of the M&E, at least until the uncertainties are resolved. The iterative planning process then is the basis for a regular project review.

Design Considerations

The generally accepted approach to scientific investigations includes the sequence:

- a Devise alternative hypotheses
- a Devise the experiments to exclude one or more hypotheses
- a Carry out the experiment, evaluate the results, and then recycle the procedure (Platt 1964).

The M&E plan far a supplementation project begins with the template/patient analysis which leads to the list of critical uncertainties (Tables 3a - e). Where there is sufficient information on the stream/stock system, the design of the M&E can begin.

by the derivation of hypotheses from critical uncertainties. For stream/stock systems with insufficient baseline information, preliminary surveys will have to be complete& Ward (1978) recommends field surveys to estimate the structure and function of the system prior to the formulation of hypotheses and the design of environmental impact studies. A failure to carry out the survey or a survey that merely catalogues rather than determines functional relationships often restricts the success of the M&E (Ward 1978).

Ecological questions, particularly those dealing with salmon production and productivity, are not easy to partition into mutually exclusive; alternative hypotheses. Factors that determine production often have a large degree of interaction. When independence is incorrectly assumed, hypothesis testing can lead to misleading conclusions (Quinn and Dunham 1983).

Conventional wisdom seems to suggest that experimental design is the formulation a series of null and alternative hypotheses along with appropriate statistical tests. While the development of hypotheses is critical to the overall scientific approach, the purpose of experimental design within that approach; which is often overlooked, is to identify and remove irrelevant sources of variability thereby increasing the power of the test of the null hypothesis (Cohen 1988). For. a discussion of experimental design in fisheries management including alternative design approaches, see McAllister and Peterman (1992).

Statistical Power

Conventional analysis of M&E information in fisheries attempts to reject a null hypotheses which is usually stated as no effect. For example, a null hypothesis for supplementation might be: There is no difference in smolt-to-smolt survival between naturally produced and supplemented salmon. When a null hypothesis is rejected the significance level (a) of the test is also reported. When the data fail to reject the null hypothesis, managers often fail to report power of the test (Peterman 1990) or the probability that the test will lead to a rejection of the null hypothesis (Cohen 1988). This failure can lead to erroneous conclusions if the power of the test is low and the manager decides to accept the null hypothesis (Peterman 1990).

To illustrate the point above, consider this example: A manager is experimenting with release timing and size to increase smolt-to-smolt survival of supplemented fish. The objective is to increase the survival of supplemented fish to equal the survival of naturally produced fish. The data fails to reject the nullhypothesis and the manger assumes the experiment was a success and survival of supplemented and natural fish is equivalent. However, because of a small sample size and high sampling variability, the power of the test is low. In this case the manager erroneously terminates the experiment when in fact the survival of supplemented fish has not changed and remains below that of natural fish.

The importance of statistical power lies in its capacity to minimize the potentially harmful results of decisions based on erroneous conclusions. Incorporating g statistical power into the experimental designs improves the quality of experiments and demonstrates to decision makers the risks associated, with decisions based on experimental results. Some variables such as survival and adult abundance are difficult to measure with high levels of statistical power. DeLibero (1986) concluded that the best one could expect from survival studies of hatchery fish is a coefficient of variation of 25%. In most cases, over reasonable experimental periods, that level of variation would lead to low statistical power. Lichatowich and Cramer (1979) found that studies of survival and abundance may require 20 to 30 years to produce an 80% chance of detecting a 50% change.

Power of an experiment can be improved by the choice of variables to be measured. Although survival and abundance of adult salmon and steelhead tie important variables that measure the performance of supplementation, our inability to measure them with reasonable statistical power suggests the need to search for alternatives (Lichatowich and Cramer 1979). Appropriate performance measures such as size and timing of juvenile migration (Lichatowich and Cramer 1979) could-serve as surrogates for survival and abundance in some experimental designs. Appropriate performance measures could give an early indication of the success of a supplementation strategy or indicate corrective action long before the outcome in terms of returning adults can be determined.

M&E design

To improve the probability of success of supplementation projects, the risk associated with critical uncertainties needs to be managed by reasonable assumptions followed by research and/or monitoring, Prior to designing the research or monitoring projects, the critical uncertainties should be subjected to a qualitative scoping process (Table 4) to establish priorities and set guidelines for the experimental design.

Table 4. Scoping process far critical supplementation uncertainties.

