Status and Future of Anadromous Fish of Western Oregon and Northern California: Rationale for a New Approach

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A Non-Profit Corporation

Anadromous Fish Populations and Forest Practices of Oregon and Northern California: Rationales and Perspectives:

Santa Barbara, California and Portland, Oregon

PREFACE

The Center for the Study of the Environment (CSE) was established in 1992 as a private, non-profit organization to conduct research directed toward finding constructive solutions to environmental problems. The Center seeks to provide an objective basis from which research and education can be used to determine environmental policy options and facilitate sound environmental decision-making.

This CSE report is the first in a series of reports published as part of a study of the anadromous fish of western Oregon and northern California conducted by the Center in accordance with a contract from Oregon State University. In 1991, the Oregon Legislature charged the Oregon Board of Forestry to commission a study to "assign the relative importance of forest practices" to the decline in anadromous fish and to "make recommendations as to how forest practices can assist in recovery of anadromous fish populations." CSE is conducting the study through funds provided by Oregon Senate Bill 1125 Section 25 (1991); additional funds have been made available from the State of California Department of Forestry and Fire Protection (CDFFP).

The goals of the study are to conduct an objective, non-ideological analysis of existing information and provide a synthesis of policy options for constructive solutions to the decline of the fisheries. The implications each policy option could have on environmental conditions and ecological processes will be explored. CSE will also suggest ways that management can be improved by improving its connection with scientific research.

Anadromous Fish Populations and Forest Practices of Oregon and Northern California: Rationales and Perspectives:

This report, *Status and Future of Anadromous Fish of Western Oregon and Northern California: Rationale for a New Approach* (Report No. 931001), was written to provide an overview of the approaches, rationale, and underlying assumptions of the larger study. *Status and Future of Anadromous Fish of Western Oregon and Northern California: Related Studies* (Report No. 931002) describes 25 studies directly or indirectly related to the issues of anadromous fish and their habitats in the Pacific Northwest. *Status and Future of Anadromous Fish of Western Oregon and Northern California: Available Data on Fish Populations* (Report No. 931003) provides a listing of 183 data sets available on anadromous fish populations and forest practices. Additional reports, including a final report, incorporating all interim findings as well as conclusionary material and options, will be written in 1994 and submitted to the Oregon Legislature and the CDFFP in January 1995.

This report does not contain recommendations or conclusions, nor provide a set of policy options. Such recommendations and policy options are the purpose of the final report. We invite readers of this report to contact CSE with their comments, suggestions, and information regarding additional data. For this purpose, reply forms are available from CSE and can be obtained from the Santa Barbara office: CSE, 301 E. Carrillo Street, Santa Barbara, CA 93101.

Acknowledgments

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Coastal Zone Management Association, the Oregon Department of Water Resources, and the Oregon State University College of Forestry. We also appreciate the time, effort and suggestions of the Overview Committee under the direction of Dr. Thielges. The authors would like to acknowledge the contributions made at open meetings by citizens and citizen organizations.

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THE STUDY

CSE has been commissioned through this study to conduct a scientific inquiry into the relative effects of forest practices on anadromous fish runs in western Oregon and northern California. Specifically, the Center will:

- identify the leading causes, both on-shore and off-shore, for declines in anadromous fish populations, if that is found to be the case;
- assign the relative importance of forest practices to these declines;
- identify the relative importance of various habitat characteristics in streams in limiting anadromous fish production;
- determine how forest practices have affected fish production;

◦ determine how forest practices have affected these habitat characteristics and anadromous fish populations before and since 1972;
◦ identify the extent to which forest practices are limiting the recovery of depressed anadromous fish populations; and
◦ make recommendations as to how forest practices can assist in recovery of anadromous fish populations.

Structure of the Study

This study is composed of the following elements:

(1) a "Blue-Ribbon Panel" of independent experts (see below) that oversees the entire process and is responsible for the final report and recommendations;
(2) a project director, Dr. Daniel B. Botkin, who is responsible for conducting the project;
(3) the staff of CSE, including a full-time research assistant, which gathers, compiles, and assists in the analysis of the data; and
(4) subcontracts awarded to individuals and organizations to conduct specific tasks essential to the project beyond the scope of the panel, director, and CSE staff.

Subcontracts are made primarily to accomplish the following:

(a) seek out, make available, and integrate unpublished data in reports that are not widely accessible;
(b) integrate and synthesize these data with published data;
(c) conduct new kinds of analyses on existing data; and
(d) infrequently, obtain new data and conduct new research on specific, applied topics essential to the study.

Anadromous Fish Populations and Forest Practices of Oregon and Northern California: Rationales and Perspectives:

The CSE Panel of Experts

The CSE Blue Ribbon Panel consists of scientists who have established national and international reputations, but have not been involved directly in the environmental controversies concerning anadromous fisheries and forest practices in the Pacific Northwest. These scientists represent a range of disciplines important to the broad concerns of the study. The panel oversees the study, which means that it will determine the set of policy options and author and accept responsbility for the content of the final report. In this task, the panel does not seek to establish policy, which is a matter for the legislature and citizens of Oregon, but to provide the basis from which solutions can be found and policies adopted. The approach taken here emphasizes the cooperative effort of all interested parties in formulating constructive solutions.

Dr. Daniel B. Botkin is an ecologist who has worked on forest ecosystems and on large-scale assessment of forest conditions, as well as on assessments of endangered species. He is the Director of the Program on Global Change, George Mason University, and President of CSE.

Dr. Kenneth Cummins, whose field is stream and river ecosystems and fresh water fish populations, is Professor of Biology and Director, Pymatuning Laboratory of Ecology, University of Pittsburgh.

Dr. Thomas Dunne, whose field is effects of land-use practices on the shape and form of streams, is a Professor in the Department of Geological Sciences, University of Washington, Seattle.

Dr. Henry Regier, whose field is the Great Lakes as ecosystems and is experienced in the processes of international agreements for the conservation and management of these lakes, is Professor at the Institute for Environmental Studies, University of Toronto, Canada.

Dr. Matthew Sobel, who is an applied mathematician who works on stochastic processes and risk analysis, is Dean of Harriman School of Management and Policy, State University of New York, Stony Brook.

Dr. Lee M. Talbot, whose field is biological conservation and who is a leader in international conservation, is a former director of the International Union for the Conservation of Nature, and currently Senior Ecologist, Environment Division, Africa Region, The World Bank, Washington, D.C.

Study Area and its Divisions

The study area includes western Oregon south of the Columbia River and west of the Cascades, continuing south to include the Klamath and Trinity watersheds in California (Figure 1). It includes four geographic regions: (1) from the Columbia (but excluding that river) south to (but not including) the Umpqua River; (2) from the Umpqua south to (but not including) the Rogue River; (3) from the Rogue south to the Klamath River in California; and (4) the Willamette watershed (from the crest of the Cascades west to the Willamette River and the western limits of its watershed).

From a landscape perspective, a unit of this study is the watershed of a major river. A major river is defined as one within the study area that flows into the ocean, and the Willamette, which flows into the Columbia. Because migratory salmon spend a part of their lives in the ocean, and habitat conditions in both streams and the ocean strongly affect the sustainability of salmon stocks, what can be done in streams to foster salmon is related to what can be done to protect salmon in the ocean. Thus the study area extends to the relevant coastal and oceanic waters. From a population dynamics perspective, a unit of the study is either a species of fish or a specific stock of a species, depending on the goal chosen and the question asked. A stock is defined as a population within a species that spawns in a specified, geographic region, the size and configuration of that region varying with landforms and the history of the population.

