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STATUS AND FUTURE OF SALMON OF WESTERN OREGON AND NORTHERN CALIFORNIA: OVERVIEW OF FINDINGS AND OPTIONS

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Research Report 951002
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PREFACE

This is a summary of the eighth report published by the Center for the Study of the Environment (CSE) as part of a study of salmon 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 conducted the study through funds provided by Oregon Senate Bill 1125 Section 25 (1991); funding was provided by the State of Oregon, the U.S. Department of Agriculture, Forest Service and the U.S. Department of Interior, Bureau of Land Management; additional funds have been made available by the state of California Department of Forestry and Fire Protection (CDFFP).

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 decision-making.

The first three reports of the study were published under the title *Status and Future of Anadromous Fish of Western Oregon and Northern California.* They are:

Rationale for a New Approach
(Report No. 931001)
Related Studies
(Report No. 931002)
Available Data on Fish Populations
(Report No. 931003)

Beginning with the fourth report of the series, the main title became *Status and Future of Salmon of Western Oregon and Northern California:* The reports under this title are:

Available Data on Land Use
(Report No. 941001)
Analysis of Fish Models
(Report No. 941002)
Forecasting Spring Chinook Runs
(Report No. 941003)
Management of the Riparian Zone for the Conservation and Production of Salmon
(Report No. 941004)
Findings and Options
(Report No. 951001)
Overview of Findings and Options
(Report No. 951002)

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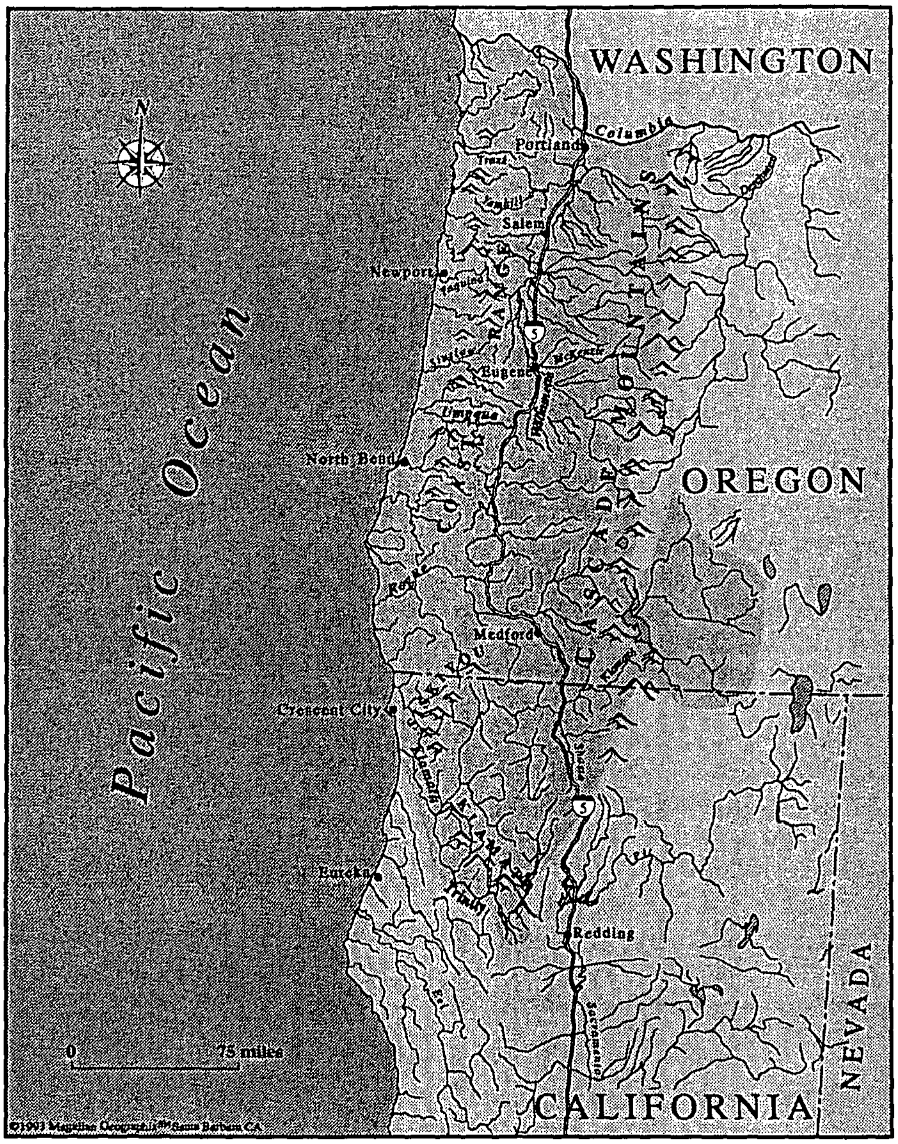

Figure 1: Map of the study area. Study area is the shaded area, shown here for orientation purposes. The intent of this map is to orient the viewer and delineate the study area, not to specify watershed boundaries.

THE STUDY

STATUS AND FUTURE OF SALMON OF WESTERN OREGON AND NORTHERN CALIFORNIA

The charge of the study was set forth in Oregon Senate Bill 1125 (1991), which called for a "scientific inquiry on the state of knowledge of the anadromous fish runs in western Oregon" that would address the following six charges:

1. "identify leading causes, both on-shore and off-shore, for anadromous fish populations declines if that is the case;
2. "assign the relative importance of forest practices to these declines, compared to other leading causes;
3. "identify the relative importance of various habitat characteristics in streams in limiting anadromous fish production;
4. "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;
5. "identify the extent to which forest practices are limiting the recovery of depressed anadromous fish populations; and
6. "make recommendations as to how forest practices can assist in recovery of anadromous fish populations."

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).

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, or the Willamette (which flows into the Columbia). Because migratory salmon spend a part of their lives in the ocean, 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 study examines the status of coho salmon (*Oncorhynchus kisutch* Walbaum), chinook salmon (*Oncorhynchus tshawytcha* Walbaum), chum salmon (*Oncorhynchus keta* Walbaum), steelhead trout (*Oncorhynchus mykiss* Walbuam), and sea-run cutthroat trout (*Oncorhynchus clarki* Richardson). Resident steelhead and cutthroat trout are included in the study. Because all of these species and their stocks have recently been placed in the same genus, we refer to them collectively as salmon throughout this report.

STRUCTURE OF THE STUDY

This study is composed of the following elements:

1. a "Blue-Ribbon Panel" of independent experts who oversaw 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 who gathered, compiled and assisted in the analysis of 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.

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 salmon fisheries in the Pacific Northwest. These scientists represent a range of disciplines important to the broad concerns of the study.

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 ecology, including aquatic invertebrates and fish populations, holds a "Distinguished Scientist" position with the South Florida Water Management District, Department of Research, West Palm Beach.

Dr. Thomas Dunne, whose field of geomorphology includes the 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 who 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 is an applied mathematician who works on stochastic processes and risk analysis. He is Dean of Harriman School for Management and Policy, State University of New York, Stony Brook.