FACTORS	COMMENTS
Critical Uncertainties	List initial assumptions (see Tables 3a - 3e) used in developing the supplementation plan and projections.
Applicability	Describe the relationship between the uncertainty and supplementation objectives (see Tables 3a -3e).
Prioritize critical uncertainties	Determine the relative importance of the critical uncertainties. Some uncertainties can be evaluated through the RASP model; others will have to be ranked by qualitative weighing of the potential impact on objectives.
Hypotheses	Where possible convert the assumptions associated with each uncertainty to testable hypotheses or monitoring elements.
Feasibility	State the feasibility of testing the hypotheses: identify sources of variability, baseline data needs, controls, blocks, etc.
Statistical Considerations	State the desired level of statistical power. How reliable do the research results have to be? Can the desired level of statistical power be achieved?
Scope	List species, stocks, strategies and areas within the subbasin for which the uncertainty is critical.
Risks	Will the experiments pose a biological risk?
Opportunities	Are there other supplementation projects better suited to conduct the experiments? Can the results be extrapolated to other projects?
Remaining needs	Questions and information needs not expected to or unlikely to be met under current plans.

Once the project has undergone preliminary scoping, those projects that are identified as high priority and feasible will require statistical design. Green (1979) gives ten basic statistical rules for the design of environmental studies:

1. Be able to state concisely to someone else what question you are asking. Your results will be only as coherent and as comprehensible as your initial conception of the problem.

2. Take replicate samples within each combination of time, location, and any other controlled variable. Differences among can only be demonstrated by comparison to differences within.

3. Take an equal number of randomly allocated replicate samples for each combination of controlled variables. Putting samples in representative or typical places is not random sampling.

4. To test whether a condition has an effect, collect samples both where the condition is present and where the condition is absent but all else the same. An effect can only be demonstrated by comparison with a control.

5. Carry out some preliminary sampling to provide a basis for evaluation of sampling design and statistical analysis options. Those who skip this step because they do not have enough time usually end up losing time.

6. Verify that your sampling device is sampling the population you think you are sampling, with equal and adequate efficiency over the entire range of sampling conditions to be encountered. Variation in efficiency of sampling from area to area biases among-area comparisons.

7. If the area to be sampled has a large-scale environmental pattern, break the area up into relatively homogenous subareas and allocate samples to each in proportion to the size of the subarea. If it is an estimate of total abundance over the area that is desired, make the allocation proportional to the number of organisms in the subarea.

8. Verify that your sample unit size is appropriate to the size, densities, and spatial distribution of the organisms you are sampling. Then estimate the number of replicate samples required to obtain the precision you want.

9. Test your data to determine whether the error variation is homogenous, normally distributed, and independent of the mean. If it is not, as will be the case for most field data, then: (a) appropriately transform. the data, (b) use a distribution-f& (nonparametric) procedure, (c) use an appropriate sequential sampling design, or (d) test against simulated H_o data.

10. Having chosen the best statistical method to test your hypothesis, stick with the result. An unexpected or undesired result is not a valid reason for rejecting the method and hunting for a better one.

These basic rules should be consulted in the design of supplementation projects as well as their supporting research projects. While the ten rules give a set of guidelines that are generally applicable to environmental studies, the individual project leader will have to determine if, and how, they apply in each specific case. -A conscientious review and application of the appropriate rules will improve the quality of supplementation investigations.

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APPENDIX A

GUIDELINES FOR COMPLETING A TEMPLATE/PATIENT ANALYSIS

APPENDIX A

GUIDELINES FOR COMPLETING A TEMPLATE/PATIENT ANALYSIS

Tables A.1 - A.3 of Appendix A describe the three important life history stages of spawning and incubation, rearing, and migration in terms of habitat, timing, survival and demographics. Completing Tables A.1 - A.3 requires a significant level of understanding of the relationships among the stock's life histories, its habitat, and production. Under the policy of adaptive management, it is not necessary complete the template/patient analysis to implement a project,, but the manager must supply what is known in all the information categories. In many cases the only information available to the manager to complete the tables will be qualitative. Information gaps in Tables A.1 - A.3 lead to uncertainties which are addressed in the risk analysis and project monitoring and evaluation. As new information is obtained, the gaps are reduced and uncertainties, risks and project methodology are modified as appropriate. For those projects that are implemented with a great deal of uncertainty, planning becomes an iterative process.

A brief description of the information called for under each life history is given below. Where appropriate, the manager should indicate whether limiting factors are density-independent or density-dependent.

Spawning and Incubation

Tables A.la - A.lb require the information described in this section.

<u>Life History Type</u> is a designation given to a group of fish whose spawning time or location, rearing habitat preference and/or migration timing are similar within the group. There may be multiple life histories within each stock. The tables should be expanded so that there is a line for each life history.

