STUDY PLAN FOR EVALUATING CARRYING CAPACITY: MEASURE 7.1A OF THE NORTHWEST POWER PLANNING COUNCIL'S 1994 FISH AND WILDLIFE PROGRAM

REPORT 2 OF 4
FINAL REPORT

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Task 2.5
Project Number 93-O 12
Contract Number DE-AI79-X6BP626 i 1

PREFACE

This report is one report of four that the Pacific Northwest National Laboratory (PNNL) staff to address Measure 7.1A in the Northwest Power Planning Council's (Council) Fish and Wildlife Program (Program) dated December 1994 (NPPC 1994). Measure 7.1 A calls for the Bonneville Power Administration (BPA) to fund an evaluation of salmon survival, ecology, carrying capacity, and limiting factors in freshwater, estuarine, and marine habitats. Additionally, the Measure asks for the development of a study plan based on the critical uncertainties and research needs identified during the evaluation.

In the evaluation of carrying capacity (Neitzel and Johnson 1996) we concluded that defining capacity and listing the determinants of capacity is not a simple exercise. The process of examining individual determinants of capacity is an "oversimplification of complex ecological processes" (Reeves et al. 1991). Capacity is a complex variable among the attributes that all together define salmon performance. To pursue the capacity parameter, that is, a single number or set of numbers that quantify how many salmon the basin or any part of the basin can support, will not lead to the development of a useful study plan. To increase understanding of ecology, carrying capacity, and limiting factors, it is necessary to deal with the complexity of the sustained performance of salmon in the Columbia River Basin.

At this time, it is necessary to report the information we have assembled and present our recommendations to complete a study plan to evaluate carrying capacity in the Columbia River Basin. This report describes the elements of a study plan that could be used to increase our understanding of ecology, carrying capacity, and limiting factors that influence salmon survival under current conditions. Three other reports were prepared based on the work addressing Measure 7.1A:

1. "Evaluation of Carrying Capacity: Measure 7.1A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program, Report 1 of 4."
2. "Proceedings from a Workshop on Ecological Carrying Capacity of Salmonids in the Columbia River Basin, Measure 7.1 A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program, Report 3 of 4."
3. "A Literature Review, Bibliographic Listing, And Organization of Selected References Relative To Pacific Salmon (*Oncorhynchus* spp.) And Abiotic And Biotic Attributes Of The Columbia River Estuary And Adjacent Marine & Riverine Enviorns, for Various Historical Periods, Measure 7.1 A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program, Report 4 of 4."

ACKNOWLEDGMENTS

Our sincere thanks to the people who helped with this study. Dr. Mark Schneider, formerly of BPA, wrote the statement of work that started the development of a study plan. Nora Berwick and John Marsh of Council staff helped interpret Measure 7.1 A. Tom Vogel of BPA was the contracting officer's technical representative for the project after Dr. Schneider moved to the National Marine Fisheries Service. Dr. Dennis Dauble reviewed the report and Melanie Desmet edited the report.

ABSTRACT

We pursued answers to questions asked in Measure 7.1A and concluded that the approach inherent in 7.1A will not result in a study plan that can increase understanding of ecology, carrying capacity, or limiting factors that influence salmon under current conditions. Measure 7.1A requires a definition of carrying capacity and a list of determinants (limiting factors) of capacity. The implication or inference then follows that by asking what we know and do not know about the determinants will lead to research that increases our understanding of what is limiting salmon survival. It is then assumed that research results will point to management actions that can remove or repair the limiting factors. Most ecologists and fisheries scientists that have studied carrying capacity clearly conclude that this approach is an oversimplification of complex ecological processes. To pursue the capacity parameter, that is, a single number or set of numbers that quantify how many salmon the basin or any part of the basin can support, is meaningless by itself and will not provide useful information for developing a study plan..

To develop a study plan that can increase understanding of ecology, carrying capacity, and limiting factors, it is necessary to deal with the complexity of the sustained performance of salmon in the Columbia River Basin. Density independent factors affect salmon performance, as well as density dependent factors. Factors that affect performance in one part of the salmon life cycle can manifest their effect in later phases of the life cycle. Factors can have different effects on different populations in different parts of the Columbia Basin or marine environment. Factors can affect different populations or stocks in different ways. There are potential negative impacts of focusing on abundance alone (NRC 1995). For example, how do the many populations and stocks of salmon affect one another? When we understand the ecological complexity of salmon performance. the region will be better able to make decisions to improve salmon survival in the basin.

Before developing a study plan, we suggest that the region evaluate carrying capacity from more than one viewpoint. Platt (1964) provides a method for scientific inquiry and Pepper (1966) provides at least four views that can be used to define capacity in a way that helps identify critical uncertainties and research needs while dealing with the complexity of salmon performance.

There are tools available to evaluate salmon performance that incorporate the complex interrelationships among diversity, productivity, and complexity. The Patient-Template Analysis is a tool that could be used to develop a plan for studying capacity. The Council should call for a Patient-Template Analysis, as described by Lichatowich et al. (1995). The region will be able to evaluate carrying capacity under current conditions, compare current conditions to historic conditions and thus, predict possible future conditions for salmon in the Columbia River Basin.

We recommend seven steps be completed to develop the study plan. The steps are: set objectives, define alternative strategies, state the assumptions and uncertainties, plan for the resolution of uncertainties, analyze the potential benefits and

risks of each strategy, develop a monitoring plan, and establish a documentation and review process.

FIGURES

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Chapter 1: INTRODUCTION

Measure 7.1 A in the Northwest Power Planning Council's (Council) Fish and Wildlife Program (Program) dated December 1994 calls for the Bonneville Power Administration (BPA) to fund an evaluation of salmon survival, ecology, carrying capacity[1] and limiting factors in freshwater, estuarine, and marine habitats. The Measure has two parts (7.1 A. 1 and 7.1 A.2). The objective of the evaluation (7.1A. 1) is to increase understanding of the ecology, carrying capacity, and limiting factors that influence salmon survival under current conditions. The second part of the Measure (7.1A.2) asks for the development of a study plan based on the critical uncertainties and research needs identified during the evaluation of carrying capacity. The report addresses Measure 7.1 A.2, develop a study plan.

1. Analysis of competition between non-native species and anadromous salmonids and competitive interaction resulting from hatchery management practices.
2. Estimate of current salmon carrying capacity for the Columbia River mainstem, tributaries, estuary, plume and nearshore oceans for juvenile fish.
3. Evaluation of the effects of the alteration and timing of the ocean plume on salmon survival caused by the construction and operation of the hydroelectric system.
4. Identification of residence time for juvenile salmonids and their level of smoltification.
5. Identification of management measures to protect and improve estuary habitat as well as increase the productivity of the estuary.
6. Recommendations for management responses to fluctuating estuary and ocean conditions such as adjusting total numbers of releases to take such conditions into account.
7. Identification of critical uncertainties and research needs, and estimates of incremental gains in survival from improvements in each area.
8. Monitoring program to identify optimal timing for residency in the estuary and nearshore environment.