Dr. Lee M. Talbot, whose field is ecology and environmental affairs and who is a leader in international conservation, is a former Director General of the World Conservation Union (IUON) and currently senior environmental advisor to the World Bank, Washington, D.C.

In the process of overseeing the study, the panel held 1 0 open public meetings in six Oregon cities, visited many field sites, met to discuss the study and to listen to and interact with many experts, and determined a set of policy options. The panel authored and accepts responsibility for the content of the final report. There has been no attempt to establish policy, which is a matter for the legislature and citizens of Oregon. The goal has been to provide the basis from which solutions can be found and policies adopted. The approach emphasized cooperative effort of all interested parties in formualting constructive solutions.

Five Crucial Assumptions

This study makes five fundamental assumptions:

1. Scientific knowledge is a necessary basis for sound policy for the conservation and management of wild, living resources.
2. Scientific data, objectively and legitimately analyzed, are preferable to the opinions of scientists, however expert they may be.
3. The less you know scientifically, the more careful and protective one must be in taking actions. When data are entirely lacking or so sparse as to be prohibitive to valid scientific analyses, then the expert opinions of scientists can be of some value, but only if they are clearly identified as the opinion of an expert.

4. It is not the role of scientists to make policy, but to provide the background information and understanding upon which rational policy can be based. With wild, living resources, scientists can explain which policy options are available given the current understanding of natural ecological systems, what is required to achieve each option, and what is given up or exchanged.
5. The public should be involved in the process of policy making.

ACKNOWLEDGEMENTS

The authors of the report appreciate the cooperation of the Oregon Department of Forestry, the Oregon Department of Fish and Wildlife, the California Department of Forestry and Fire Protection, the U.S. Bureau of Land Management, the U.S. Forest Service, the Oregon Coastal Zone Management Association, the Oregon Water Resources Department and the Oregon State University College of Forestry.

We would like to acknowledge the special contribution of Mr. Jim Welter of Brookings, Ore. We would also like to acknowledge statistician Dr. Benjamin Stout who conducted many statistical analyses, including a large number of screening statistical analyses that laid the foundation for the work presented here, and whose insight has been of great help to the authors. We also appreciate the time, effort and suggestions of the Overview Committee under the direction of Dr. Bart Thielges of Oregon State University.

The authors would like to acknowledge the contributions made at open meetings by citizens and citizen organizations.

The authors thank Dr. Robert Nisbet for directing the geographic information system analysis; Kathryn Thomas for conducting much of that analysis; Joan Melcher and Susan Day for excellent editorial assistance; Susan Day for ensuring that the entire study process was conducted according to plan; Angela Magness for excellent secretarial work; Bill Kuhn for providing extensive literature review, data analysis, and editing; Mark Meleason and John Cleary for assistance in literature review; and Eric Kreis for production of graphics. We also acknowledge the contributions of Rebecca Johnson and Hans Radtke for an economic analysis made possible through a subcontract.

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EXECUTIVE SUMMARY

OVERVIEW

The issues adressed in this summary are discussed in more detail later in this report and greater detail in *Status and Future of Salmon of Western Oregon and Northern California: Findings and Options*. The reports discuss the status of salmon and salmon habitat at a *regional* level as requested by Oregon Senate Bill 1125 (1991). Therefore, the reader will find issues addressed at a regional scale with less focus on individual organisms and habitats in small order watersheds. This summary outlines the major findings followed by suggested recommendations, which are indented below the findings.

• At the beginning of the study, the panel expected to provide specific sets of options for the people of Oregon. However, we found that much of the available data was not useful for regional scale analyses.

> *Improve data collection in areas such as: counts of fish, maps of all land use conditions, history of logging (geographic location, methods, size), and number of fish released by hatcheries.*

• In spite of various forms of cooperation, it has proven difficult, and in some cases impossible, to retrieve data from the government agencies.

> *Data availability should be improved, and in an electronic format.*

• Of the 26 rivers that flow into the Pacific in the study area, there are statistically valid counts of returning adult fish for only two rivers. These counts are available for approximately the past 20 to 30 years.

> *Establish annual counts of returning salmon according to statistically legitimate methods on all rivers that are to be managed for wild salmon.*

• The most widely-used method to estimate the number of spawning adults, called "the peak count method," is statistically unreliable and does not correlate with valid counts on the Rogue and Umpqua.

> *The peak count method should be discontinued and replaced by statistically valid methods.*

• Available data in the study area for salmon returning to spawn on the Rogue and Umpqua Rivers show no consistent pattern in population trends. Total Oregon landings of ocean caught coho from 1893 to 1992 show a significant downward trend. However, the spawning river of these fish is unknown.

> *Historical records, along with archeological and anthropological research not available for this study, might provide information about earlier catches of salmon. A study should be undertaken to determine historic bench marks against which present conditions can be evaluated.*

• Variability, rather than constancy best characterizes the year-to-year pattern in the number of salmon returning to spawn during the past 50 years.

> *Salmon management plans should recognize that there is natural variability in salmon populations on top of and/or in spite of human actions.*

• Models have played an important role in fisheries management, serving as the basis for setting harvest quotas. However, models currently in use do not consider environmental change, either natural or human induced, so they are not adequate for accurate projections of populations trends, harvest quotas, or for estimating the effects of human action on salmon.

> *Develop a set of realistic, pragmatic models. These are essential to the conservation and management of salmon.*

• Water flow, especially minimum flow in November, is strongly correlated with variation in the number of adult spring chinook returning to the Rogue River. Variations in water flow, hatchery releases, and ocean-troll catch account statistically for 80 to 90 percent of the variation in the number of returning adults during the past 20 years. Of this 80 to 90 percent, variation in water flow accounts for the largest share.

Use variation in water flow to forecast adult fish returns to help set harvest quotas. Do this in conjunction with adequate monitoring.

Check for persistent trends in the deviation of predicted and actual adult returns.

• Preliminary analyses of available data on one river suggest that hatcheries may not be effective in increasing the return of salmon.

Contingent on the outcome of a more thorough study, the panel recommends that salmon hatcheries be converted from providing fish for sport and commercial harvest to breeding threatened or endangered salmon stocks. The exception would be on rivers selected primarily for the production of commercial catch, if this turns out to be cost-effective.

• One common belief is that in presettlement times, western Oregon was a continuous cover of ancient forest and that such continuous cover was an important factor in high salmon production. However, Bureau of Land Management maps show that in 1850, approximately 40 percent of the forests were older than 200 years, 62 percent were older than 100 years, 64.5 percent were older than 50 years, and 34.5 percent were mapped as burned.

Support research to better understand, at a regional level, the connection between forests and salmon.