Assumptions of the Study

CSE, the panel, and those involved in this study assume the following tenets:

- Rational solutions are possible for complex environmental problems. By a rational solution we do not mean a complete, definitive solution. We mean more simply a solution that is based on the best available data, and is the result of analyses of those data and of deductions drawn from those analyses.
- Rational solutions based on the best available scientific information are preferred to solutions based largely on emotion or ideology.
- It is possible to take constructive actions even though information may be incomplete.
- Research and management are integral parts of the same

processes and should proceed continually and concurrently.

- A completely definitive answer based on all the data desired or needed is seldom possible. With complex issues such as those concerning anadromous fish of western Oregon and northern California, the best that usually can be done is to accept what has become known as "weight-of-evidence" approach. One arrives at a decision from insights based on experience and knowledge, and from deductions — both arising from analysis of available data, however incomplete. This is, in fact, what we mean above when we discuss rational solutions.

Valid scientific information is defined as information that has been gathered according to a valid sampling protocol, for which an estimate of error exists, and which is open to objective tests of falsification. Simply stated, we have looked for information that has a sound scientific basis and can be tested as valid or invalid. In the work conducted to date, a major constraint has been the gray literature and non-peer-reviewed nature of the literature containing most of the relevant information. The term "gray literature" refers to reports that are not published in standard scientific journals or professional books, but are found in files or as occasional reports from government agencies and non-governmental organizations. Typically, gray literature is difficult to obtain, and is rarely subject to review by scientific peers. When most of the information exists as gray literature, and when there are major gaps in data, standard scientific analysis is often not possible. In such cases, one must use the weight of evidence approach mentioned earlier. The weight of evidence approach must go beyond the usual scientific method. Conventional rigorous science is necessary, but not sufficient for such complex issues.

Stages in the Study

The study consists of three phases: an initial phase during which CSE staff and the panel examined what is known and the scientific quality and reliability of the existing information about anadromous fish and their habitats. In this phase, CSE attempted to separate scientific belief from valid scientific information as defined above.

The first phase indicated areas for which new analyses, synthesis, and in some cases new data were required. In the second phase, some of these areas are pursued, in part by CSE staff and the panel, in part through subcontracts to individuals and organizations with appropriate expertise. In the third phase, the panel will take the results of phases I and II and write a final report, providing the panel's understanding of the situation and its recommendations for a set of policy options.

INTRODUCTION

This paper has been written to give a concise overview of the assumptions, rationale and perspectives underlying the new approach taken in CSE's study of anadromous fish populations and forest practices in western Oregon and northern California.

(TABLE 1: Major Rivers of the Study and Their Characteristics)

Why Another Study?

In CSE's *Status and Future of Anadromous Fish of Western Oregon and Northern California: Related Studies* (report no. 931002) we provide a brief description of 25 studies related to anadromous fish populations and their habitats in the Pacific Northwest. An obvious question the reader might ask is: Why another study? The short answer is: Major changes are taking place in the perception of environmental issues, in our abilities to deal with these issues, and in the context within which these issues are viewed. New times, new problems, and new perspectives call for new approaches to environmental issues. Underlying the CSE study of the anadromous fish of western Oregon and northern California is an attempt to seek a new approach. This paper explains this new approach.

Changes in the Responsibilities of Government Agencies

Among the changes taking place in environmental problem-solving is an altered perception of the mission and responsibility of government agencies. Those in state agencies in charge of natural resources such as the Oregon Department of Forestry (ODF), the Oregon Department of Fish and Wildlife (ODFW), the California Department of Forestry and Fire Protection (CDFFP), and the California Department of Fish and Game (CDFG) are undergoing major transitions.

There are approximately 25 different agencies that have jurisdiction over the fresh water habitats and associated terrestrial ecosystems. Each government agency has its unique set of jurisdictions and a different, specific set of actions available to it. Previously, these agencies were primarily in charge of providing an abundance of a single harvestable resource, such as timber or fish; now a primary responsibility of each is to assist in sustaining entire ecosystems. They find themselves under pressure to conserve the landscape for many uses and to accommodate the desires of a majority of people in our society who are changing their evaluation of environmental resources. This change in the perceived goal requires a very different approach to management, and it is one of the strong factors underlying the need for the study reported on in this document. In addition, the processes of arriving at agreements about how to deal with environmental issues are undergoing a change. There is a movement away from a heavy reliance on legal confrontation to participating in conflict resolution or even co-management (See Table 2: New Transdisciplinary Inquiry). There are also major changes in scientific understanding of ecological systems, as discussed in the next section.

Changes in Environmental Science

Natural ecological systems are complex, and the sciences that deal with these systems are new. Although rapid advances have been made in environmental sciences during the past several decades, often little pertinent historical data has been collected at the appropriate time and space scales, resulting in little understanding of the processes that determine changes in these systems over time.

Environment has always been important to people, and there is a set of deeply held cultural attitudes about nature. One of the most tenacious of these myths is the belief in the classic "balance of nature" — the belief that nature is constant in form and structure and would persist forever in a single condition as long as people did not interfere. According to this myth, the populations of anadromous fish of western Oregon and northern California would have maintained a constant abundance prior to human intervention, regardless of changes in climate, ocean water masses and currents, or the abundances of predators, diseases, and competitors. According to an extremely unrealistic version of this myth, the forests of the Northwest would have existed as a homogenous, continuous old-growth entity from the oceans to the Cascades.

Sometimes, mere anecdotes and analogies are accepted as if they were scientific explanations. For example, some experts on whales have explained social behavior of sperm whales on the assumption that the organization of a group of whales must be the same as the organization of a herd of antelopes in Africa. Unfortunately, such simple analogies are not likely to be true, and therefore are a poor basis for policy.

Modern scientific information tells us that all ecological systems, including these forests and fish populations, are dynamic and undergo radical changes over time. Populations of fish change in abundance over time. Natural forests are subjected to fires, storms, and other longer term sources of variation and changes in state, such as volcanic activities and climatic changes. Such processes that lead to comparatively rapid changes in the state of ecological systems are commonly referred to as "disturbances."

Experience has shown that management policies derived from the "mythical" beliefs previously discussed typically lead to failures, rather than successes.[1] [2] Given this situation, it is essential that we approach complex environmental issues by determining the extent and limitations of existing information and by developing a thorough understanding of ecological processes. We must then seek to establish methods for assessing policy options and making practical decisions with the insufficient information that is available and with events that vary over time.

Implicit in the approach we are taking is a new paradigm that centers on an understanding that old growth forests always consisted of young, intermediate, as well as old-growth stages; that there is not a single "natural" condition, but a variety of conditions that could be considered natural; and that fisheries must be managed with the understanding that these populations will vary in predictable ways over scales of space and time with or without human intervention.