To address all eight issues and accomplish the objective of the evaluation of capacity, we were told by Council staff to:

- Review existing data.
- Conduct a workshop.
- Use the information from the review and the workshop to define capacity and list the determinants of capacity.
- Ask. "What do we know about the determinants of carrying capacity?"
- Ask, "What do we not know about the determinants of carrying capacity?"

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[1] In this report, we use the terms: capacity, can-ying capacity, and ecological carrying capacity interchangeably. Attempting to remain consistent with the intent of Measure 7.1 A, we use these terms to describe *"the upper level for a population, beyond which* no *major increase* can *occur"* (Odum 1959). Many authors that we cite throughout this paper have other definitions for these terms or use them in a specific context with other population descriptors. We have tried very carefully to cite these authors and strongly suggest that readers turn to the original books or articles for clarification.

- Ask, "What research can we do to understand what we do not know about carrying capacity?"
- Ask, "What management actions can we implement immediately, relative to carrying capacity, that will improve salmon survival'?"
- Use the information collected and the answers to the questions to develop a study plan based on the critical uncertainties and research needs identified in the evaluation.

This process is illustrated in Figure 1. The study plan was to provide a process for implementing the management actions and conducting the research. The results of the research and monitoring the management actions would lead to increased understanding. This increased understanding would lead to the implementation of an ecosystem approach to protect and enhance salmon in the Columbia River Basin.

We pursued the answers to questions asked in Measure 7.1 A, but concluded that this approach would not meet the objective. That is. the approach illustrated in Figure 1 would not increase understanding of ecology. carrying capacity, or limiting factors that influence salmon under current conditions. Responding to the requests in Measure 7.1A, requires a definition of carrying capacity and a list of determinants (limiting factors) of capacity. The information that we learned during the workshop[2] and from our review of ecological literature lead us to the conclusion that the proposed process (Figure 1) breaks down (Figure 2) as one attempts to define capacity as a simple ecological process (Odum 1959, Reeves et al. 199 1).

The capacity parameter, that is, a single number or set of numbers that quantify how many salmon the basin or any part of the basin can support will not provide useful information for developing a study plan. To increase understanding of ecology, carrying capacity, and limiting factors. it is necessary to deal with the complex interrelationship among the characteristics of salmon performance. for example, diversity, capacity. and productivity (Paulik 1973. Hankin and Healey 1086. Moussalli and Hilborn 1086. Hilborn and Walters 1992. Mobrand et al. in press). Accordingly, we revised the approach to evaluate capacity (Figure 3). The approach we used followed the work on scientific discovery by Platt (1064) and the works on world hypotheses by Pepper (1966).

In the first report to BPA related to the work we conducted on Measure 7.1 A.[3] we describe four views of capacity: mechanistic. formistic, contextualistic, and organistic. These views can all be used to describe animal populations. However, some of these views are not always useful for describing animals with complex life histories or for animals that live in complex environments. Nor, arc all the views useful for developing study plans. We concluded that the contextual view provides a scientific basis for

[2] Proceedings from the Workshop on Ecological Carrying Capacity of Columbia Basin Salmon (September 6-7. 1995 in Portland, OR) are reported elsewhere (Johnson et al. 1996).

[3] Neitzel. D.A., and G.E. Johnson. 1996. "Evaluation of Carrying Capacity: Measure 7.1 A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program Report 1 of4." Prepared for the Bonneville Power Administration, Portland, Oregon by the Pacific Northwest National Laboratory, Richland, Washington.

developing a study plan that could lead to an increased understanding of the ecology, carrying capacity, and limiting factors that influence salmon survival in the basin under current conditions.

Having recommended a scientific basis for developing a study plan, we decided we next needed to establish the elements that would go into and make up the plan. For a study plan, related to one issue (in this case carrying capacity), the plan has to be inextricably integrated to the whole (in this case the Program). To assure that a study plan for carrying capacity meets the goal of integration, we described seven elements to place any critical uncertainties and research needs into a plan. These elements are based on strategic planning described by Lewis (1991), Steiner (1979), and Kershner et al. (1991). The seven elements are 1) set objectives, 2) define strategies, 3) state assumptions and uncertainties, 4) develop an uncertainty resolution plan, 5) analyze benefits and risks, 6) develop a monitoring plan, and 7) develop a documentation and review process.

The report contains a description of the elements for a study plan (Chapter 2), and a draft study plan (Chapter 3). The report ends with our conclusions and recommendations (Chapter 4) to the region for completing a study plan based on critical uncertainties and research related to carrying capacity. The books, journal articles, and technical reports that we cite in this report are listed (Chapter 5).

Several other activities are part of this study. We completed a evaluation of carrying capacity. We conducted a workshop in Portland, Oregon to ask the questions about the determinants of carrying capacity. We initiated a review of existing data to determine what is known and not know about carrying capacity in the Columbia Basin. These results arc presented in separate reports to the Bonneville Power Administration.