<u>Smolt Age</u> describes age at smoltification: 0,1,2,or mixed.

<u>Habitat</u> describes the area in the subbasin or tributary where fish of a specific life history type spawn.

<u>Habitat Quantity</u> is either a physical measure of the habitat area or an estimate of the percent of the total area available or suitable for spawning.

Table A.1a. Template/patient analysis - spawning and incubation.

Life History Type	Smolt Age	SPAWNING AND INCUBATION					
		Habitat	Habitat Quantity	Habitat Quality	Timing	Incubation Survival	Prespawning Mortality
		Template					
		Patient					
		Template					
		Patient					
		Template					
		Patient					
STOCK SUMMARY							

Table A.1 b. Template/patient analysis - spawning and incubation.

Life History Type	SPAWNING AND INCUBATION				
	Species Interactions	Age Structure	Sex Ratio	Fecundity	Life History Summary
	Template				
	Patient				
	Template				
	Patient				
	Template				
	Patient				
STOCK SUMMARY					

Table A.2a. Template/patient analysis - spring/summer rearing.

Life History Type	SPRING/SUMMER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								

Table A.2a. cont'd.

Life History Type	SPRING/SUMMER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
STOCK SUMMARY									

Table A.2b. Template/patient analysis - fall/winter rearing.

Life History Type	FALL/WINTER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								
	Template								
	Patient								

Table A.2h. cont'd.

Life History Type	FALL/WINTER REARING								
	Habitat	Habitat Quantity	Habitat Quality	Timing	Density	Growth	Survival	Species Interactions	Life History Summary
	Template								
	Patient								
	Template								
	Patient								
STOCK SUMMARY									

Table A.3a. Template/patient analysis - presmolt migration

Life History Type	PRESMOLT MIGRATION					
	Hydrograph	Timing	Survival/ Blockages	Species Interaction		Life History Summary
	Template					
	Patient					
	Template					
	Patient					
	Template					
	Patient					
STOCK SUMMARY						

Table A.3b. Template/patient analysis - smolt migration

Life History Type	SMOLT MIGRATION					
	Hydrograph	Timing	Survival/ Blockages	Species Interaction	Mainstem Passage	Life History Summary
	Template					
	Patient					
	Template					
	Patient					
	Template					
	Patient					
STOCK SUMMARY						

Table A.3c. Template/patient analysis - adult migration

Life History Type	ADULT MIGRATION						
	Hydrograph	Timing	Survival/ Blockages	Species Interaction	Ocean Distribution	Fisheries Interception Ocean/Estuaries/ Rivers	Life History Summary
	Template						
	Patient						
	Template						
	Patient						
	Template						
	Patient						
STOCK SUMMARY							

Habitat Quality is an estimate of the biophysical condition of the; habitat relative to survival or productivity. For spawning habitat, quality might be described in terms of gravel composition (% fines) or the stability of the streambed (frequency and depth of scour).

Timing gives the interval (dates) when spawning occurs and the peak (Julian Week) of spawning activity.

Incubation Survival gives the survival from egg to fry. This might be extrapolated from the relationship between survival and percent fines in the gravel (Cederholm et al. 1980 and Hall and Lantz 1969).

Prespawning Mortality can be estimated directly from surveys or indirectly from counts at dams or diversions and redd counts adjusted for redd:fish ratio. Indicate if disease is a mortality factor.

Species Interaction is an estimate of the effects of competitors or predators on successful spawning and incubation.

Age Structure is simply the age distribution of the spawning 'population.

Sex Ratio and Fecundity are self explanatory.

Life History Summary records summary comments and observations regarding a single life history type across all factors influencing spawning success. Conclusions such as the; apparent limiting factor can be entered here.

Stock Summary records summary comments and observations across all life history types for a given factor influencing spawning success.

Rearing

Tables A.2a - A.2b require the information describedbelow:

Life History Type. See description under spawning and incubation,

Habitat. See explanation under spawning and incubation above.

Habitat Quantity. See explanation under spawning and incubation above.

Habitat Quality is an estimate of the physical quality of the rearing habitat relative to survival and production. For rearing, measures of habitat quality might include: the pool to riffle ratio, temperature, flows (absolute and seasonal patterns), stream structure, condition of the riparian zone, winter refugia, etc.

Timing gives the interval (dates) when rearing occurs in the specific section/area of the subbasin or tributary identified under Habitat.

Density gives the rearing density of juveniles. Appendix B gives rearing densities of juvenile chinook and steelhead reported in the literature for comparative evaluation.