The idea of rapid changes in the state of an ecological system will appear repeatedly in this document. It is therefore worthwhile to make the following point. The term "disturbance" is used in ecology to refer to two kinds of events: those that are variations characteristic of the system, such as fire and floods in forests of the Pacific Northwest, and novel alterations, such as the introduction by people of a new chemical pesticide. The first is "natural" in the sense that this kind of change has occurred throughout the history of the system and species have evolved and adapted to such changes. Alterations such as fires and floods are therefore not disturbances in the sense that they are unusual. Whether such processes have desirable or undesirable effects on the system depends on frequency, intensity, and size of the events.

There have always been changes and variations in ecological systems, such as fires and floods, but the spatial arrangement and time course of these events is on scales that are quite different in the last several 100 years as opposed to the last several 1,000 years. Since the end of the last glaciation, forests in the Pacific Northwest developed so that old-growth stages dominated much of the land, interspersed with less abundant patches of early and mid-successional stands. In several hundred years this has been reversed. We have created a landscape in which the dominant pattern is early and mid-successional stages interspersed with much less abundant patches of old growth. The basic elements of the system have not changed but the spatial pattern and rates of change are unprecedented in the 10,000 years since the glaciers.

Changes in Societal Attitudes

In recent years there has been a major shift in the perception of environmental issues by our society. A 1990 national survey by the Environmental Opinion Study, Inc. of Washington, D. C. suggests that 82 percent of voters place the environment among the top three or four national issues. If required, 72 percent would sacrifice economic growth for environmental quality, but 82 percent believe that creating a cleaner and greener environment will increase jobs and income levels. Today, most elected officials profess to be "environmentalists." This is a far cry from the 1960s. The 1960s was a decade of environmental confrontation. In this decade new environmental legislation began to emerge, such as the Water Pollution Control Act of 1962. Confrontation established public awareness and was perhaps necessary; much that was of benefit to the environment began in this decade, setting the stage for the 1970s.

The 1970s was the decade of national environmental law. We began to control pollution and promote conservation through landmark legislation. At the 1972 Stockhom Conference on the Human Environment, the global extent of human influences on the environment was recognized. In the 1980s, awareness of the global extent of our environmental problems became widespread. Hopefully, the 1990s will mark the beginning of a new era in which environmentalism rises from emotionalism and matures into rational problem-solving. Because of new advances in sciences and changes in our perception of problems, this decade could be the time when we begin to understand the role of citizens, politicians, and experts in solving environmental problems. (See Table 2).

SCIENCE, VALUES, MINDSETS, UNDERSTANDING AND INTERVENTION

The discussion earlier in this report suggests that "solving environmental issues" means participating in a process that is continually refined as information and understanding improves, but where, at any time, we may arrive at decisions using the best information available. It does not mean obtaining final, definitive answers. If we accept the idea of a "solution" as part of an ongoing process, the question is not so much *can* we find a way to deal with environmental problems from a technical and scientific point of view. Rather, it is *whether* we have the political and personal will, within the context described earlier.

In the end the course we take in environmental problem-solving may determine whether we can resolve environmental problems within a democratic form of government. Most people want both continued use of environmental resources and an environment of high quality. These dual desires require that we find a way to achieve sustainability of forest products while also maintaining sustainable forest ecosystems, sustainable fish products while maintaining sustainable fisheries; and, needless to say, sustainable wildlife populations.

A Need for Scientific Information

To achieve these objectives we need soundly-based scientific information, scientifically-based concepts about the environment, and collaborative problem-solving. The goals that are possible depend on the inherent characteristics of ecological systems and human societies. We base our choice of these goals on societal values. How we achieve these goals depends in part on people's understanding and methods — in other words, on the interface between scientific practice and environmental management.

One of the problems that we face when addressing environmental issues is a significant lack of basic information — information about the current state of the environment, about how the environment has changed in the past,and about what the environment was like before large-scale and accelerated human intervention and the impacts of modern technological civilization. Such information is necessary if we are to make realistic projections about how the environment will change in the future.

In our rush to address pressing environmental problems, there is a danger that we will seek to establish policies without seeking the information and scientific understanding necessary for wise policy-making. As a society, we have not yet determined how scientific information and knowledge will contribute to the process of establishing environmental policy. In the past two decades Americans have relied heavily on the courts to do this.

They have been disappointed and are seeking alternative or complementary means that are not yet well worked out. At one extreme, some believe that knowledge and scientific understanding should play no role and that the issues are entirely aesthetic and moral. At the other extreme are those who believe that science can and will provide a final, definitive answer independent of human values, and that we must wait until that answer is obtained before changing policy or taking action. We believe that neither of these points of view is appropriate.

The limitations of these extreme points of view is perhaps clarified by a medical analogy. Suppose you break your leg today in a complex manner while skiing. Your doctor does not say, "I won't fix your leg now, because I know that in a few years medical research will find a much better way to repair it." Rather, he uses the best available techniques to do the best job he can. On the other hand, because he can repair your broken leg does not mean that all medical research on bone injury should stop. In medicine, practice and research are understood to continue simultaneously and to contribute to each other's progress. So it should be with environmental issues. A prudent person would act now, using the best available information, but would also be willing to modify his policies and actions as new information becomes available. He would support the continuation of research and monitoring with the hope that this will provide better understanding and better information in the future.

Applied scientific research and public policy-making are both social processes, both are linked, and both must be part of the approaches and solutions to environmental problems. The role of the scientist is to advise: 1) what options are available to achieve a goal; 2) the implications of each option for the human population; and 3) the implications of each option for the environment (effects, benefits, changes in states of ecological systems, and so forth).

What lies before us is the difficult task of honestly confronting the means to address environmental issues. We can no longer take the easy path of confrontation, in which we satisfy ourselves with our own self-righteousness and with which we can win environmental skirmishes. In following such a path we will lose the ability to sustain our natural resources. Why? Because these issues are too complicated to be solved in a yes or no way.

In Oregon and California, the situation has reached a crucial apex over issues of logging old-growth forests, conservation of endangered species, maintenance of the anadromous fish, and sustainable, economically-viable industries centered on forestry, fishery, tourism and energy-intensive manufacturing. The danger is that the old traps — of confrontation, emotionalism, simplistic scientific assumptions, and abandonment of the search for scientific knowledge — tendencies that occur on all sides of issues — may lead to a situation in which the lines are so strongly drawn that no solution is possible. If we accept this situation, we are in danger of losing both the viable forest and fishery industries as well as our biological resources.

A Rational Approach to Environmental Issues

Earlier it was suggested that a certain kind of "rational" approach to environmental issues was possible. It is worth repeating that by a rational approach we do not mean a complete, definitive answer that applies to all places and all times.

Instead, we intend a much more restricted meaning: that it is possible to work out a reasonable way to deal with an environmental issue by careful examination of available data, from logical deductions gained from analysis of those data, and by insights gained from both the data and analyses. Several steps are involved in a rational approach to environmental issues:

(1) setting up a program for long-term baseline measurements and monitoring of key ecological and resource factors;

(2) achieving an understanding of ecological systems by moving beyond myths to hard facts and observations;

(3) understanding the various societal roles of scientists, government administrators, elected officials, and citizens;

(4) determining which variables are the source of disagreement and how these variables might be better measured so that we can focus on facts; and

(5) determining how the variables that depend on personal values can be put on the table, clearly defined, and alternative methods considered — in other words, engaging in cooperative problem-solving.