• Our study considered correlations between land conditions and stocks of salmon that are present, threatened, or locally extinct. Effects of forest practices vary with species and their habitats. Correlations show that: 1) the presence of winter and summer steelhead is correlated positively with some amount of forest cover greater than 33 percent of the watershed; and *local extinction is most strongly correlated with non-forest land use*; 2) *past forest conditions are one of the factors correlated with local extinction of steelhead and coho*, species that spawn and breed in the smaller, upper streams in watersheds. But *forest conditions are not strongly correlated with local extinction of chum*, which spawn and breed in estuaries and main river stems; and 3) sea-run cutthroat trout exist where there are sufficient mixed stands of trees; however, *the larger the area in clearings, grass and shrubs, the less likely sea-run cutthroat will be present.* In summary, comparison of maps of the status of salmon stocks with maps of land conditions indicates some significant correlations and raises a number of questions about causes and effects.

Using the maps and statistical analyses provided in the main report, conduct field research to explain these correlations.

• All species of salmon in the study area, except for sea-run cutthroat, have undergone a decline in geographic distribution, resulting in a loss of specific stocks. The area previously occupied by now-extinct stocks varies widely among species, with summer steelhead extinct from 44 percent of its historic range within the study area, to coho extinct from 4 percent of its historic range within the study area.

• Major factors known to affect salmon are: agriculture, dams and other obstructions, drought, forestry, fish harvest, and urbanization.

Related to agriculture and urbanization; establish riparian rules and conduct experiments to test their ecological and cost effectiveness.

Related to forestry; monitor and conduct experiments to test the ecological and cost effectiveness of the new Oregon Department of Forestry (ODF) Water Protection Rules (riparian rules).

Reform water rights provisions to prohibit the use of agricultural diversion dams that can temporarily block salmon passage or significantly reduce water flow.

Where possible, use existing dams to increase water flow, especially during summer and early fall low water flows.

Develop new strategies of fish harvest management that use reliable data to set catch limits with a goal of sustainability over the long term.

- Potentially important factors that affect salmon include gravel harvest, irrigation, legal bycatch and noncatch mortality, hatchery fish interference, unfavorable ocean conditions, and unregulated or illegal fish harvest.

  The importance of these factors should be investigated further.

- This study confirms the importance of the protection of riparian zones for salmon. In many of the forest, agricultural, and urban areas of western Oregon, habitat characteristics required by salmon have been severely damaged or completely eliminated.

  Establish riparian protection rules for agricultural and urban areas similar to those now in use for Oregon forest land. These should include restoration as well as maintenance and monitoring.

- Prior to 1980, summer observation during low flow led to the mistaken conclusion that debris dams posed a barrier to winter salmon migration. In addition, because much of the debris included marketable logs, there was a large-scale removal of large woody debris (LWD). This removal policy had major, long-term destructive effects on salmon habitat. Areas subjected to LWD removal are still limiting the quality of salmon habitat.

  Enhance and extend LWD restoration programs.

  A management strategy will be needed to recreate an adequate loading of LWD in a time scale relevant to salmon. Before-and-after monitoring and determination of cost effectiveness.

- Historical documentation shows major simplification of stream and floodplain habitats during agricultural settlement and logging. This simplification resulted in large differences in the amount of woody debris, volume of pools, and gravel stored per unit length of stream. This also impoverished thousands of miles of fish habitat.

  Reestablish functioning riparian zones along stream channels through regulation of clearing.

  Enhance riparian restoration, especially where stocks are threatened or endangered, choosing methods based on cost effectiveness will also be needed.

- It is the opinion of the panel that the proposed federal (FEMAT option 9) riparian standards and the new ODF Water Protection Rules will improve protection of salmon habitat, if enforced as specified to us. However ODF rules may not provide sufficient loading of LWD to the stream channel, especially in the short term in secondary forests.

  Require a monitoring program for the new ODF Water Protection Rules.

  The rules and monitoring program should also be written in a form which makes them open to scientific review.

• Attempts to restore salmon in watersheds where they have become extinct are generally not successful; apparently, successful migration and adaptation of salmon to new streams requires more than a single human lifetime.

Restore riparian zones where threatened and endangered stocks persist in preference to restoration where stocks have become extinct.

• To the best of our knowledge, no studies have been made of how gravel supply is affected by recent technical innovations and regulatory measures in road siting and construction.

Conduct studies to determine how new regulatory measures may be effecting gravel supply caused by road siting and construction.

• The amount of unregulated and illegal ocean catch is generally unknown, but may be significant.

In cooperation with other states and nations, seek to determine the total amount of unregulated and illegal catches.

Include estimates of unregulated and illegal ocean catch in total mortality as part of setting annual, legal commercial and sport harvest quotas.

• At present, bycatch (the inadvertent taking of salmon while catching other fish) is monitored for only one fishery in Oregon, the whiting fishery.

Extend bycatch monitoring to all fisheries that might impact salmon and use the estimated total bycatch as one factor in setting annual legal harvest quotas.

• Available data show that marine mammals are a minor factor in salmon mortality.

Remove marine mammals only where they pose a local problem to a specific threatened or endangered salmon stock. Remove only after thorough study has established that it is necessary. This should be done in accordance with the Marine Mammal Protection Act.

• Upwelling is a vertical ocean current that brings nutrients crucial to biological production to the surface. Some scientists have found a positive connection between strength of ocean upwelling and coho production. However, statistical analysis of available data for salmon returns to the Rogue River show only a nonsignificant correlation with upwelling indices. Data are available for 20 years, which may be too short a time to detect correlations.

Conduct further investigation of the relationship between ocean upwelling and the production of salmon species.

• Long-term variation in ocean currents may shift conditions that are good for salmon from north (off Alaska and British Columbia) to south (off Washington, Oregon and California) and back again.

International agreements on ocean fishing should take potential variations into account, so that some quid pro quo arrangements are included to provide for reciprocal terminal fishing variations.

• Present methods for data collection about river of origin for wild fish caught in the ocean are inadequate.

Specific actions to improve the collection of data that should be considered include: restrict ocean fishing to terminal fishing; use advanced underwater techniques to monitor passage of fish in (upstream) and out (downstream) of estuaries. Consider social and economic costs in making decisions about which actions to take.

• Under the Endangered Species Act, there are many more management options available for a stock listed as threatened than for one listed as endangered. Therefore, for legal as well as good resource management reasons, it benefits all involved to prevent threatened stocks from becoming endangered.

To help prevent threatened stocks from becoming endangered, the following is recommended: habitat improvement for threatened stocks; controlling catch of these stocks where possible; and using hatcheries for assistance with threatened stocks.

• Of the total economic value from sport fishing on all rivers in the study area, 62 percent comes from five watersheds: the Rogue, Tillamook Bay, Umpqua, Nestucca, and Nehalem. Adding five more rivers, the Alsea, Elk, Chetco, Salmon and Siletz, raises the percentage to 84. Adding the Siuslaw and Coquille raises the percentage to 90.

Consider, with public input, the possibility of establishing a new category of "sport-fishing rivers," where the primary goal would be to produce fish for recreational fishing.

Consider, with public input, the possibility of delineating certain rivers as major locations for production of salmon for commercial catch, essentially using these rivers for mariculture.

If such new categories seem useful, then the question will be raised of differential changes in economic value of land. One solution would be to make use of the practice of transferable development rights, which establishes swapping rights for land use changes.