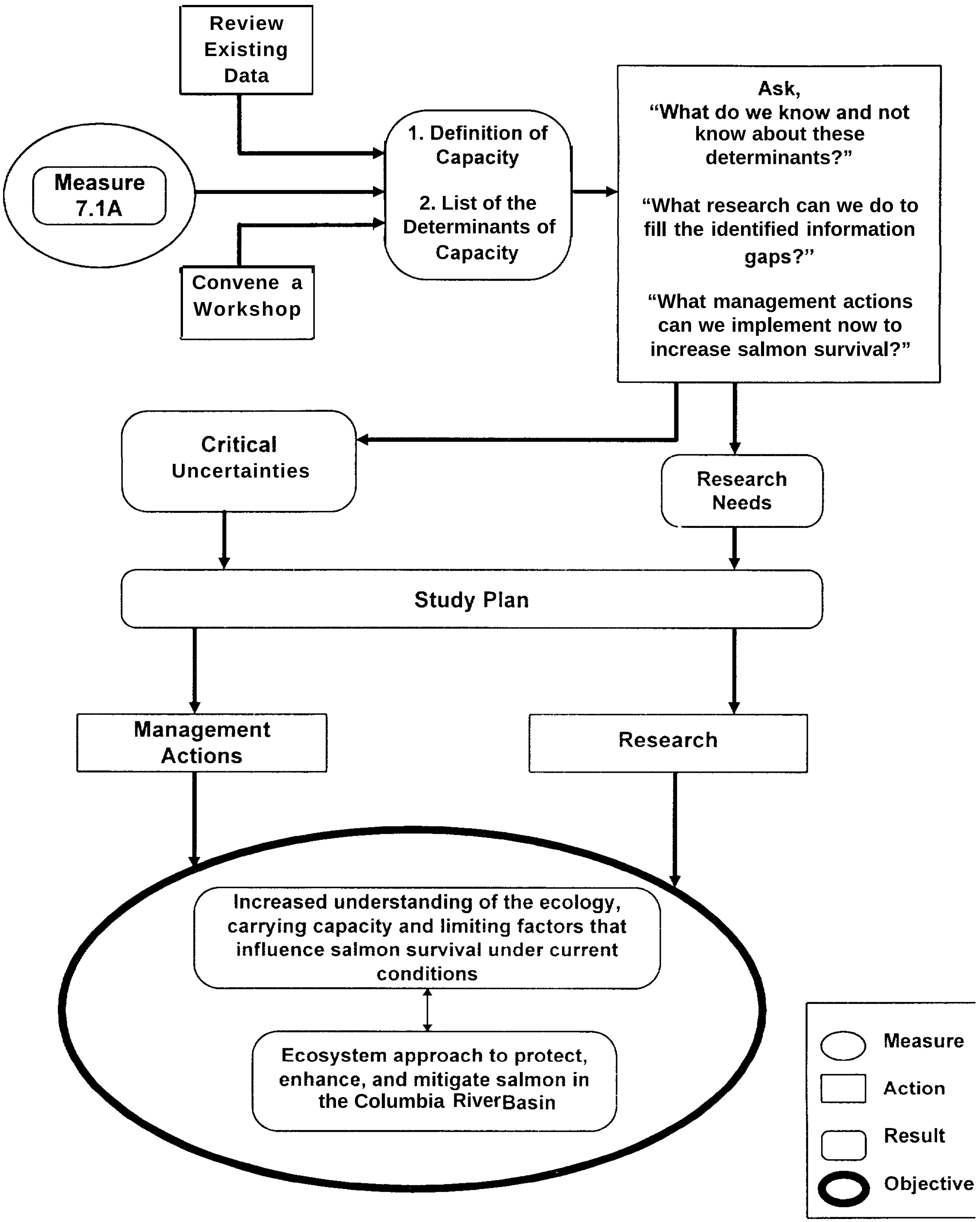


Figure 1. Flow Diagram Illustrating the Approach We Tried to Use to Analyze Carrying Capacity and Develop a Study Plan.

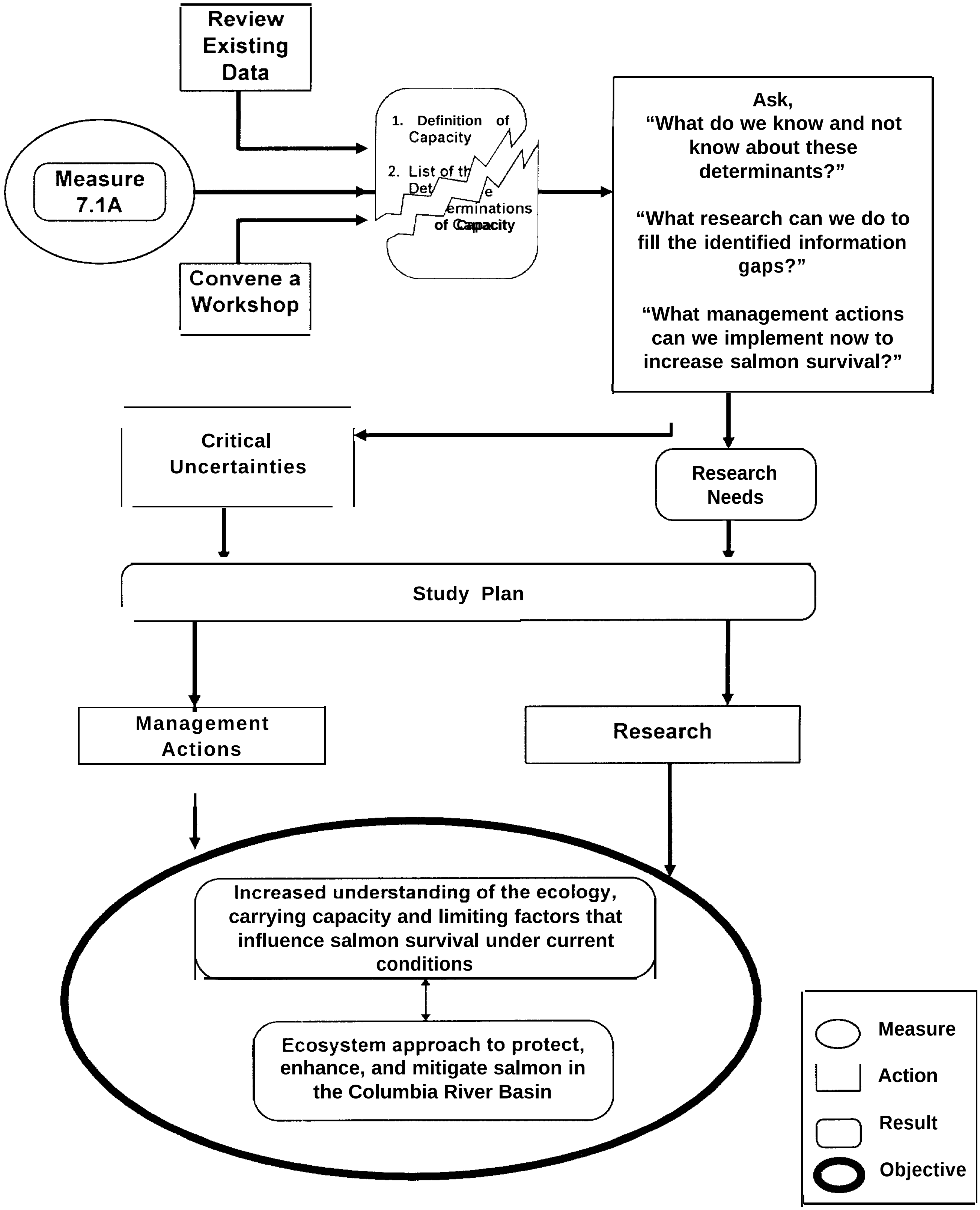


Figure 2. Flow Diagram Illustrating the Breakdown in the Approach We Tried to Use to Analyze Carrying Capacity and Develop a Study Plan.