In this process we must set down goals and assemble the facts in a straightforward manner so that we know their implications, understand the policy options, and then, through our democratic processes, choose which option to follow.

In the approach described earlier and in the approach used in this study, the scientific method is a necessary basis for addressing issues concerning the management of the forests of western Oregon and northern California, including the formulation of regulations for these forests. The scientific method includes both sufficient information — facts, data, statistics — and soundly-based scientific concepts. These concepts should have their base in scientific findings, not informal beliefs about the environment. However, to say that we need good scientific information does not mean that social processes, including policy-making, must stop until science achieves some perfect, final answer. Scientific study is a process, as is policy formulation. Both must proceed at the same time. Policy formulation can proceed using the best, currently-available scientific information, while the pursuit of additional scientific information can lead to improvements in policy in the future. The process is one of successively improving approximations, which is sometimes referred to as "adaptive management."

Although the process of developing an adequate scientific basis is necessary to the formulation of policy, these are separate activities and should not be confused. The role of scientists, as scientists (in contrast to their role as a part of the citizenry) is to explain what policy options are possible, to delineate the consequences of these options and the scientific/technical means available to achieve each option, and to explain the tradeoffs between the consequences. When this information becomes available, citizens and government can then formulate better goals, policies, regulations, and practices.

Placing a Value on the Environment

The intensity of debates and conflicts in recent years over various wild living resources, such as forests, fish, birds, and endangered species is indicative of major changes taking place in the way that people value the environment, and in the way that valuation is made. It is useful to consider these changes as part of understanding the present study and the concepts that motivate this study.

Those who write about ethics and the environment generally group the reasons that people value the environment into four categories, referred to as: utilitarian, aesthetic, ethical (sometimes referred to as "moral"); and ecological.

The *utilitarian* justification is that an object or an aspect of the environment has a direct benefit to people. As an example, many pharmaceuticals are derived from plants. An argument for the conservation of endangered species is the need to search for more of these chemicals. The recent discovery that a chemical from the Pacific Yew tree provides a new treatment for some forms of cancer is an example of a utilitarian justification for the conservation of nature.

The *aesthetic* (and cultural) justification is that the environment is important to people for the quality of life, providing some of the most beautiful and appealing aspects of our existence. Throughout human history, people have emphasized the importance of the diversity of life. Since ancient times, people have believed that the diversity of life is related to the purpose and meaning of human existence. Thousands of years of art and literature, from ancient epics to modern novels, films, and television, testify to the fundamental aesthetic importance of nature and its diversity in human existence. The growth of ecotourism, with large sums spent by tourists to see and learn about areas of special ecological value, from tropical rain forests and coral reefs to the Arctic tundra, underscores economic implications of aesthetic and cultural values.

Aesthetic justifications are used frequently in regard to the natural resources of the Northwest. As an example, some sociological studies indicate that people choose to retire to towns on the Oregon coast because they enjoy seeing the fishing boats and fishing activities, even if they are not directly involved in fishing.[3]

The *ethical* justification refers to the belief, as stated in the U. N. General Assembly World Charter for Nature 1982, that species have, from a human perspective, a moral right to exist — perhaps more accurately stated, that it is a human moral precept that non- human species have a right to exist and it is our moral obligation to assist in their persistence. Consequently, the argument follows that, in our role as global stewards, it is a human obligation to assist in the continued existence of species and to conserve natural ecosystems. Such ethical reasons have been used in discussions regarding the natural resources of the Northwest.

An *ecological* justification means that organisms are necessary to maintain the functions of ecosystems and the biosphere and are therefore of direct or indirect benefit to us, in other words, necessary for our survival. As we learn more about the biosphere, we begin to understand how species affect one another around the world. For example, bacteria carry out chemical reactions that affect the chemical makeup of the atmosphere. Some bacteria convert molecular nitrogen in the atmosphere to nitrogen compounds that can be used by other living things. Wild vertebrates, invertebrates, and micro-organisms play major roles in the pollination of wild and crop plants and in the germination and dispersal of seeds. And they affect rates of nutrient cycling within ecosystems.[4]

Forests and fisheries exemplify all four kinds of environmental values.[5] For example, forests have *utilitarian value*, producing timber products. Forests also have *ecological value*, retarding soil erosion, especially in areas of high rainfall, high rates of tectonic uplift, and soft bedrock.[6] Forests stabilize water supply and runoff. The *aesthetic value* of conserving old-growth forests in the Northwest is familiar to many, as exemplified by the many books that provide guides to hiking in old-growth and tourist guides to the Columbia River Gorge and areas in western Oregon that make frequent mention of the beautiful forests. An *ethical value* would be the assertion that species of anadromous fish have a right to exist and it is our obligation to help in their survival, or at least not threaten it.

Mindsets, Value Orientation and Information Services

Given these four general categories for placing a value on aspects of the environment, there are, broadly speaking, four *human perspectives* with respect to nature. Bryan Norton, a philosopher of environmental ethics, has referred to these as: *exploitist; utilist; inherentist; and integrist*.[7] Each of the four enjoys some legitimacy, but the political process is changing the ranking of their relative importance. Each of the four is served by appropriate scientific information; there are differences among the four as to what kind of science and information is particularly relevant. The four mindsets/value orientations are described below.

1. Exploitist: This viewpoint states that objects, such as renewable resources and features of the natural environment, have no value in themselves. Objects become valuable if they are needed and in short supply or if humans add value to them by craftsmanship, manufacturing, etc. Useless objects are seen as valueless, and what happens to them is inconsequential.

2. Utilist: From this value orientation most objects are seen to have beneficial and/or harmful attributes from the perspective of a particular human interest. What is harmful to a particular interest may be beneficial to another. Attributes of nature are viewed as though they should be managed primarily to the advantage of legitimate human interests.

3. Inherentist: This mindset states that at least some parts of nonhuman nature have intrinsic or inherent value of the same general type we ascribe to humans. Ethical codes appropriate for interhuman conduct are viewed as though they should be extended to inter-relationships between humans and the identified parts of nonhuman nature.

4. Integrist: This viewpoint states that humans are part of nature, though strongly different in some ways from other parts of nature. In practical importance, the differences do not override the similarities and commonalities. It is normal that two parts of an integrated system, e.g., the natural and cultural, do not act continuously in pure harmony but often, and sometimes unexpectedly, interact in discordant ways. Such tension is typical of living systems. However, some forms of tension are undesirable or impermissible. Distinguishing between creative sustainable tension and destructive tension is and will remain a continuing challenge when operating from this perspective. Because the system (i.e., ecosystem) is open and evolving, the science should emphasize learning, adaptation, and creative innovation.

Scientific information services have been developed reasonably well for the benefit of interest groups related to the first three of these mindset/value orientations: the explorer/developers (exploitist); the multiple-use conservationist (utilist); and the parks and species preservationists (inherentist). A commitment to sustainable development — with equal emphasis on cultural (i.e., economic and social) and natural features of a system — is creating a need for science in support of the fourth type of value orientation (integrist). (See Table 2 on page .) Interdisciplinary ecosystem study, cumulative impact assessment, scenario creation using probability/game theory, etc., are scientific approaches consistent with an integrist emphasis. In such an approach information will likely be shared in stakeholder negotiation and conflict resolution.