• The present state of science does not allow us to make precise determinations of the genetic differences among stocks of Pacific salmon.

Support research to better define the genetic makeup and genetic distinctions within and among all stocks, especially threatened and endangered ones, to determine viable population levels for salmon.

• More than 30 government agencies manage salmon environments in western Oregon and northern California. The vast body of scientific data on stream and river ecosystems clearly indicates that the watershed is the basic unit of landscape-stream/river function.

Develop watershed-based management, either through establishment of new watershed-level agencies or through formal coordination of existing agencies, as is being attempted in a few instances now.

Create positions of "river-keeper" as practiced on the Hudson River. The job of river-keeper would be to ensure that policies of many agencies with jurisdiction over salmon and their habitat are in effect and to play a major role in organizing and implementing monitoring programs.

• Every policy change creates an experimental situation; we can only learn from these experiments through measurement. The need for adequate measurements is a persistent theme in our report, and a list of important factors to measure is provided in Section V.

With every new policy or change in policy, ensure that before and after measurements are made of responses of salmon to changes in specific habitat conditions.

Measurements of particular importance are: counts of adult fish returns, catch, and of smolts returning to estuaries; periodic remapping of vegetation; and recording logging permits by geographic location, date, size and amount of harvest.

• Salmon have one of the most complex life cycles of any vertebrate animal, and some aspects of their habitats vary in ways that are not subject to control by people.

A process of risk assessment should be part of any management scheme and management decisions should be made based on the awareness that some factors are beyond human control.

Management should formulate adaptive policies that change with fluctuations in environmental circumstances and advances in public and scientific knowledge.

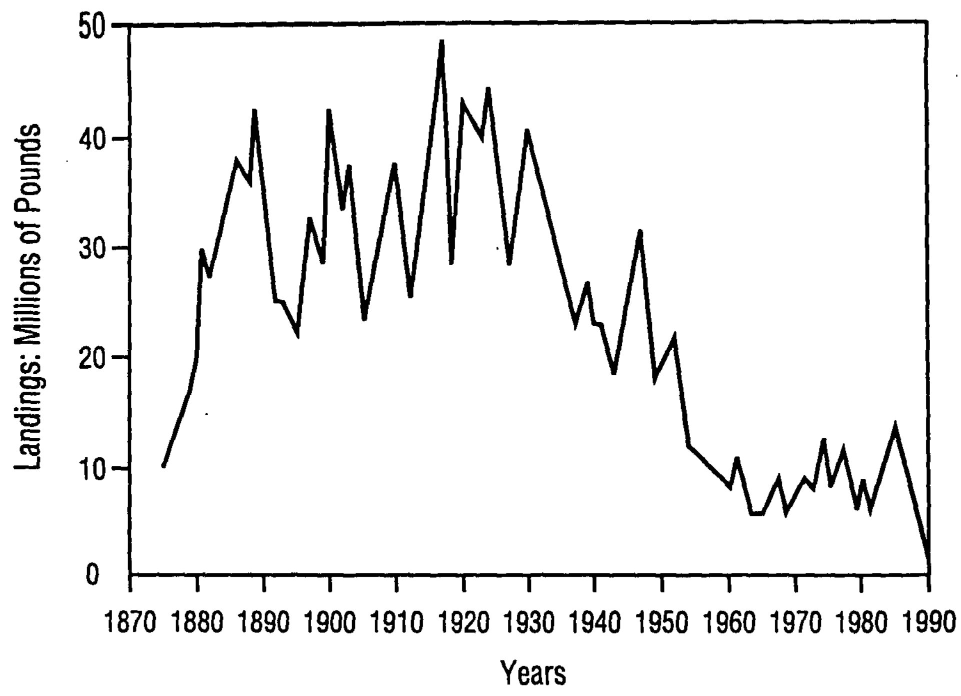

Figure 2: Total commercial landings in millions of pounds of all salmonids on the Columbia River between 1875and 1990. From 1875 to approximately 1952, the catch oscillated between 50 and 15 million pounds. Between 1952 and 1990 the catch oscillated within the range of 15 and 1 million pounds. The ocean troll salmon fishery began in 1912 and from then on this fishery may have affected the catch on the Columbia River.

INTRODUCTION

Much of the lore about salmon and their habitats is based on the history of the Columbia River and its tributaries, backed up by records of the landings of salmon on that river, which have been kept since soon after the Civil War (Figure 2). In the 1800s people in the Pacific Northwest boasted of crossing rivers "on the backs of salmon and never getting your feet wet." In 1805 Lewis and Clark found Indians depending heavily on salmon for their food, and these explorers ate salmon soon after they crossed the Continental Divide

Exploitation by people of European descent began in earnest soon after the Civil War. As Figure 2 shows, Columbia River landings increased rapidly in the late 19th century, exceeding 40 million pounds for a number of years and remaining at about 20 million per year from approximately 1880 to 1950, after which the landings declined and have remained less than 15 million pounds per year. Records of harvest on the Columbia show that in the 19th century tons of salmon were thrown away because canneries were unable to process such quantities. In the 1990s Columbia River landings amount to less than half of those a century earlier.

Common Beliefs About Salmon And Their Habitats

One of the purposes of this study was to look at the set of common beliefs that form the background to the debate about salmon in the Pacific Northwest. These beliefs include the ideas that prior to European settlement: there was a superabundance of salmon; the forests of western Oregon and northern California were essentially composed of large, ancient trees; this extensive old-growth was essential to the abundance of salmon; the forests and salmon were pretty much at a steady state - constant in abundance and distribution; and native Americans had little if any effect on the extent and composition of the forests and the abundance of salmon.

It is also commonly believed that human actions account for much of the decline of salmon including: overfishing, poor forest practices (especially near streams), and construction of dams (especially on the Columbia River system). Other commonly mentioned causes of declines in salmon include: channelization of streams, gravel mining from stream beds, hatcheries (through various mechanisms including dilution of genetic characteristics and spread of diseases), predation by birds and marine mammals, road building, and reduction in river flows as a result of human activities.

The purpose of this study was to move beyond commonly held beliefs and answer the question: What do we actually know about the regional status of salmon and the causes of change in that status, using existing scientific information and applying objective analyses? The study also attempted to provide a synthesis of policy options for constructive solutions to the perceived status of salmon fisheries.

A New Ecological Paradigm

There is a major change taking place in the public's perception of wild, living resources and expectations for the management of these resources by government agencies. In the past, fisheries and forests were viewed as resources to be managed for the maxi-

DISCUSSION

In the 1800s people in the Pacific Northwest boasted of crossing rivers "on the backs of salmon and never getting your feet wet."

mum production of a single commodity. Today, there is widespread public expectation that these resources be conserved and managed from a broad perspective for a number of goals, including conservation of biological diversity and recreation.

In recent years a new ecological paradigm has begun to develop: a paradigm that accepts change as natural, expected, and necessary to the persistence of many species. This new ecological view can help us look at salmon and their habitats in a constant state of change, usually without long-term stability and affected by a set of randomly occurring factors. Variation can occur over periods shorter than, as long as, and much longer than one year. The main practical implication of this new view is that management must recognize environmental uncertainty as an overriding factor, even to the extent that there is uncertainty as to whether we can achieve some specific objectives.