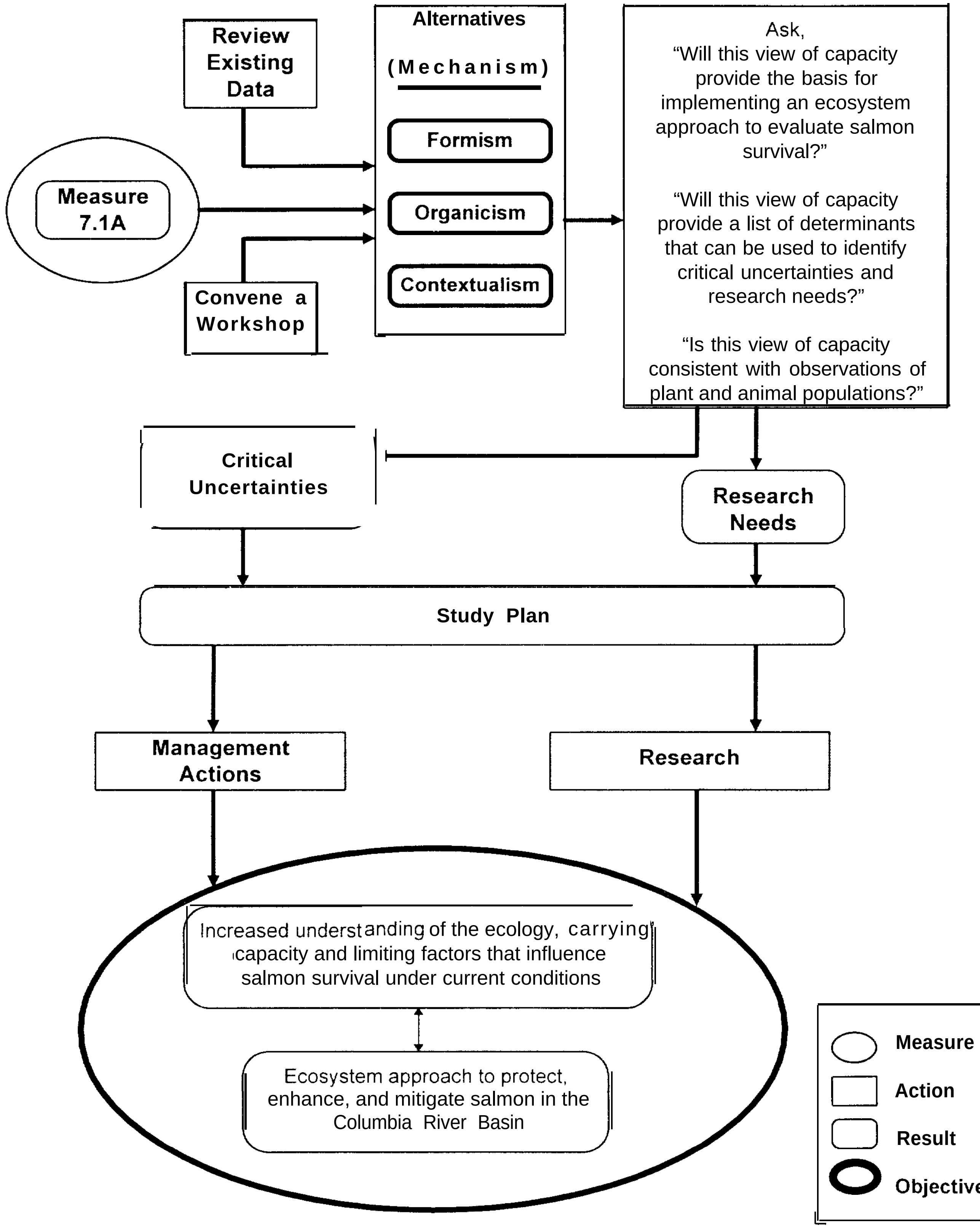


Figure 3. Flow Diagram With a Revised Approach to Analyze Carrying Capacity and Develop a Study Plan.

Chapter 2: ELEMENTS OF A STUDY PLAN

There are definitions or processes to develop study plans in the project management (Steiner 1979, Lewis 1991) and fisheries literature (Kershner et al. 1991). Planning is an iterative or evolving process beginning with a statement of objectives or goals. Objectives must be clearly stated and measurable (Kershner et al. 1991, NRC 1995, Wolff 1995). After the objectives are set, the process follows with the strategies for accomplishing the objectives. the tradeoffs among alternative strategies; culminating with procedures for monitoring progress and documentation of results. We have described seven steps for developing a study plan. They are: set objectives. define alternative strategies. state the assumptions and uncertainties, plan for the resolution of uncertainties, analyze the potential benefits and risks of each strategy, develop a monitoring plan, and establish a documentation and review process.

Objectives

The objectives are statements of planned accomplishments, in other words, what are the objectives of the management measures defined during the evaluation. Objectives should be defined in terms of the question, "w-hat do we want'?" Objectives must be clearly stated. Objectives that are not clear will be resisted and/or ignored because the region will not understand or appreciate what is expected of them (Steiner 1979, Lewis 1991). Objectives must be realistic and achievable. Objectives that demand too much or need to be realized too quickly will overwhelm the region. On the other hand, objectives that demand too little or are too slow to be implemented will challenge the patience and endurance of the region.

Objectives must be measurable. Objectives should state what is expected to happen in precise terms and when. Measures can be stated in terms of quality, quantity. time. cost, ratio, percentage. rate, or specific steps that need to be followed (Steiner 1979).

Strategies

The strategies are the statements of actions to achieve specific objectives. Strategies should be defined in terms of the question, "what will we do to get what we want?" There is almost always more than one possible strategy to achieve an objective. For example. there is more than one way to analyze competition, estimate habitat types, or evaluate effects. Alternative strategies must be identified and clearly defined in the study plan.

Assumptions and Uncertainties

A study plan's assumptions are suppositions or statements of conditions or perceptions under which the stated strategies will achieve the objectives. Assumptions are those statements that we believe are true and therefore provide the basis for developing a strategy to get what we want. The statement of an assumption includes some degree of uncertainty. The strategy may not be doable at a planned time, or for a given quantity or occurrence. This point is of particular importance as study plan elements later become possible research projects. The underlying uncertainties may make some research very risky (i.e., expensive, high likelihood of failure, potential risk to protected species). The assumptions will be the basis for the benefits and risk assessment. Thus, it is very important that we are diligent when we write out all the assumptions. When assumption are not written, benefit and risk analyses become tainted with hidden assumptions that are worthless and misleading in public policy debates (Lackey 1995). To successfully implement the strategies and potential research plans, the uncertainties must be resolved or the risks associated with the uncertainty must be monitored.

Uncertainty Resolution Plan

Within the context of adaptive management, the Uncertainty Resolution Plan (URP) is an operational experiment designed to acknowledge and circumscribe the uncertainties of scientific assumptions underlying the objectives and strategies. The first step in resolution of uncertainties is their categorization according to degree of uncertainty and the perceived ability to resolve the uncertainty. **Acceptable assumptions** are those 1) whose uncertainty present little, if any, risk of adversely affecting the accomplishment of an objective, 2) about which so much is already known that additional research would not be cost-effective and 3) for which management of any risk is highly feasible.

Assumptions with **unresolvable uncertainties** are not expected to be resolved before a management decision must be made, even if the uncertainty is studied during implementation, For most unresolvable uncertainties, resolution is neither feasible nor cost-effective, and may extend beyond the scope the of the project. The risk associated with these assumptions must be addressed in the monitoring plan. As long as the objectives of the management action or research activity are clearly defined and achievable, monitoring will allow for the tracking of potential failure and unexpected change. The ability to distinguish success from failure depends upon the quality and effectiveness of the risk-containment or monitoring program. This is where we test the hypothesis that project strategies in fact work (meet objectives at a minimum risk) and organize the information required to make rational decisions about the future of the project, based on projected benefits and risks. Conclusions about success (achievement of objectives) are manifested in decisions to continue or to reshape the project. The information needed to deal with unresolvable uncertainties can only come from an effective monitoring plan.

There will be some uncertainties that can be **resolved in the near-term.** This should be the most common reason for research. Near-term resolution of an uncertainty will allow managers to select from among alternative strategies to achieve their stated objectives. Finally, there are those **uncertainties that will require long-term studies.** The only apparent means of resolution is hypothesis testing during the implementation phase of selected management actions.