In the past the utilist orientation acted as a kind of compromise of the exploitist and inherentist positions. Now the integrist orientation may be emerging as the new dominant point of view, as a center of gravity for the whole set. This change in perception of the environment leads to new requirements for conservation and management of the environment and its resources. One of the underlying tenets of this study is that new perceptions broaden the context within which we analyze environmental issues and require new kinds of solutions. We are at a crucial time in our relationship to the environment. This time requires bold new approaches because of the unprecedented spatial extent and rate of environmental change. The first steps in this bold new approach are understanding our old beliefs about the environment and their basis, then allowing ourselves to view the environment, environmental science, and our various roles in relationship to the environment in new ways.

Environmental Uncertainty

Along with new perceptions of the value of the environment is the development of a new understanding of natural ecological systems. One of the most important aspects of this new understanding is a recognition of environmental change and uncertainty. The anadromous fish of the Pacific Northwest illustrate the importance of change and uncertainty. A virtually universal problem with management of free-ranging fisheries (and with management of most other free-ranging renewable natural resources) is the assumption by fisheries biologists and managers that, given enough research and the right models or other analytical approaches, exact numbers can be determined for population size, components of population dynamics, and the population responses to given harvest levels.

This assumption is nearly always erroneous. Environmental uncertainty means that we cannot measure many things about the environment in an exact manner. Environmental risk means that there are typically "chance" events that influence the outcome of any natural processes (see Table 3: Type of Environmental Uncertainty). Even if we could make exact population counts, projections of future conditions involve chance and can be stated only in terms of probabilities, not exact numbers. Some recent analyses of open self-organizing systems suggest that chance events can lead to uniquely new phenomena through self-organizational processes, so that predictions about these systems might be even more difficult.

Because of the effects of environmental uncertainty, exact or correct numbers are rarely if ever possible to obtain, and the result is that: (1) wrong numbers and harvest levels are recommended; or (2) biologists and managers delay recommendations until they have "more information." The latter case leads decision-makers to set their own limits, based on economic or political considerations instead of biological ones. This almost always results in overfishing and degradation of the resource or leads to a continuation of the status quo "until the biologists have adequate information," which in turn can lead to overfishing and degradation of the resource.

TABLE 3.
Types of Environmental Uncertainty

Uncertainty Type 1: Incomplete information regarding the current state of affairs

Example: What is the size of the population of spring chinook in the ocean this year?

Uncertainty Type 2: Incomplete information on details of cause-and-effect relationships

Example: What are the relative effects on habitat quality and fish survival of differing amounts of large woody debris per mile of stream channel all else held constant?

Uncertainty Type 3: Intrinsic unpredictability in nature

Example: Will turbulance bring food to one fish who will eat it or bring it to another?

Not only are the kinds of uncertainties listed above natural, but species have adapted to them. For example, salmon appear to have evolved so that the timing of a particular phase of their life cycle occurs during the time of highest long-term probability of appropriate environmental conditions. For example, upstream migration occurs in late fall-winter when long-term probability is highest of adequate stream flow.

There will always be various types of uncertainty with most environmental processes. In general, a population of free-ranging fish cannot be counted directly. (The exceptions are special locations where a total population can be observed and counted, for example where fish pass a single point in migration over a dam site). Most population estimates are based on relatively small samples. In addition, a large number of intrinsic and environmental variables are involved in determining future population size. In most cases the full range of these variables has not even been identified, much less studied in sufficient detail to specify and quantify their impact on the population involved. Therefore data should be collected using systematic random samples from which probabilities can be estimated and updated.

Chance events act over many different scales that can affect population sizes. Examples of chance events that can affect anadromous fish populations range from a local event, such as whether a tree falls into a stream this year or next, to regional events, such as if precipitation is high or low this year or next, to longer and larger scale environmental patterns, such as whether ocean upwellings are strong or weak this decade or the next.

As a consequence of environmental uncertainty, conservation and management of anadromous fish and their habitats must be formulated in terms of probabilities. When we believed that we could know the size of a population exactly, we could attempt to set a single maximum sustainable yield level. Recognizing environmental uncertainty, we understand that we can seek only a sustainable range of harvests, and that, as population sizes vary over the years, harvests will also vary. In some cases, stocks can be extinguished from natural as well human-induced causes, such as pollution. At other times new, valued stocks may reach a previous unused stream such as following rehabitation.

Management must also be based on the recognition of environmental uncertainty. Assessment of uncertainties must be a key component of management. Such an approach usually involves development of simulation models that explicitly include the full range of variables, the range of uncertainties, and an appreciation of the risks.

Among the considerations that must be involved are the following:

1) a definition of the objectives;
2) an identification of key driving factors;
3) a definition of what managers can do, that is, what decisions they can make (e.g., catch limits, restrictions on types of actions, efforts at rehabilitation, etc.); and
4) an identification of what data are available.

Once we understand that change and uncertainties are involved, we are forced to also recognize that there are many possible states of an ecological system, and that "letting nature take its course" could result in many different states. Upon examination, some of these states may be desirable to humans and others not. Desirability and undesirability of states applies to conservation goals as well as to goals for the harvest of resources. Thus we find that we are required to define specific objectives.

To summarize some of the points discussed so far, the definition of objectives usually helps clarify what the key driving variables are, but it is also possible that additional work will be required to define these variables. One must know these variables in order to determine what data must be obtained, as well as to determine how the system functions and what may be the most sensitive factors; a small change in one factor may have a large effect on the system. Once it is clear that objectives must be defined, driving factors identified, and goals selected, it also becomes clear that it is necessary to obtain quantitative information — both spatial and temporal — about the system (i.e., it is necessary to collect data).

From a comparison of the available data relative to data that ideally is needed, an assessment of the uncertainties can be made. Combined with an evaluation of the likely losses from mistakes, this assessment can provide the basis for estimating risk. This approach leads to a conservative style of management, with adequate factors built in for safety and evaluation of the results. The management is undertaken as an experiment in an adaptive way, with constant monitoring and assessment, and with the results fed back into modified and improved management.

Management of Environmental Resources as a Continuing Experiment

Management of any renewable natural resource involves so many variables and uncertainties that absolute certainty is virtually impossible. Consequently, any management is, by nature, experimental — regardless of the care, detail and sophistication of its underlying assumptions, planning and execution. Whatever management policy is implemented, in order to assure that lessons learned and managerial improvements are achieved, management must be considered an experiment and a kind of applied research. Prior to the initiation of new actions, baseline data should be obtained. Where possible, controls and treatments should be established, so the effects of the management can be monitored. For example, if a change is planned in the management of forests in a watershed, a pair of watersheds should be identified. New procedures would be initiated in one and the other maintained as a control, with appropriate data recorded in both. Measurements should be made on both before and after a change is initiated. Of course, it would be ideal to have a number of control watersheds and a number of experimental ones, in order to get a valid estimate of the statistical variance between the treatment and the control.

The assumptions and procedures should be spelled out clearly. Provisions should be made for appropriate feedback of the results. As a corollary, the results and analyses should be made available in timely fashion for appropriate review, in the manner of any valid scientific experiment. This is especially important when such procedures are first followed, because there is no history of experimentation to rely on. As it becomes an established practice to integrate research with management, more and more information will accumulate. From this history, it is likely that generalizations can be developed, which will relieve some of the future burden of monitoring.