The complexity of the lives of salmon, the many habitats they use, and the different way each species uses these habitats would suggest that it is unlikely that a single factor will be the cause of all declines.

The Life of a Salmon

To understand what available data tell us about the causes of changes in salmon abundance, it is useful to follow salmon through their life cycle. Salmon have complex lives, moving through and depending on many kinds of habitats, each with its own kinds and rates of environmental change. The life of a salmon begins with its birth in freshwater streams; there it feeds on aquatic invertebrates for a period of time referred to as "rearing". Next the young salmon swims down river to the ocean. Rearing and downstream migration can occupy a few months to a year or more. Once in the ocean the salmon grows and matures, a processes that may take from one to six years. The average rearing and time spent in the ocean vary with species. Finally the mature salmon "escapes" from the ocean, swimming back to its natal stream where it spawns before dying (Figures 3A and 3B). Salmon depend heavily on the biological and physical conditions in their spawning and migratory streams and must survive a virtual "mine field" of human and environmental threats to complete their life cycles. Their journey, often a thousand miles or more, takes them through every type of environment and governmental jurisdiction in the study area. To add to this complexity, each species of salmon uses different parts of river systems and spends different amounts of time in fresh waters and the ocean. The great complexity of the lives of salmon, the many habitats they use, and the different way each species uses these habitats would suggest that it is unlikely that the same, single factor will be the cause of all declines.

APPROACH & METHODS

This study was concerned with broad, regional issues, not with specific local details. It attempted to answer the question: What can we tell from existing information through objective, scientific, non-ideological analyses, about the overall present regional status of salmon and about the causes of changes in status? The study also attempted to provide a synthesis of policy options for constructive solutions to the decline of salmon fisheries. It is important to emphasize that the study dealt with existing data, and was not designed to collect new data or to carry out new research projects.

The focus of the study was at the regional level because the charges of the Oregon Senate Bill 1125 are specified at that level. The study was not designed to deal with aspects of other levels, such as the response

OVERVIEW

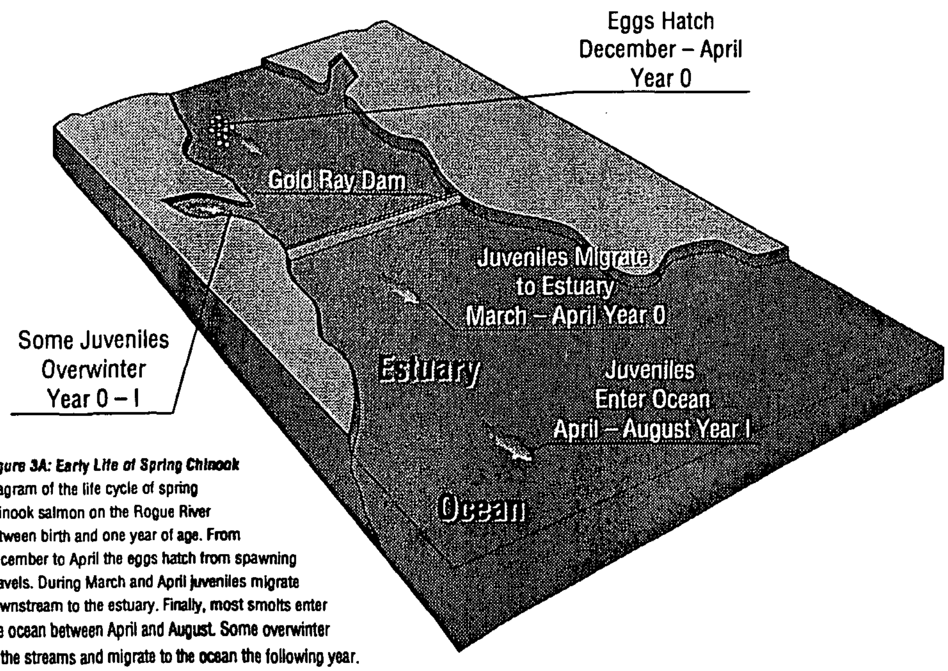

Figure 3A: Early Life of Spring Chinook
Diagram of the life cycle of spring chinook salmon on the Rogue River between birth and one year of age. From December to April the eggs hatch from spawning gravels. During March and April juveniles migrate downstream to the estuary. Finally, most smolts enter the ocean between April and August. Some overwinter in the streams and migrate to the ocean the following year.

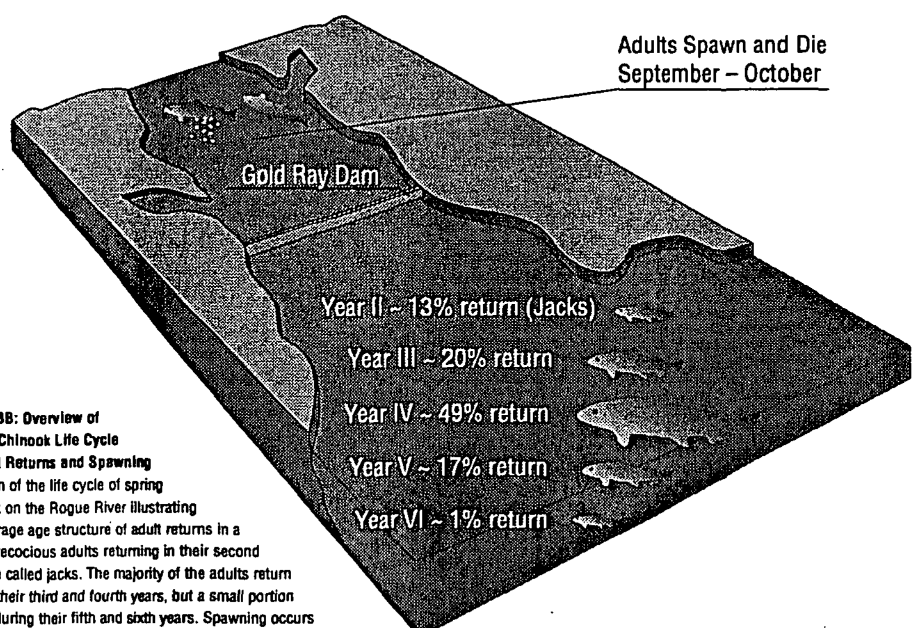

Figure 3B: Overview of Spring Chinook Life Cycle in Adult Returns and Spawning
Diagram of the life cycle of spring chinook on the Rogue River illustrating the average age structure of adult returns in a year. Precocious adults returning in their second year are called jacks. The majority of the adults return during their third and fourth years, but a small portion return during their fifth and sixth years. Spawning occurs during September and October after which the adults die.

of individual fish to changes in environmental conditions, or the dynamics of small watersheds, although information from these levels of research are discussed where pertinent.