Resolvable uncertainties are a high priority in the near-term because they effect the ability to implement strategies, and because the return on investments of time and resources is high and will facilitate a management decision. Thus, careful prioritization and execution of resolution taskwork (research) are critical to resolving short-term questions. Uncertainty can be resolved through scientific literature searches; small-scale, short-term field and laboratory experiments; large-scale, long-term studies; and by observing studies being conducted in similar systems.

Additionally, an URP needs a project schedule. This is the heart of the URP; the schedule serves to tie everything together. It provides a way of estimating resource requirements, budgets, and schedules. Finally, the project schedule provides a point-of-reference against which to track progress.

The project schedule is embodied in the URP as the sequential pathway composed of experimental and operational components to resolve uncertainties while accomplishing milestones. Although the schedule is interior to the URP, it serves as the interlinear thread between objectives, strategies, assumptions, research (uncertainty resolution), monitoring. and documentation and review. The schedule lays down the critical path, that is, the tasks (research and management actions) that must be completed on schedule, the hierarchy for implementation of these tasks, and delineates the predecessor/successor relationships among tasks. Research and actions can be given specific duration and resources. Research and actions must have specific objectives and must be stated in terms of being completed on schedule. When the assigned research or action is accomplished. a milestone is reached which serves as the start-up of a new component, and thus the adaptive management cycle can continue.

Benefit/Risk Analyses

Is the study plan going to work? Can the elements of the draft study plan provide information to resolve all the questions in Council's Measure 7.1 A? The risk lies in the assumptions that we make[4]. If an assumption is false, then planned research may not provide the answers we seek. Figure 4 describes a decision tree that will help the region rank the assumptions and consequently provide the mechanism to identify risk.

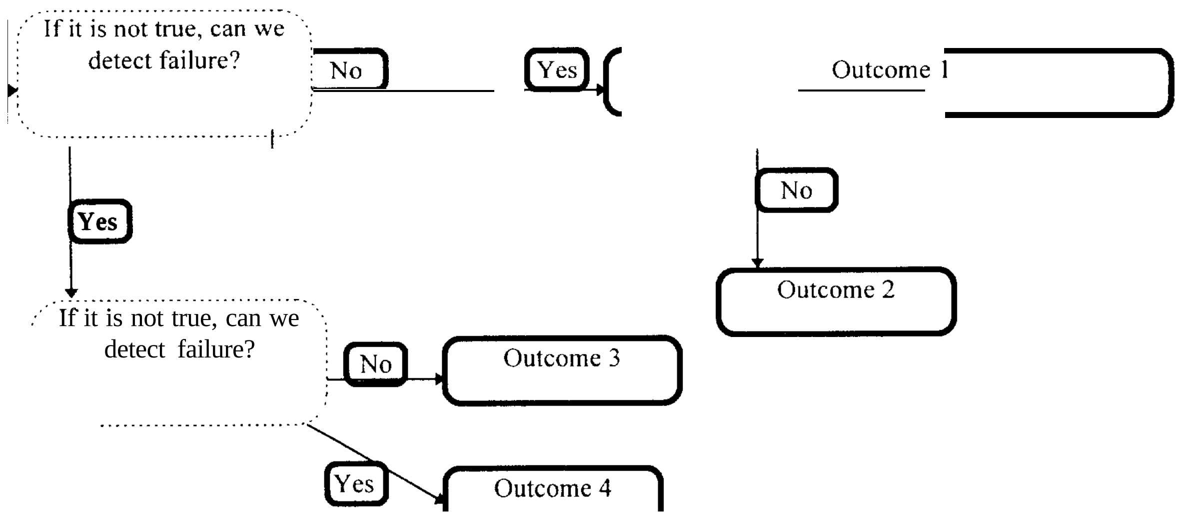
The set of questions displayed in Figure 4 are asked and answered for the selected strategy and must bc repeated for each assumption that is stated in the study plan and all other assumptions that we develop or learn of as we proceed through the evaluation of carrying capacity. The questions asked in Figure 4 can also be used, and perhaps should be used in selecting a strategy. The "most important" assumptions will vary depending on the importance of each of the points in the Council's Measure 7.1 A. For example, if someone contends that competition is the most important limiting factor in the estuary, then those assumptions about competition and the estuary will have greater importance than assumptions about timing. If someone contends that limiting factors in the tributaries are more important than residency time in the mainstem. then those assumptions about the tributaries will have greater importance than assumptions about residency time. The order in which assumptions are assessed is relative to the importance

[4] Risk here refers to the likelihood of failing to meet objectives. The implications of risk as it relates to a strategy or alternative strategies refers to the cost and other potential impacts (e.g.. handling threatened or endangered species. adversely impacting agriculture. not meeting Tribal Trust obligations).

placed by the stakeholder's constituents. This process lays the foundation for BPA to develop a monitoring plan related to recommendations in the study plan.

Monitoring Plan

Failure to meet objectives suggests that a evaluation should be significantly modified or perhaps ended. The ability to distinguish success from failure depends upon the quality and effectiveness of the monitoring program. Conclusions about success are manifested in decisions to continue or to reshape the evaluation. However, these decisions are never final; rather, they are reexamined on an iterative basis. At each iteration, an assessment is made regarding benefits and risks of the evaluation of carrying capacity. Conclusions about benefits and risks are affected not only by new information but also by changing priorities.



Outcome 1	Outcome 2		Outcome 3	Outcome 4
Minimum Benefits and Maximum Risks			**Maximum Benefits and Minimum Risks**	
Correctly conclude strategy fails to meet objectives. There is low probability that we've increased our understanding of ecology, carrying capacity, and limiting factors.	**Incorrectly conclude strategy meets all objectives.** Benefits not realized, risks high. We may increase our understanding of ecology, carrying capacity, and limiting factors, but there is no correlation to the strategy.		**Incorrectly conclude strategy fails to meet all objectives.** Lost opportunity; low probability of increasing our understanding of ecology, carrying capacity, and limiting factors with little risk.	**Correctly conclude strategy meets all objectives.** Hoped-for result. We increase our understanding of ecology, carrying capacity, and limiting factors for salmon and the risks are managed.

Figure 4. Decision Tree for Analyzing Benefits and Risks

Monitoring of any research to evaluate carrying capacity will be related to the risks. Risk relates to: What are the hoped for results (objectives)?, What can fail (strategies)?, and What is important (assumptions)'?

Documentation and Review

Given the fluidity of the adaptive management approach. the process of documentation and review must also be fluid in nature (Hollings 1978, Lewis 1991). Documents must be developed and maintained to reflect 1) the evolution of the evaluation of carrying capacity, 2) evaluations of benefits and risks, and 3) progress toward milestones. Reviewing what is learned will enable the region to map the boundaries of unresolved uncertainties, identify needed resolution taskwork, and lay out the tools necessary to move the evaluation of carrying capacity towards an increased understanding of the ecology, carrying capacity, and limiting factors for salmon in the Columbia Basin. In the best tradition of the business of science, sound documentation will permit reviews from within and outside of the region.