Growth give8 the size at the end of the interval (spring/summer or fall/ winter).

Survival gives the survival to the end of the interval. Appendix B gives survivals of juvenile chinook and steelhead reported in the literature for comparative evaluation.

Species Interaction is an estimate of the effects of predators or competitors on rearing.

Life History Summary records summary comments and observations across all factors influencing rearing success. This might include a comparative evaluation of rearing density and survival between the target stream and values reported in the literature (Appendix B).

Stock Summary records summary comments and observations across all life history types for a given component of rearing success.

Migration

Tables A.3a - A.3c present information related to migration at different stages. The information is described below:

Life History Type. See description under spawning and incubation.

Hydrograph describes the relationship between flow patterns and migration.

Timing describes the normal timing of migration.

__Survival/Blockages__ describes impediments to migration (exc pt mainstem passage problems) and problems causing mortality luring migration. For example, an impassiile dam or mortality at irrigation diversions would be listed here.

__Species Interaction__ is an estimate of the effect of competitors or predators on migration. For example, predation by squaw fish would be described.

__Mainstem Passage__ gives the effect of mainstem passage problems on survival of smolt migrants.

__Ocean Distribution__ gives the ocean distribution of the stock.

__Fisheries Interception__ gives the points of fishing interception of the stock in the ocean, estuary and river.

__Life History Summary__ records summary comments and observations across all factors influencing migration success.

__Stock Summary__ records summary comments and observations across all life history types for a given component of migration success.

As stated above, in very few if any cases, will the manager be able to complete the template/patient analysis shown in Tables A.1 - A.3,. --At first, the task might appear impossible and the-manager may be tempted to skip it altogether. However, this is an important step in the planning process and even a partial analysis will be worth the effort. RASP recognizes that any attempt at historical reconstruction will include some thoughtful speculation and will be subject to debate and criticism. In the absence of hard information, a review of the literature, thoughtful speculation, and debate are important ingredients of successful planning and the identification of the best supplementation strategies. Information that can be used to describe the template may be obtained from the following:

- __Historical reports from the target stream/stock__. In the ideal situation, the manager has sufficient empirical observations from historical reports to complete the template analysis.

- __Historical reports from similar streams/stocks__ Appropriate information from nontarget streams/stocks c&be used in the template analysis.

- <u>Baek[redacted]from pu[redacted]ture</u>. The template can be back calculated from published reports which describe the life histories of the target or a similar nontarget stream/stock at a point between the healthy condition and the current state of degradation.

- <u>Back[redacted]om the patient</u>. In some cases, the description of the patient will provide insight help in completing part of the template analysis.

To help the manager complete the template analysis, Appendix B summarizes selected literature on salmon life history/habitat relationships. Appendices C and D give the reported ranges in rearing density ad survival of chinook salmon and steelhead.

APPENDIX B

SELECTED REFERENCES ON LIFE HISTORY

Appendix B. Selected References on Life **History.**[2]

Paper	Species/Stock	Life History Diversity	Relationship to Habitat	Importance to Production
Reimers, P.E. (1973)	Fall chinook, Sixes River, Oregon	Identified five life histories based on duration of fresh water/estuarine residence and timing of ocean entrance.	Related life history types to fresh water and estuarine habitat. Also discussed the influence of temperature.	Discussed the relationship between life histories and potential enhancement, including hatchery enhancement. Identified most successful life history pattern and its principal habitats.
Schluchter and Lichatowich (1977)	Spring chinook, Rogue River, Oregon	Identified seven juvenile life histories.	Related life history types to fresh water estuarine habitat. Discussed influence of growth on life history.	Discussed relative importance of juvenile life history types in the adult population.
Carl and Healey (1984)	Chinook salmon, Nanaimo River, British Columbia	Identified three juvenile life histories. Varlation in allelic frequencies in the three life histories indicated genetic differences. Also observed morphologiod differences.	Suggested genetic adaption to early sdt water rearing in one life history.	Discussed ths implication of this work to hatchery enhancement.
Everest (1973)	Summer steelhead, Rogue River, Oregon	Seven life history patterns based on duration of residency in fresh and salt water. Steelhead entered the river in three distinct groups by time, but these were not treated as separate racial components.	Rogue summer steelhead moved into small tributaries to spawn. These tributaries were intermittent or dry in summer.	Habitat use, i.e. spawning in intermittent streams made spawning, timing, and flow patterns critical to production.
Nichdar and Hsnkin (1988)	Chinook salmon, Oregon coastal streams	Comprehensive review of life histories of chinook salmon in 27 coastal basins.	Discussed life history and habitat relationships.	Discussed implications of life history to natural and artificial produotion.