This is analogous to what happens in medicine, where a doctor makes use of the best information available at any time, and meanwhile medical research continues, in an attempt to improve our understanding of the causes and cures of diseases.

THE UNIT OF MANAGEMENT

Another major change in the understanding of how to approach the conservation and management of living resources is a great broadening of the context in which conservation and management are viewed. Earlier in this century, when scientific approaches to the conservation and management of living resources were just beginning, the context for management was simply a single species, or in some cases, two interacting species, such as a predator and its prey. Today, following a generation of rapid growth in environmental science, there is recognition that the basis for conservation and management lies in the broader contexts of ecosystems, landscapes, and even in the global context that comprises Earth's life-containing and life-supporting system, the biosphere.

To focus on the management of anadromous fisheries, as well as many other living resources, there is general agreement that the appropriate unit of management is the watershed or river basin. This study accepts the watershed (the basin of a river) as the appropriate unit for management on the land, together with the oceanic area within which the basin's stocks spend their marine existence. The major units of this study, as mentioned earlier, are the Willamette River Basin and the basins of the rivers that drain directly to the ocean from the Columbia River (but not including that river) south to the Klamath and Trinity Rivers in California.

An important implication of this broader approach is that it seems less likely today than before that the causes of increases and declines in abundances of anadromous fish would be the result of a single factor, acting alone. Similarly, achieving higher abundances is likely to necessitate several changes in human behavior.

Context and Goals

Previously, questions regarding the management of living resources focused on one or two simple questions: how do we achieve a maximum harvest and/or maintain a maximum population. In both cases, these maxima were believed to be single, fixed quantities.

In the present context of anadromous fish populations, forests, rivers, oceans and humans, there are a series of management questions that emerge from the idea of environmental change, and uncertainty, including:

1) How will abundances of anadromous fish change in response to environmental change, both human-induced and nonhuman-

induced?
2) Of the many kinds of environmental attributes that could influence a population of anadromous fish, which set provides the best leading indicator of future population size?
3) What is an acceptable range of variation in the size of the harvest, and how will this range change in response to environmental change?
4) What are the best environmental and biological leading indicators of the acceptable levels of harvest in the future?

Given the great uncertainties in our knowledge, both of present conditions and of the cause-and-effect relationships that affect future population sizes and growth rates, how can we estimate these factors? In this case, a best estimate means not simply the most accurate, but the estimate that is acceptable for our purposes, practical to obtain within economic constraints, and reliable and reproducible so that it can become part of a monitoring system.

A Set of Policy Options

The discussion at the beginning of this document suggests that there may be more than one appropriate societal goal for any specific living resource. In a democracy it is not the function of scientists, in their role as scientists, to make decisions for society about goals. Citizens and their elected representative make decisions about goals. The role of scientific expertise is to explain what goals are possible, given the way in which natural ecological systems function, and what methods are feasible to achieve these goals. This study provides a basic discussion of possible goals. Later reports will address the question of how these can be achieved.

What Are We Trying To Achieve?

It is important that we clarify the management goals related to anadromous fish populations. For example, do we want to achieve a production of fish sufficient for some total level of commercial and sport harvest, but without regard to the geographic distribution of the fish? Do we want to maintain a specific stock on a specific stream, because that stock or that stream has some special attribute (or by implication a set of specific stocks on specific streams), at the cost of sacrificing other streams or a high level of total production? These are only a few of the potential options. The reader can undoubtedly think of more. These examples are provided simply as illustrations.

In the past, it may have seemed that achieving one goal would automatically lead to achieving another. For instance, maintaining many stocks of fish on many rivers would ensure a high total production, and vice versa, achieving high total production would ensure preservation of the genetic diversity of the fish. But this has not necessarily been the case. For example, it might be possible to achieve an abundance of anadromous fish open to commercial and sport harvests by focusing all efforts on a few basins that are known to be the most productive and are most likely to continue to permit fish reproduction. This approach could sacrifice many streams and stocks. On the other hand, the goal might be to maximize future biological diversity of anadromous fish. In this case, efforts would be geographically wide spread, and the maintenance of genetic stocks would take precedence over the possibility of a higher rate of harvest.

Hypothetical Policy Options.

One of the purposes of this study is to explore, in as objective and unbiased a manner as possible, what options are attainable, given the present data and current understanding of ecological systems. If we phrase these options in terms of the abundance and biological diversity of the fish, we can identify three extreme options, which are as follows:

1) To maintain wild anadromous fish populations of western Oregon and northern California in compliance with the Endangered Species Act, but at abundances and production rates that may be too low to sustain any harvest, either sport or commercial;
2) To maintain anadromous fish populations of western Oregon and northern California in ranges that allow at least moderate sport and commercial catch; and
3) To return the abundances of anadromous fish populations of western Oregon and northern California to a range consistent with the "presettlement" level, i.e. the level prior to exploitation after the Civil War by 19th and 20th century technological methods and the large influx of people. We take this range to be represented by abundances of 1860 to 1870.

At first glance, these three policy options may seem to be simply different points on the same axis of a graph — an axis defined by population abundance. It might seem that the first option — meeting the requirements of the Endangered Species Act — would differ from the other two only in requiring a smaller population size, while the second option — allowing sport and commercial harvesting — would require an intermediate population size, and the third option — achieving a presettlement abundance — would require the largest population size. From this perspective, solving the second option might seem to include a solution to the first, and solving the third might seem to include solutions to the first and second. As previously stated, these options are frequently confused in the sense that we tend to think that solving one solves all, and therefore that a global solution to all the options can be found. In fact, the three options are distinct and can lead conservation efforts and resource management in quite different directions.

Closer consideration of these options brings out intrinsic differences. The first option focuses on biological diversity, the second on biological production, and the third on population abundance. It is possible that a solution that provides for adequate commercial and sport harvest could fail to achieve a biodiversity option, and vice versa. Similarly, achieving the presettlement abundances might sacrifice sport or commercial harvests. It is important to recognize that these options are distinctive extremes. By considering these, we can shed light on both what is possible and desirable.

Biodiversity Considerations

The first policy option listed above, meeting the requirements of the Endangered Species Act, focuses on biological diversity. To understand the implications of choosing this option, it is useful to discuss biodiversity as a concept and as an issue, in the context of the goals of this study. It is worth noting at the outset of this discussion, that the concept 'species' is not well defined for salmonid generally, which complicates the option of conservation of salmonid biological diversity – if we are not clear about the what a species means for salmonids, then we will have greater difficulty in measuring a change in biological diversity of salmon than with other better defined species. With regard to the Endangered Species Act, heretofore listing has been sought for genotypes (i.e., reproductively isolated 'species' — the 'biological species' of Ernest Mayer.) In the case of salmonids, arguments are being made for the listing of phenotypes (i.e., genetic strains of each species or a portion of the total gene pool).