We suggest that three sets of documents be developed for the final study plan. First, a record of the objectives, strategies: assumptions, categorization of the assumptions. benefits and risk analysis, and monitoring plan will be developed. This document will describe the long-range objective of the evaluation. It will also serve as a repository of proposed amendments that grow out of new learning throughout the evaluation.

Second. a record of the tasks designed to resolve the uncertainties identified during the evaluation will be developed. This document should include an evaluation schedule, a sequential pathway of tasks, and evaluation milestones. This will provide an interlinear thread between the evaluation objectives, strategies, and assumptions in the evaluation record. The relationship in the schedule provides a system oftemporal priorities among the uncertainty resolution tasks and the recommended management actions related to understanding the ecology, carrying capacity, and limiting factors for salmon. The schedule considers both the duration of tasks and the sequence in which the evaluation must be done. The schedule contains a critical path which is the longest path through the evaluation and therefore determines the earliest end date for the evaluation (Lewis 199 1). The task hierarchy is established to delineate the predecessor/successor relationships between tasks and milestones.

Third, a record of all the evaluation documentation will be developed. Any report, journal article, letter, memo, or other communication that is used to resolve an uncertainty is recorded and archived. This record communicates the documentary evidence and critical review of' new knowledge gained during the evaluation. Resolution of uncertainties, technical input to management decisions should be based on scientific evidence; hence it is important to have all the technical input peer reviewed.

The seven steps defined here will allow the region to understand carrying capacity and the limiting factors that influence salmon survival under current conditions. Outside the limits of a carefully defined plan, critical uncertainties and research needs are nothing more than a list. A plan should define the objectives of the project, the approach to be taken, and the commitments being assumed by the mangers and key contributors (Lewis 1991).

Chapter 3: DRAFT STUDY PLAN BASED ON CRITICAL UNCERTAINTIES AND RESEARCH NEEDS

The evaluation of carrying capacity was expected to result in the identification of critical uncertainties and research needs (Part 7.1 A.2 of the Measure). We pursued answers to questions asked in Measure 7.1 A and expected results that we could use to develop a study plan as we outlined in Chapter 2 of this report. We conducted a workshop on carrying capacity (Johnson et al. 1996) and started a review of existing data (Costello 1996 a,b). Based on our evaluation, we concluded that the approach inherent in 7.1 A will not result in a study plan that can increase understanding of ecology, carrying capacity, or limiting factors that influence salmon under current conditions (Neitzel and Johnson 1996). However. we did identify some possible objectives, strategies, and assumptions that could be used in a study plan.

These objectives, strategies, and assumptions are listed below. This information is not a study plan. No research or management actions are implied nor should they should be inferred from these lists. We present this information here to illustrate the connections among the various elements of a study plan.

Before completing a study plan for increasing the understanding of the ecology, carrying capacity, and limiting factors that influence salmon survival under current conditions, we recommend that BPA and the Council examine their objectives and all possible strategies. We recommend some methods for accomplishing this examination (Chapter 4). Before we state our recommendations, we present the objectives. strategies, and assumptions that we identified during our evaluation of carrying capacity.

Objectives

Objectives that we identified are:

Table 1. Objectives for Evaluating Carrying Capacity

Objective Number	Objective Description
1	Increase understanding of the ecology of salmon under current conditions in the Columbia Basin
2	Increase understanding of the carrying capacity of salmon under current conditions in the Columbia Basin
3	Increase understanding of limiting factors that influence salmon survival under current conditions in the Columbia Basin

The objectives that we identified are listed in Table 1. Each of these objectives is taken from Council Measure 7A. 1. There are at least two tasks that need to be completed to include these statements as objectives. First, specific elements that clearly define what should be accomplished must be carefully stated. Second. the end point at which each objective is realized should be clearly defined. If possible the end point should be quantified.

Strategies

Seven strategies were identified. As the study plan is developed, a link needs to be established between each strategy and the objective or objectives that will be met by implementing the strategy. As shown in Table 2, we have designated where the linkages can be recorded. We did not complete this task. We did not make a determination about the appropriateness of these strategies as a means of meeting the objectives listed in Table 1. A brief explanation of these strategies and our source for these strategies is discussed in the text following Table 2.

Table 2. Strategies for Evaluating Carrying Capacity

Strategy Number	Strategy Description	Objective Relationship
1	Conduct a patient-template analysis of the Columbia River Basin salmon	
2	Establish refugia with good habitat for salmon	
3	Secure riparian areas, restore them, and restore entire watersheds	
4	Separate, segregate, and partition ocean and estuarine effects from fresh-water effects as much as possible to evaluate humans effects on the river	
5	Protect and improve estuary habitat as well as increase the productivity of the estuary	
6	Adjust the total number of (hatchery) releases in response to fluctuating estuary and ocean conditions	
7	Analyze existing data to identify critical uncertainties, researc needs, and incremental gains in survival from improvements	

Strategy 1 - Conduct a patient-template analysis

The proposed strategy is based on the use of the Ecosystem Diagnosis and Treatment (EDT) process described by Lichatowich et al. (1995). Lichatowich et al. (1995) outline six steps: 1) identify project objectives, 2) patient-template analysis, identify alternative management actions, 3) analyze risk, 4) refine objectives, 5) implement management action and, 6) evaluate results. Lichatowich et al. (1995) provide some of the steps needed to complete much of this study plan. Additionally, these steps are consistent with the guidelines for effective project planning described by Lewis (1991) and the steps for "managing salmonid habitats" by Kershner et al. (1991). The basis for this recommendation is taken from the words of the workshop participants.

Peter Bisson: "...looking at the Yakima historically and now...the reason to do this is to [understand] what has disappeared. What, in reality, can you actually tackle as far as restoring fish populations and habitats?"

Dun Bottom. "(It] comes buck to the patient template idea. To the extent that we remove habitat, we are not just changing the quantity of fish, we are qualitatively changing the system through time.

(Thus,] a life history type may not he able to express itself anymore."

Reg Reisenhichler. "if you are worried about not making things worse with a hatchery program, that is, how many hatchery smolts can you dump into the mainstem Columbia River? [The answer to this question]... will fall out with a patient template analysis..."

Reg Reisenbichler: "... there are two levels of the patient template analysis. One is to prevent further harm being done by some actions we might do, as well us (selecting] a recovery goal. The patient template analysis, it seems to me, to include it all. If we simply go with it all the way...from diversity within stocks out to the ocean."

Strategy 2 - Establish refugia

The proposed strategy is modeled after the watersheds in the Forest Ecosystem Management Team report (FEMAT 1993). Refugia would be set aside with natural salmon production as the primary management objective for the refugia. The basis for this strategy is taken from the words of one of the workshop participants.

Peter Bisson. "I think (it] becomes very important from a management standpoint that we get around to designating areas to act as refugia—for example, in the President's forest plan, there are key watersheds thut were identified in FEMAT. These are areas with good habitat where fish are near the top in terms of management decisions."