Cause-and-Effect Approach and Statistical Correlations

Given the present state of scientific knowledge, in most cases the best scientists can do is to look for statistical correlations. With existing research, the process is not yet at the stage where complete cause-and-effect linkages can be made. If we cannot at present provide a complete answer on the basis of clear cause and effect, then what can we do? There is a second approach: to carry out statistical analyses to determine what correlations exist between environmental variables and salmon populations. To do this, we must have measurements of the environmental factors that we believe to be important, ideally, over many watersheds and long time periods. Next, we need measurements of the salmon for the same area and same time periods. The best measurements would be of abundance, but even data on presence versus extinction can be useful.

This study was done to determine what could be learned with valid methods from available data.

This is the approach attempted in this study. Scientists are less satisfied with correlations than with cause-and-effect relationships because the goal of fundamental scientific study is to understand cause and effect. But correlations often provide valuable practical methods for forecasting, and they are useful for conservation and management. In addition, correlations also suggest which factors could or could not be important, and therefore give insight into possible causes. For this study, the statistical correlation approach has been limited because the most basic and important kinds of monitoring of environmental conditions and salmon populations are lacking.

The Expert Witness Approach

When faced with the absence of sufficient cause-and-effect explanations and with insufficient data and statistical analyses, scientists often respond to questions such as those posed by the first and second charges of Oregon Senate Bill 1125 by giving personal opinions based on their experience as naturalists and working scientists. They respond as would an expert witness testifying on a case which has inadequate scientific information and analyses, but about which he has had more experience than the average person. Sometimes there is no other choice with major practical questions. The advice given by a scientist acting as an expert witness may be legitimate as long as both the scientists and the audience understand that such statements are opinion based on experience. Too often, because science tends to be highly respected in our society, the distinction is not made between a scientist's expert opinion and a scientist's report on the results of scientific cause-and-effect studies or the results of valid statistical analysis. As a result, opinion is accepted as scientific conclusion. It has been the attempt of this study to avoid this confusion. This study was done to determine what could be learned with valid methods from available data. In some cases we have found that so little appropriate data existed that the only recourse was for the panel to serve as expert witnesses and for their opinions to be stated as such. The expert witness approach is useful when it is acknowledged as such, but would be counterproductive if mistaken to represent the results of specific scientific research and experiments.

Open Public Meetings Had Major Effects on the Study

Whenever the panel met in Oregon, an open, public meeting was announced through a mailing and in newspapers. The panel held ten open public meetings in six Oregon cities including several in Portland, Corvallis, Gold Beach, and Newport. The reports were released in draft form as part of the open, public process and made available to the public for comment. The panel recognized that to submit a draft report is somewhat unorthodox in that the public is more accustomed to scientists discussing matters among themselves and then providing the public with a final statement of what should be done. However, the panel found that the open public meetings provided significant contributions to the study.

As an example, when the panel met in Gold Beach the meeting began with Jim Welter, an old time fisherman, showing graphs he had drawn illustrating the relationship between fish catch and water flow in the Rogue for the past 30 years. Then a representative from a fishing guide organization presented data showing differences between actual counts and catch of fish and government estimates of fish abundance. Other groups addressed the need for better data and understanding of the complex river systems and life histories of the fish.

One result of the meeting was that Mr. Welter's idea was examined. He had observed that these relationships might be used to produce useful forecasts three and four years in advance of escapements. As shown in our report *Forecasting Spring Chinook Runs* (Sobel and Botkin 1994), he was correct.

Availability of Data

The panel found that available data are inadequate to provide definitive answers to the questions posed by Oregon Senate Bill 1125. However, the panel also found that existing data has been under-utilized. In this report we show how careful analyses of existing data can provide valuable insights about salmon and their habitats. At the beginning of the study we expected to be able to provide rather specific sets of options for the people of Oregon. Because a bill was passed that called for a review of the data concerning the decline of salmon and the relative effects of forest practices, this suggested that adequate data for such an analysis existed. However, the panel found that few data of sufficient quality at a regional scale were available in spite of a history of salmon data collection in some cases going back to the 1930s and in spite of many scientific research projects concerning the forests, fisheries, and land use of the Pacific Northwest. Many of these studies conducted during the last 30 years provide valuable, legitimate scientific information, but too often at a local scale, inappropriate for the questions posed by Oregon Senate Bill 1125.

Of the 26 major rivers that flow into the ocean within the study area, there are scientifically valid counts only on the Rogue and on the Umpqua.

One example of the lack of adequate data is that although there are counts of salmon at many locations, of the 26 major rivers that flow into the ocean within the study area, there are scientifically valid counts only on the Rogue and on the Umpqua, and only at one location for each.

Moreover, in spite of various forms of cooperation, it has proven difficult, and in some cases impossible, to retrieve data from government agencies. We estimate that approximately one-quarter of CSE staff time was spent in attempts to retrieve data that we were initially told was available.

An example of one unsuccessful attempt to obtain data was our search for the historical data on the number of smolts released by hatcheries. These data are important because they are part of our development of new methods to forecast return of adult fish, which we were able to do for spring chinook on the Rogue River. Because of the failure to obtain the data for coho, it has not been possible to develop the same forecasting tools for that species. This method is important not only for forecasting, but for understanding what is happening to the various salmon species.

Variability rather than constancy or a single, clear trend best characterizes the numbers of returning salmon.

FINDINGS

How does one begin to determine changes in the status of salmon, causes of those changes, and forecast possible future abundances of salmon? First, one clarifies the question. When one asks: Has there been a change in the status of salmon, one is actually asking two questions.

> The first is: Has there been a change in overall numbers?
> The second is: Has there been a change in geographic distribution of stocks?

Regarding these questions, we made three analyses that give new insights with practical applications: 1) an analysis about the relationship between yearly variations in adult fish returns to their spawning river. Among other finds, this analysis suggests a new method to forecast salmon returns and set harvest levels; 2) computer mapping techniques show changes in the geographic distribution of stocks of each species; and 3) using these computer mapping techniques, we conducted statistical analyses relating the geographic status of stocks to land use and land conditions, including the amount of forest cover. This section concentrates on these analyses; other findings and results are also given.

To understand the analysis of yearly variations in adult fish returns, it is helpful to begin simply by inspecting graphs of measurements of salmon that have been recorded consistently using reliable methods. There are, unfortunately, few such records. Beginning in the 1940s, estimates were made of the number of fish going over two dams - the Gold Ray Dam on the Rogue River and the Winchester Dam on the Umpqua River - using direct counts of fish that pass by a viewing window on a fish ladder (Figure 4A)

The most striking thing about this graph is the great variation in the number of adults that return to spawn from year to year. Graphs for other species show similar variation. Variability rather than constancy or a single, clear trend best characterizes the numbers of returning salmon. Statistical analyses confirms what we see in this graph. First, there is no trend for spring chinook at Gold Ray Dam on the Rogue River. Second, there is no consistent trend that applies to all species on both rivers. On the Rogue River, only fall chinook and summer steelhead show statistically significant trends, which are upward. On the Umpqua, summer steelhead and fall chinook show significant downward trend.