Because there is considerable interest in biodiversity, and because some of the discussions about anadromous fish focus on biodiversity issues, it is worthwhile to make certain distinctions clear.[8] One of the most striking features of life on Earth is its great variety of living things, referred to as biological diversity. Most people think of diversity in terms of species. However, there are actually three main components of biological diversity: species, genetic, and ecosystem diversities. Species diversity and genetic diversity have been the primary, and often only, focus for biological diversity conservation. But these are affected by other kinds of diversity that are normally defined under the heading of ecosystem diversity. For example, in the view of many ecologists, endangered species are simply surrogates for the much broader ecosystem properties. Consequently, the standard definitions of all three components of diversity are given below, with particular reference to their relationship to forests.

Species diversity: A species is a group of individual organisms capable of interbreeding under natural conditions. Species diversity has two attributes, each with its own measure, usually referred to as species richness and species evenness. *Species* *richness* is simply the number of species per unit of land area. *Species evenness* refers to the relative abundance of the species in an ecosystem; highest total species diversity occurs when there are many species and all species are equally abundant. Species diversity is a major variable in all ecosystems and varies significantly between ecosystem types.

Genetic diversity: This refers to the variety of genes that are present within individuals and their propagates, both within a single species and between species. From a technical point of view, genetic diversity is the diversity of DNA, the chemical compound of genes that transmits genetic information. The number of genes per species and per individual varies greatly. A typical mammal has about 100,000 genes, a flowering plant about 400,000, a fungus about 10,000, and a bacterium about 1,000.[9]

It is generally assumed that once a species is reduced to a remnant of its former abundance, much of its genetic diversity (i.e., its total gene pool) is likely to have been lost. This could be the case if there were considerable within-species genetic variability. If a species were made up of only one genotype — if all individuals had exactly the same DNA, then every individual would carry the same genetic information, and genetic diversity would not decline as the population size decreased until the population actually became extinct.

It is also generally assumed that the likelihood of persistence of a species increases with genetic diversity, because the diversity makes it possible for the species to respond to environmental change. When this is true, a small, isolated remnant of a species can be much more vulnerable to extinction than a genetically more diverse population. By the time a species is recognized as endangered, it may have lost so much genetic diversity that its chances of survival may be slight, and it may be too late to save that species. Thus genetic diversity is a particularly fragile resource.

To seek to sustain the biological diversity of the anadromous fish, it is necessary to understand the genetic diversity of each of the species. We need to determine whether there is a broad or narrow range of genetic diversity for the entire species (among the stocks that make up a species), and within a specific stock on a specific spawning ground. This can be referred to as "between" stock diversity and "within" stock diversity.

To understand between and within stock diversity, let us consider several rose gardens. If each garden has one color rose and no two gardens have the same color, then the within diversity is low and the between diversity is high. To conserve all of the colors, you would have to save all the gardens. Suppose all the gardens had only the same red rose. Then between and within diversity are both low. To save all the diversity, you need save only one garden. Now, suppose each garden had all the colors of the rainbow, and that every garden had the same set of colors. Both the within and between diversity would be high. To conserva all the diversity, you need save only one garden.

To return to the aquatic world, if both between and within diversity of anadromous fish is low, then the total diversity is represented by any stock or a few stocks, and all the genetic diversity of a species could be protected by maintaining populations on only a few rivers. If the within diversity is high and the between diversity is low, then it is possible that a single stock will contain all the genetic diversity of the species. If this were the case, then once again one a few stocks might be required to conserve all the genetic diversity of the species. On the other hand, if the between diversity is high and the within diversity is low, there is likely to be little overlap among stocks of the same species. Many stocks — perhaps all — would have to be maintained in order to conserve all of the genetic diversity.

Ecosystem diversity: Ecosystem diversity may be considered from the standpoints of (1) habitat, (2) succession, and (3) landscape.

(1) *Habitat diversity* refers to the diversity within the environment. As an example, in the Pacific Northwest, a watershed of a river consists of many habitats, and anadromous fish require a number of sub-habitats and conditions within these habitats to complete their life cycle. In general, high habitat diversity leads to high species diversity, and maintenance of natural habitat diversity is important to sustain species and genetic diversity. Some reasons for this relationship are obvious: without waterways there will be no stream or river animals; without drier uplands there will be no upland animals and plants.

(2) *Successional diversity* Forests regenerate following occasional natural and normal disturbances through a pattern of development called *ecological succession*, which progresses from open conditions immediately following a disturbance toward a closed canopy of a mature forest. There may be a number of states of the "mature" forest, and natural events

such as fires, storms, floods, and landslides may continually push the forest away from these later stages, but the stages — early, middle, and late succession — are identifiable. Species are better adapted to some stages of forest development than others in this process; for instance some species do best during the open, early phases while others dominate the late phases. Because forests develop slowly over long periods, and because the structure of forests provides many kinds of habitats, the process of succession provides varied opportunities for species. However, there are species whose survival is linked to only one of the successional stages.

Species diversity varies with the stages of succession. In temperate and boreal forests, species diversity peaks during mid-succession and declines thereafter. In these forests, highest species diversity will occur on a natural landscape with a complex mosaic of forest stands in various stages of succession. In temperate and boreal forests many species of economic importance, such as aspen and pines, are characteristic of early successional stages. In addition, diversity varies with the scale of variations imposed on the system or arising from processes within the system. For example, diversity could vary in a forest of the Pacific Northwest with the size of an area that has been burned and the average time between fires.

(3) *Landscape diversity*: A large area of land might be composed solely of a homogenous forest of one type. For example, in the Rocky Mountains of North America large stands of aspen trees that became established at about the same time may occupy many contiguous hectares, and some of these may

have sprouted from a single original individual. In contrast, another land area might contain many habitats and many different stages in the development of a forest, so that the landscape is a mosaic with great spatial diversity of habitat, and therefore with high overall biological diversity (although parts of the mosaic may have locally low diversity).

Because spatial habitat diversity tends to increase biological diversity, forests subject to disturbances that increase spatial and habitat diversity will tend to have greater biological diversity than similar forests in which such events have been suppressed. Where disturbances such as fire and storms have been common for a time long enough for species to adapt to them, the presence of such events will tend to increase biological diversity for this reason as well. Another effect of spatial habitat diversity is that species diversity in riparian areas is usually higher than in the surrounding landscape.

Most of the focus relating to biological diversity for the anadromous fish of the Pacific Northwest has concerned genetic diversity, with the recognition that the maintenance of genetic diversity requires the conservation of habitat and ecosystem diversity.

One consequence of this discussion is that the degree of within and between stock genetic diversity affects the costs of maintaining biological diversity. The primary point of this discussion is that the phrase "conservation of biological diversity" may not have a single operational meaning, but might differ between species of anadromous fish and between habitats. Another consequence is that conservation of genetic diversity is linked to the conservation of habitat diversity. This connection is stronger when the between stock diversity is greater.

Biological Production as a Goal

The second hypothetical option — maintaining an abundance of fish so that there can be commercial and sport catch — brings into focus biological production. Here we mean net biological production — the net change in total abundance or total biomass over a year. During the past 40 years or more — as long as formal mathematical methods have been applied to the management of fish populations — calculations of biological production assumed exactly or approximately steady-state conditions for the environment and for the population.

This has led to comparatively simple methods for estimating future production and setting allowable catches even though such steady-states do not exist. The challenge is to understand how to set allowable levels of catch for a resource whose productivity varies annually and may vary due to random processes that limit the accuracy of the prediction of the next year's production. There is, however, much more understanding of the factors that affect reproduction, survival, and growth in salmonid populations than is contained in existing methods. Much more realistic models are possible, given that understanding, existing data about fish abundances, however meager, and the powerful tools of modern computers and simulation languages.