Strategy 3 - Secure, restore riparian areas and entire watersheds

The proposed strategy is based on the assumption that early life history habitat (spawning and rearing habitat) are limiting and that enhancing habitat in the tributaries will be an important contributor to increasing abundance. The basis for this strategy is taken from the words of the workshop participants.

Robert Wissmar: "[Examining] FEMAT's plan, the federal government's ripurian research or key watersheds, ..let's make sure we reserve these -- these basins. They muy he 500 square miles or 3,000 square miles, hut they are reserves for the Jirture. We've got to muke sure that we secure these areas and make sure that we understand what is happening. Indeed, are there enough habitats?; Are there the right types of habitats? Do we huvc a hedge, for the future?"

Dale McCullough: "...restore an entire drainage basin from the headwaters down to the mouth, say, the Grand Rhonde, und not tweak the system like we have been... That's not going to result in habitat restoration. We need to open up the rearing areas in the mainstem Grand Rhonde that are no longer usable because they are too warm.. if we restored the habitat. ..genetic capacity would reexpress itself and we'd find thut we could.. huve spring chinook that..fully utilize the habitats, if we really restored it.

Strategy 4 - Separate, segregate, partition ocean/estuarine effects

The proposed strategy is based on the assumption that understanding ocean life history for salmon is needed to meet the Council's objectives for studying carrying capacity. This will permit the region to partition ocean and estuarine effects from humans effects on salmon survival. The basis for this strategy was taken from the words of the workshop participants.

Bill Pearcy: "..we need to get better information on the ocean conditions in the region of the Columbia plume. We do not have good long-term duta there."

Bill Pearcy: "...And I think with [a study of ocean conditions] you cun sort out ocean effects from fresh-water effects und in some cases compare hatchery fish with wild fish from the same system. I think this is really important."

Strategy 5 - Protect/improve estuary habitat/increase productivity

The proposed strategy is based on the assumption that estuarine habitat is limiting and that enhancing habitat in the estuary will be an important contributor to increasing abundance. This strategy is similar to Strategies 2 and 3 in that it provides for habitat protection and enhancement. The basis for this strategy is taken from the Council's Measure.

> *7. IA. 1. " Management measures to protect and improve estuary habitat us well us increase the productivity of the estuary should be identified. "*

Strategy 6 - Management in response to ocean/estuary conditions

The proposed strategy is based on the assumption that ocean and estuary conditions are limiting salmon in the Columbia Basin. The strategy also assumes that management actions can be adjusted on the temporal and spatial scales needed to positively impact the abundance of salmon in the basin. The basis for this strategy is taken from the Council's Measure.

> *7. IA. I. " The evaluation [of carving capacity] should make recommendations for management responses to fluctuating estuary and oceans conditions, such us adjusting total numbers of releases to tuke such conditions into account. "*

Strategy 7 - Analyze existing data to identify critical uncertainties, research needs, and incremental gains in survival from improvements

The proposed strategy is based on the assumption that critical uncertainties and research needs can be identified using existing data. Additionally, there is the assumption that salmon abundance can be quantified and changes in abundance can be attributed to specific improvements in Columbia Basin habitat. This strategy requires a scientific basis in which the analysis will be accomplished and should be considered a subset of Strategy 1 (Patient-Template Analysis). The basis for this strategy is taken from the Council's Measure.

> *7. IA. I. " The evaluation [of carrying capacity] should include analysis of existing data, identification of critical uncertainties and research needs, and estimates of incremental gains in survival from improvement in each area "*

We have listed seven strategies. There may well be many more strategies that can be used to achieve the region's objectives related to understanding the ecology, carrying capacity, and limiting factors that influence salmon. The search for strategies should never end. The discussion of possible alternatives is a chance to re-emphasize the importance of a good monitoring plan. As long as the objectives of the management action or research activity are clearly defined and achievable, monitoring will allow for the tracking of potential failure and unexpected change. The ability to distinguish success from failure depends upon the quality and effectiveness of the risk-containment or monitoring program. This is where we test the hypothesis that the project strategies in fact work (meet objectives at a minimum risk) and organize the information required to make rational decisions about the future of the project. If all proper planning for a study of carrying capacity is completed, decisions about the project's future can be based on projected benefits and risks. This process also provide the mechanism for clearly communicating to all stakeholders about the benefits and risks of the project. Information needed to continued a selected strategy will come from an effective monitoring plan.

Designing the specific elements of a selected strategy (actually the region may want to pursue the objectives by implementing more than one strategy) should be preceded by listing all (as many as possible) the assumptions underlying the strategy. Assumptions are "the facts," "the reasons," "the truths" that we know about what we plan to do (the strategy) to get what we want (the objective). Assumptions should be documented and specifically tied to the planned strategies.

Assumptions and Uncertainties

Thirty-eight assumptions were identified. As the study plan is developed, a link needs to be established between each assumption and the strategy or strategies to which the assumptions relate. As shown in Table 3, we linked these assumptions to strategies listed in Table 2. The assumptions listed are taken from the Council's Measure 7.1 A, statements of the workshop participants, and information gleaned from the literature review.

Table 3. Assumptions Related to the Strategies Identified in Table 2

Assumption Number	Assumption	Related Strategy
1	Current salmon survival in the Columbia River tributaries, mainstem (including reservoirs), estuary, near-shore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
2	Historic salmon survival in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
3	Current ecology in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
4	Historic ecology in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
5	Current carrying capacity in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
6	Historic carrying capacity in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7

Table 3 (Continued). Assumptions Related to the Strategies Identified in Table 2		
Assumption Number	**Assumption**	**Related Strategy**
7	Current limiting factors in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
8	Historic limiting factors in the Columbia River tributaries, mainstem (including reservoirs), estuary, nearshore ocean, and ocean can be evaluated	Strategies 1, 4, and 7
9	Competition between non-native species and anadromous salmon can be evaluated	Strategies 1, 4, and 7
10	Negative competitive interactions resulting from hatchery management practices can be evaluated	Strategies 1, 4, and 7
11	Current salmon carrying capacity of the Columbia River mainstem, tributaries, estuary, plume, and nearshore ocean can be estimated for juvenile fish using existing data	Strategies 1, 4, and 7
12	The effects of the alteration and timing of the ocean plume as caused by the construction and operation of the hydroelectric system can be evaluated	Strategies 1, 4, and 7
13	The effects of residency time and smoltification can be evaluated	Strategies 1, 4, and 7
14	Management measures to protect and improve estuary habitat as well as increase the productivity of the estuary can be identified	Strategy 5
15	Management can alter the number of hatchery fish released in response to fluctuating estuary and ocean conditions	Strategy 6
16	Incremental gains in survival of salmon can be estimated for any potential management action in the tributaries, mainstem, estuary, plume, nearshore ocean and ocean	Strategy 7
17	The optimal timing for residency in the estuary and the nearshore environment can be evaluated	Strategy 5
18	The establishment of refugia will provide information to increase our understanding of ecology, carrying capacity, and limiting factors	Strategy 2
19	The protection of riparian habitat will provide information to increase our understanding of ecology, carrying capacity, and limiting factors	Strategy 3
20	Protecting the estuary will provide information to increase our understanding of ecology, carrying capacity, and limiting factors	Strategy 5
21	Protecting the estuary will increase the productivity of the estuary	Strategy 5