Variables Related to Fish Returns on the Rogue River

Regarding the first question above, we analyzed annual variation in returns of salmon adults on the Rogue River. This analysis sought to investigate which variables explain the year-to-year variation in the returns of adult salmon on the Rogue River. Many valuable results were extracted from

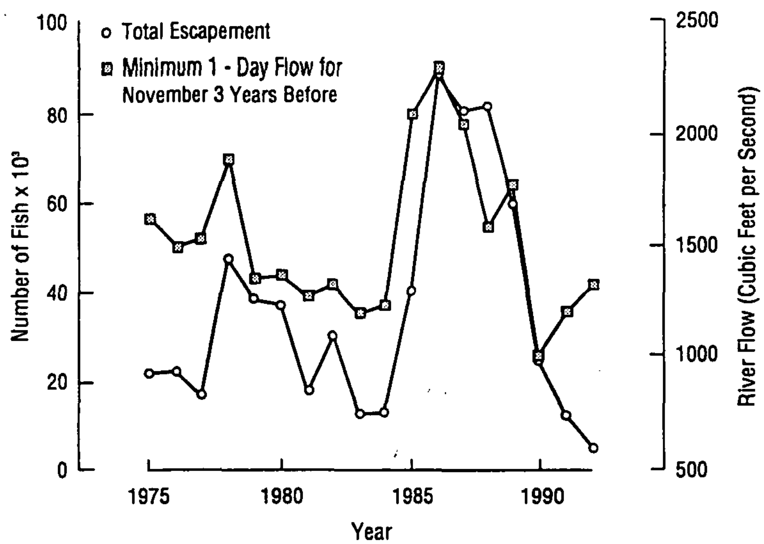

Figure 4A: Total escapement of Spring Chinook and minimum 1 day flow for November at Gold Ray Dam on the Rogue River.

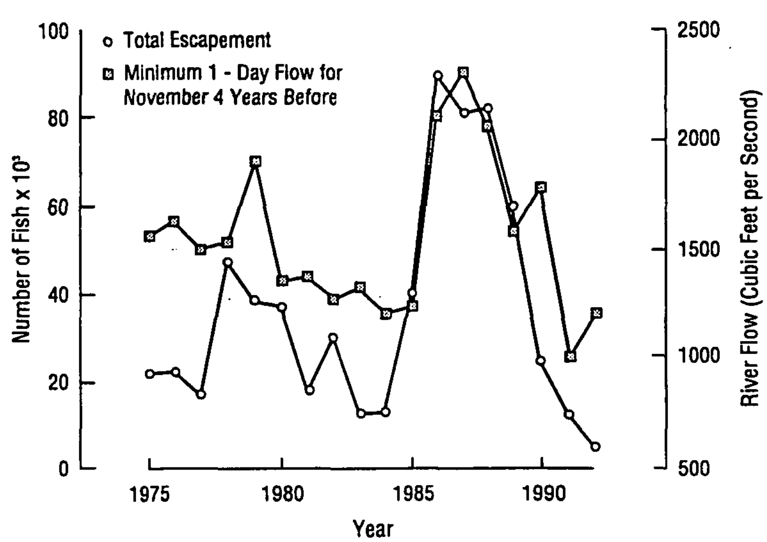

Figure 4B: Total escapement of Spring Chinook and minimum 1 day flow for November at Gold Ray Dam on the Rogue River.

this analysis.

The number of spring chinook adults returning each year to the Rogue River is strongly correlated with water flow three and four years before (Figure 4A and 4B). This variation provides a new method to forecast salmon returns and help set harvest levels. The method has several advantages over existing methods for setting harvest quotas. Since it can be used three years in advance, it provides more time for fisherman to plan their activities than is presently possible. Second, the statistical properties of the relationships are strong, suggesting the method may be more reliable.

Water flow three and four years before may provide a powerful method to forecast adult salmon returns.

The number of smolts released by hatcheries three and four years before is also statistically correlated with the number of returning adults. However, hatchery releases account for only a small percentage (between 0 and 20) of the variation in adult fish returns. This suggests *that hatcheries have not been an effective means to reliably increase the return of adults for sport and commercial catch.*

Ocean troll catches in the same year as adult returns (but taken a few months before the fish enter the river) are also statistically correlated with the number of returning spring chinook.

Taken together, these factors account for between 80 to 90 percent of the year-to-year variation in the number of returning adult salmon, based on our analyses of existing data for the last 20 years. Water flow accounts for most of this variation with minimum low flow in November being the most important factor.

More specifically, the environmental conditions examined for correlations with spring chinook returns to the Rogue River are: water flow variables (with total flow, minimum yearly flow, and minimum flow in specific months providing strong relationships); the number of smolts released by hatcheries three and four years prior to adult fish returns; upwelling indices three and four years prior to adult returns; and ocean troll catch in the same year as the adult returns upriver.

The major implications of this new analysis are: *water flow three and four years before may provide a powerful method to forecast adult salmon returns.* However, *the generality of this result must be tested for rivers other than the Rogue and stocks other than spring chinook.* These analysis must await the availability of historic data on hatchery releases.

The strong correlation between spring chinook returns and water flow does not mean that this is the only factor affecting the salmon. Water flow varies daily, monthly, and yearly. Its effects on salmon returns are more likely to show up with available data than ocean conditions or forest conditions, which change more slowly and require longer records. The quantitative relationship between water flow and adult spring chinook returns can vary with changes in background conditions imposed by more slowly changing environmental conditions including ocean upwellings and forest practices.

GIS Analysis: Geography of Stock Status

This analysis sought to determine the geographic distribution of salmon species and how their current status was related to land conditions.

Using Geographic Information Systems

(GIS), this analysis examined the geographic distribution and status of salmon species. This required obtaining maps of the location and status of stocks of each salmon species in the study area, and a map of land use and land conditions.

The only large-scale analysis of the status of salmon stocks for western Oregon and northern California that we found was done by C. Frissell with support from the Wilderness Society. From their data, we used GIS to create maps of the status of each species of salmon that occurred historically in the study area, in order to provide data for statistical analyses and for visual comparison.

Status of Salmon Stocks

Winter steelhead: Winter steelhead are distributed more broadly and appear to have been less affected in the Pacific Northwest than most other salmon populations. Its historic range included nearly 32 million hectares (ha) in the western Cascades of Washington and Oregon and extended throughout coastal California and into Mexico. Currently, winter steelhead is extinct in 25 percent of its historic range, and in 14 percent of its historic range of 7 million ha included in the study area. Throughout much of its range in the study area, steelhead still occurs, especially in the western portion. Extinctions are concentrated in the easternmost and southern portions of the study area, to the east of the Willamette Valley on the west slope of the Cascades and the western drainage of Crater Lake.

Summer steelhead: Summer steelhead were once widely distributed in Washington, Oregon and Idaho and in basins of coastal streams of northern California. This species is extinct in approximately 35 percent of its historic range of 29 million ha and 41 percent of its 1.7 million ha historic range in the study area. Its status is primarily threatened or extinct, with only a small portion not classified as such.