Presettlement Conditions as a Goal

The third hypothetical option, returning the fish to a "presettlement" condition — a condition prior to the exploitation of 19th century technology — brings into focus the desire to seek some level of abundance of specific stocks as a primary option, assuming the requirements of the Endangered Species Act as a floor, and therefore with production and biological diversity as secondary goals.

Thus each of the hypothetical options has its own major variable of interest. Here we caution that a "presettlement" condition would not be a single state of either the fish or their habitat, as they would vary over time in ways that have already been discussed in this paper, with changes in climate, ocean upwellings and currents, fires on the land, and variations in abundances of food, competing species and predators.

IMPLEMENTING THE NEW APPROACH

For all of the options discussed in this report, two fundamental needs seem clear: 1) a statistically valid estimate of the number of fish (by species and stock) entering and leaving a basin over the annual cycles; and 2) a detailed and integrated mapping of landscape patterns within each basin, updated on the same schedule as fish stock assessment. By statistically valid, we mean that measurements are obtained according to statistically legitimate sampling methods, that the raw data remain available, and that a formal estimate of statistical error can be made from the data. For fisheries, improved data about the oceans, such as more precise measurements of upwellings, samplings of fish abundances and age structure, and ocean catch throughout the entire distributional range of the salmonids are needed. Fisheries also require a set of models that yield predicted population size, at least on the spawning grounds, and age structure of the population, based on recruitment (out migration) and return (escapement) data. For forestry, a geological information system (GIS) should be established that can be queried about the effect on the fishery of present and projected land uses. For example, GIS data layers could map the location, area, and percentage of land recently logged and at various stages of regrowth. It could display information about changes in the location, area, and percentage of land in agriculture and urban land use. These data could be related to the abundances and catch of fish to improve our understanding of how land use affects anadromous fish populations.

Data requirements should be driven by relevant questions and not by availability of models, nor by the cost of obtaining necessary data. Models for which appropriate data will not be available within a reasonable length of time, regardless of their elegance, should be discarded. We must distinguish between the absence of appropriate technology that is presently "too expensive" and the lack of funds to obtain the necessary amount of data using conventional methods currently available. The above material is not meant to constitute "solutions," as this will be the focus of the final report; this report merely explains the approach and rationale of that approach.

A Multiple Factor Approach

In past years, the controversy surrounding anadromous fish has tended to seek a single factor as the *cause*. In reality, the situation is much more complex because many factors affect survival, growth and reproduction of anadromous fish, and the state of these factors change over time. As the famous early-20th-century ecologist, Charles Elton, wrote long ago, the population of each animal species is constantly varying, and since one population affects another, the resulting confusion is remarkable. Clearly, in the future there must be fish and there must be habitat. Past attempts to seek a single cause have led some to blame all the alleged problems of the fish on the destruction of habitat and others to place blame on overharvest of the fish.

An alternative possibility is that factors interact and that changing one factor can influence the importance of another factor. In populations with complex life histories, such as the anadromous fish, an action at one stage in the life cycle can affect the outcome at other stages. For example, high mortality in the ocean can affect the number of eggs laid on the spawning ground, and the number of fish that survive the first stage of life on the spawning grounds can influence the abundance of fish in the ocean, and therefore affect ocean mortality rates.

The multiplicity of factors is indicated by the matrix presented in Table 4: A Salmon's Eye View of Environmental Attributes and Factors Influencing Them. The matrix shows the stages in the life of an anadromous fish, the required habitat conditions for each stage, the factors in the habitat required for the fish, and the factors in the habitat that could influence a population of fish. Inspection of this table will make clear that a suite of factors could act on the population of fish at any one time, and that the list of factors that influence a population of fish could change. This also suggests that there could be a suite of policy options. Any one solution could involve a set of factors and actions. In this situation, the same goal might be achieved by giving several policies different relative weights by assigning values to each individual factor. The choice of relative effort exerted on any one of the factors could vary with its importance to the fish, its habitat, and the societal implications. Thus there may be considerable flexibility in an approach to a solution.

The above discussion, along with the matrix, suggests that there may be a suite of policy options and associated actions. It is interesting to recognize that, although the ecological systems we are considering are extremely complex, involving thousands of species each interacting with many others and with the environment, there are in fact a comparatively small number of possible actions that it would be prudent for us to take. Table 5: Some Possible Actions That May Influence Anadromous Fish Populations lists a number of possible actions. It is encouraging to us in our attempt to find solutions that there is a limited number of ways in which we can influence the systems. This suggests that the situations, however complex ecologically, may pose tractable problems for us in our attempts to conserve and manage.

TABLE 5
Some Possible Actions That May Influence Anadromous Fish Populations
(The following are examples and are not necessarily exhaustive lists)

(ODF: This table "should have labels to make it clear that the items listed are NOT in rank order. On this same Table, it seems that the Land Use category doesn't fit, given that Agriculture and Urban uses are separated out. Could this be labeled 'Other Land Use' and perhaps moved to the end? Or labeled 'Road Building and Maintenance'?")

I. Trees

A. Logging
- limit area of cut
- limit slope of a cut
- establish minimum riparian zone
- establish selective cutting methods (HR: "though clearcuts may be best in some places.")
- establish time of harvest (not when land is wet)

B. Planting
- Yes
- No

II. Land Use - Other

A. Road Building
- limit density

- regulate quality of road-building practice

III. Fishing

A. Commercial
- Ocean
  1. establish bicatch limit
  2. establish techniques - draft nets, etc.
  3. establish catch size
- Fresh water
  1. establish catch size, etc.
     (HR: "Time and place of catches, with individually transferable quotas to specific amounts of specific stocks.")

B. Sport
- Ocean
  1. establish catch size
- Fresh water
  1. harvest
  2. catch & release
- Accurate reporting of catch

(LT asks here: season?)

IV. Hatchery

A. Aggregate amounts
B. Size & age at release
C. Release locations
D. Percentage genetic stock
E. Time of release

V. Fish Habitat (LT asks here, riparian vegetation?)

A. Gravel Operations
  1. Amount removed
  2. Manner of removal
  3. Location of removal

B. Large woody debris
  1. Creation
  2. Maintenance
  3. Replacement

C. Restoration of stream channels and floodplain habitat

D. Control of water flow
  1. Quantity
  2. Timing
  3. Removal of dams

E. Aids to traverse dams (fish ladders, etc.)

VI. Predators

A. Harvest

B. Transport

VII. Agriculture

A. Eliminate & prohibit temporary agricultural dams

B. Riparian zones in agricultural lands

C. Control/eliminate use of fertilizers & pesticides

D. Fencing out cattle near streams

E. Limit water withdrawals from streams

VIII. Urban

A. Create & maintain riparian zones

B. (Control of monitor?) runoff

1. Separate storm & domestic waste sewers
2. Eliminate use of toxic runoff
3. Reduce peaking and augment low flows (suggested addition: HR)

C. Restoration of stream channels

D. Limit percentage of area paved

Notes

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The titles used here are different from those used by Norton ( ), but the descriptions here resemble those by Norton.

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