Table 3 (Continued). Assumptions Related to the Strategies Identified in Table 2		
Assumption Number	**Assumption**	**Related Strategy**
22	Many of these critical habitat variables can be readjusted to historical levels by some fairly simple management prescriptions (Dale McCullough)	Strategy 3
23	Sediment loading limits salmon production (Dale McCullough)	Strategy 3
24	Limiting light to the stream, reduces temperatures, expanding the available rearing area (Dale McCullough)	Strategy 3
25	Water temperature in the headwaters effects biomass downstream (Dale McCullough)	Strategy 3
26	The limits imposed by the estuary differs between ocean-type and stream-type fish (Si Simenstad)	Strategies 1, 4, 5, and 7
27	Food limits salmon survival under current conditions (Bill Pearcy)	Strategies 1, 4, 5, and 7
28	'Removing bottlenecks will result in unlimited production within the streams, lakes and rivers of the basin' (Dan Bottom quoting Seth Green)	Strategy 6
29	Limiting factors can be defined for each life stages (Dan Bottom discussing fish culture history)	Strategy 6
30	Maximum sustainable yield can be used to control harvest (Dan Bottom discussing harvest management)	Strategies 1, 4, and 7
31	Fish growth varies from year to year (Dan Bottom)	Strategies 1, 4, and 7
32	Limiting factors are constantly fluctuating (Dan Bottom)	Strategies 1, 4, and 7
33	Limiting factors are not independent (Dan Bottom)	Strategies 1, 4, and 7
34	Limiting factors between life stages interact (Dan Bottom)	Strategies 1, 4, and 7
35	There is no one habitat that necessarily over time and space is going to constitute a limiting factor (Si Simenstad)	Strategies 1, 4, and 7
36	All determinants...just about anything you can put on [a] list will be important at some time in the life-cycle (Chuck Coutant)	Strategies 1, 4, and 7
37	Dissolved oxygen can be limiting during egg incubation (Chuck Coutant)	Strategies 1, 4, and 7
38	Restoring productivity in the upstream portion of the basin does not require removing limits in the mainstem (Dale McCullough)	Strategy 3

Assumption lists are "living" documents. New assumptions should be documented (written down) as they are identified. All assumptions imply some degree of uncertainty. Adaptive strategy implementation requires decisive action in the face of uncertainty (Lee 199 1). Inevitably, some assumptions underlying selected strategies will be weaker than others, perhaps even untrue. The risks of using resources to increase our understanding of ecology, carrying capacity, and limiting factors are explicitly related to our confidence in the validity of the evaluations base of assumptions. Additionally, the potential benefits and risks of management recommendations that result from an increased understanding are founded in the assumptions we make. And we should always remember the risks are not only to the fisheries resource but also related resources (e.g., cultural, historical, nontarget species, flood control, agriculture, recreation, power generation, transportation).

Research needs are defined by the uncertainties underlying the assumptions. The most important uncertainties are the uncertainties that will command the region's resources (i.e., money, time, personnel, research fish). Priorities must be established, specific tasks must be defined, and schedules must be determined. This planning work will complete the study plan and provide the region with a plan that can be implemented to increase our understanding of ecology, carrying capacity, and limiting factors.

The elements in only three of seven steps are presented here. The work needed for steps 4-7 was not completed as a product of this contract. The Council's staff asked that the work be terminated after Step 3. *The draft study plan reported here is only a list.* The work needed to complete the study plan can be accomplished by preparing an uncertainty resolution plan, conducting a benefit and risk analysis, developing a monitoring plan, and establishing a system for documentation and review.

Chapter 4: CONCLUSIONS AND RECOMMENDATIONS

To pursue the capacity parameter as a single number or set of numbers that quantifies how many salmon the basin or any part of the basin can support, will not provide useful information to meet the objective of Measure 7.1 A. The region "must *recognize and protect...diversity...It is not enough to focus only on the abundance of salmon*" (NRC 1995). We have to realize the quality of whatever happens to be at the present time. Then, significance lies in the purpose of what we are pursuing. Bella (1995) describes the need to move toward a "*healthy environment strategy.*" He claims that the assessment and management of the many activities responsible for the decline of salmon in the Pacific Northwest are hindered by fundamental misconceptions. Management and policy have been dominated by presumptions that fail to grasp the complexity of human and salmon interactions (Bella 1995).

In closing, we conclude and recommend that:

- The study plan (Chapter 3) presented in this report is only a list of possible objectives, strategies, and assumptions. No determination has been made as to the appropriateness of the objectives for meeting the region's needs related to evaluating carrying capacity. BPA and the Council should examine their objectives and all possible strategies before completing a study plan.
- A study plan needs to have clearly stated achievable objectives. These objectives need to be linked to specific strategies and the assumptions underlying the strategies need to be documented., This will provide the means to develop an uncertainty resolution plan, analyze benefits and risks, develop a monitoring plan, and develop a documentation and review process. The Council should request that BPA use the element described in Chapter 2 of this report to complete a study plan for evaluating carrying capacity.
- Strong inference (Platt 1964) provides a scientific basis to evaluate carrying capacity in the Columbia River Basin. All proposed research and proposed management actions should include the steps defined by Platt (1964): Devise alternative hypotheses (strategies); devise experiments (research and management actions), with alternatives, to exclude one or more of the hypotheses; carrying out the experiment or action to get clean results; recycle this procedure (learn and adapt).
- The patient-template analysis is a tool that could be used to evaluate carrying capacity in a manner that recognizes the complexity of salmon performance in the Columbia River Basin. The Council should call for a patient-template analysis, as described by Lichatowich et al. (1995). The region will be able to evaluate carrying capacity under current conditions, compare current conditions to historic conditions and thus, predict possible future conditions for salmon in the Columbia River Basin.

In closing, Measure 7.1 A is a microcosm of the entire Program. It is based on a framework[5] that is not working. The carrying capacity measure and the Program as a

[5] During most of this report, we discuss hypotheses and views. When we discuss the need for a new framework, we mean to use a broader term. We include three elements, when we use the word framework:

whole need a new framework. The new framework should be based on the recognition and protection of the entire life cycle of salmon and not on abundance of salmon alone. The framework should be consistent with observations of salmon populations and incorporate the complexity of the population's attributes. The framework must accommodate the connectivity among life stages and the interrelationships among capacity, diversity, and productivity within the Pacific Northwest ecosystem. Without reevaluating the current framework-of the Program, we conclude that it is not possible to develop a useful study plan for evaluating carrying capacity.

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theory, tasks and tools. The theory is the general proposition or principles we use to explain the events we observe. Theory results from our view of the ecosystem and the hypotheses that we test. The tasks are the commitments, processes, and institutional requirements needed to carrying out the Fish and Wildlife Program. The tools are the instruments of management needed to analyze data, schedule projects, resolve conflicts, and make sure our actions are moving us toward our objectives.

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