2 This is not intended to be a complete survey of the life history literature. These papers will give managers helpful insights into life history and assist them in preparing the template/patient analysis.

APPENDIX C

SURVIVAL OF JUVENILE CHINOOK AND STEELHEAD

Appendix C. Survival of juvenile chinook and steelhead.
(From Smith et al. 1985)

SURVIVAL %

Species	State/ River	Egg to Fry	Egg to Smolt	Fry to Smolt	Smolt to Adult
SPRING CHINOOK	Idaho Lemhi R.	20.6	9.8	21.2[a]	
	Washington Yakima R.		10.9		
	Oregon Warm Springs R. John Day R. Lookingglass Cr. Fall Creek		3.5 5.2 9.5	12.4[b]	
FALL CHINOOK	California Klamath R.	14.5			
	B.C. Big Qualicum	19.8			
STEELHEAD	Idaho Lemhi R.			2.0	
	Washington Snow Cr. Gobar Cr. Kalama R.		.09 .86	4.6	
	Oregon N.F. Umpqua R.		.01		
	B.C. Keogh R.		.51		

a Presmolts released at 500/lb in 1973 and 398/lb in 1974.
b Presmolts released at an average length of 75 mm in 1970 and 56 mm in 1971.

APPENDIX D

REARING DENSITIES IN NATURAL HABITAT FOR JUVENILE CHINOOK AND STEELHEAD

Appendix D. Rearing densities in natural habitat for juvenile chinook and steelhead. (From Smith, et al 1985)

Juvenile Chinook Rearing Density

State/ River	Age/ Size	Season	Fish/m²
Idaho			
Big Spring8 Cr.		end of summer	2.08
Big Springs Cr.		winter	1.40
Lehmi R.		end of summer	1.29
Lehmi R.		winter	0.61
Salmon R.	Age 0		0.26
Clearwater R.	Age 0		0.25
S.F. Salmon R.			0.06
Lochsa R.	August		0.032
Washinaton			
Wind R.	Age 0		0.09
Wenatchee R.	Age O		0.08
Entiat R.	Age 0		0.06
Kalama R.	Smolt		0.073
Oreaon			
White R.	Age 1 +		0.08
Warm Spring8 R.	Age 0		0.05
John Day R.	Age 0		0.19
Fish Cr.			0.01
Warm Springs (Shitike Cr.)			0.05
Middle Fork John Day	Early Sept.		0.05
Siletz & Nestucca R.	Fry		0.72
B.C.			
Cowichan R.	Age 3 mos.		0.18
Big Qualicum R.	Age 3 mom.		0.30
Keogh R.	Smolt		0.027

Juvenile Steelhead Rearing Densi

State/ River	Age/ Size	Season	Fish/m²
Idaho			
Big Spring Cr.		end of summer	0.93
Big Spring Cr.		winter	0.54
Lehmi R.		end of summer	0.70
Lehmi R.		wintsr	0.13
Salmon R.	Age 0		0.11
Clearwater R.	Age 0		0.08
S.F. Clearwater R.	Age 0		0.34
S.F. Clearwater R.	Age 1 +		0.44
Lochsa R.	Age 0	August	0.34
Washington			
Wind R.	Age O		0.12
Wenatchee R.	Age 0		0.04
Entiat R.	Age 0		0.08
Snow Cr.	Smolt		0.022
Salmon Cr.	Smolt		0.017
Snow Cr.	Fry		0.70
Snow Cr.	Smolt		0.03
Gobar Cr.	Smolt		0.037
Oregon			
White R.	Ags 1 +		0.10
Warm Spring8 R.	Age 0		0.05
John Day R.	Age O		0.80
Trout Cr.		Mid August	0.69
Bakeoven Cr.		Late July	2.65
Buck Hollow Cr.		Late July	7.32
S.F. John Day R.		Early Sept.	0.03
M.F. John Day R.		Early Sept.	0.08
Chesnimus Cr.		Lat. July	0.61
Umatilla R.		Early Aug.	0.77
Meacham Cr.		Mid-Aug.	0.36
Camp Cr.		Mid-Aug.	0.87
California			
Manzanita Cr.	Age O		0.69
Trinity R.	Age 1 +		0.23
Godwood Cr.	All ages		0.14
N. Caspr Cr.	All ages		0.64
B.C.			
Big Qualicum R.	Age 3 mos.		0.021
Carnation Cr.	Smolt		0.006
Keogh R.	Smdt		0.016
Quinsam R.	Smolt		0.02