Coho: Coho were once very abundant throughout an estimated historic range of 36.5 million ha in the Pacific Northwest, 3.7 million ha of which are found in the study area. In the study area, coho is either threatened or extinct throughout its historic range. Present information indicates that coho is now extinct in about 46 percent of its total range, and in 3.5 percent of its previous range in the study area. Coho extinctions within the study area have occurred primarily in stocks that spawned in inland areas east of the coastal mountain range.

Chum: This species was widely distributed in 7.2 million ha along the Pacific Northwest coast from Washington to San Francisco Bay. Data show this species as extinct in 37 percent of its historic range in the Pacific Northwest and in 34 percent of the 1.3 million ha in the study area. Within the remainder of the study area, chum is classified as threatened.

Spring chinook: Of the 32 million ha historical range of spring run (includes summer run) chinook salmon in the Pacific Northwest, only about 8 percent (2.7 million ha) is located in the study area. Spring chinook is locally extinct in 45 percent of its historic range in the Pacific Northwest, and is locally extinct in 24 percent of its historic range in western Oregon.

Fall chinook: The historic range of fall chinook encompasses 17 million ha, of which only 2.8 million ha are in the study area. This species is extinct in 17.5 percent of its total range in the Pacific Northwest,

The effects of water flow on salmon returns are more likely to show up with available data than ocean conditions or forest conditions, which change more slowly and require longer records.

and in 17 percent of its range in the study area. It is extinct in the southeastern most portion of the study area, as are spring chinook and winter steelhead.

Sea-run cutthroat trout: Sea-run cutthroat trout occur along the coast from northern California to Washington (10 million ha) and in 2.6 million ha within the study area. It is extinct in 5 percent of its historic range. It is threatened but not extinct everywhere in the study area. Chum and cutthroat, whose historic distributions are along the coast and coastal mountains, are either extinct or threatened everywhere in the study area.

Sockeye: The historic range of sockeye in the Pacific Northwest is only about 2.8 million ha; this is primarily a northern species, and approximately only 213,000 ha are in the study area, with all stocks occurring in the southeastern most portion of the study area. Sockeye is extinct in nearly 49 percent of its historic range and in nearly all of its range within the study area (99.9 percent). Although most sockeye rear in lakes, some river-rearing populations existed in habitats in the study area that were apparently marginally suitable for them.

Except for sea-run cutthroat, all species of salmon in the study area have undergone a decline in geographic distribution.

The major conclusions of this analysis are:

- *Except for sea-run cutthroat, all species of salmon in the study area have undergone a decline in geographic distribution,* meaning that there has been a loss of specific stocks.
- *Chum and sea-run cutthroat,* distributed primarily along the coast and in drainages that begin in the coastal mountains, *are considered everywhere to be threatened or extinct.*
- *Coho,* which has a wider historic distribution, but which is also concentrated west of the Willamette Valley, *is also either threatened or extinct in all areas of the study area. This suggests that there might be factors at work to the west of the Willamette Valley that have negatively affected these species.* If such factors are occurring, it is something that does not seem to have affected fall chinook or winter steelhead. *This suggests that the factors affecting changes in the distribution of salmon vary within species.*
- Finally, *the maps also suggest that there are some important factors at work in the southern part of the study area, near the California border.* The causes of these patterns cannot be resolved with existing data; however, *the patterns suggest that valuable insights could be gained from new research projects that would attempt to ascertain the causes of the patterns.*

From research conducted during the past 30 years, forest conditions essential to spawning, rearing, and migration of salmon are well understood at the local level of a single stream or small watershed. Also well understood are the effects of altering forest conditions, including effects of clearcutting or conversion of land from forest to agriculture or urban areas.

Because forest growth and development takes place over longer time scales than a single year, *effects of forest growth and development are not likely to show up on a year-to-year time frame. Instead, these set a baseline condition for potential production against which water flow exerts an annual variation.* A degradation of forest conditions that affect riparian and stream habitats would lower salmon potential; restoration would increase this potential.

GIS Analysis: Correlations Between Salmon Status and Land Use/Conditions

This analysis sought to determine which land uses and land conditions are most related to or explain the current status of salmon species.

We compared the maps of the geography of salmon status with a 1988 map of land conditions and uses derived from Landsat satellite remote sensing. We divided the status of each species into three categories: "present" (meaning present but not threatened or endangered, but otherwise making no other comment about numerical status); "threatened" (which included the Wilderness Society categories of threatened and endangered); and "extinct" (meaning present historically but extinct now) (see Figures 5A-5H, and transparency in the back cover). There are 14 categories in the 1988 land condition map, some of which are forest types which differ only by the amount of their fragmentation: 1) conifer with no fragmentation; 2) conifer with low fragmentation (0 to 33 percent open areas); 3) conifer with medium fragmentation (33 percent to 67 percent); 4) conifer with high fragmentation (greater than 67 percent); 5) mixed conifer and hardwoods with no fragmentation; 6) mixed conifer and hardwoods with low fragmentation (0 to 33 percent open areas); 7) mixed conifer and hardwoods with medium fragmentation (33 percent to 67 percent); 8) mixed conifer and hardwoods with high fragmentation (greater than 67 percent); 9) hardwoods; 10) riparian areas; 11) clearings; 12) grass/shrub/other; 13) agriculture; and 14) urban. (Note that fragmentation is defined as the percentage of open space in forests. The higher the degree of open space, the higher the percentage of fragmentation. Documentation for the 1988 land condition map is ambiguous in that the category "high fragmentation" overlaps with the category "clearings".)

Statistical regression equations were calculated between each salmon stock status and land conditions. For those not familiar with statistical methods, regression analysis essentially determines the amount of variation in the dependent variable (stock status) accounted for by each independent variable (land condition/use), and the amount of variation in the equation as a whole. Results are presented in Tables 1, 2, and 3.

We chose to consider land conditions only within a buffer zone around streams in each river basin. With the spatial resolution of the vegetation map, this included all the land conditions within 0.5 km on either side of each stream. Because of the abundance of stream channels, this method included an average of 80 percent of the land area within a watershed.

Presence of stocks: Conifer stands with no fragmentation or medium fragmentation are strongly correlated with "present" stocks of spring and fall chinook and winter steelhead. Clearings, and grass and shrub categories are negatively correlated with "present" stocks of chinook and winter steelhead, but contribute little to the variation of status. Agriculture is significantly correlated with the presence of only two of the salmon groups: fall chinook and winter steelhead. The latter shows a very weak correlation, to which little interpretation can be attached.

In watersheds where spring and fall chinook remain abundant, chum have become locally extinct.

Table 1. Stock status and land use conditions. Present salmon stocks in relation to land conditions within a 0.5 km buffer zone along streams. The first column is the salmon species, the second column is the land condition variable included in the equation (only statistically significant land condition variables are included), the third column is the coefficient, the fourth column is the amount by which R-squared is increased by adding the variable to the equation that includes the variables listed above it. All is the R-squared for the equation which includes all the variables.

SALMON STOCK	LAND CONDITION VARIABLE	COEFFICIENT	R-SQUARED
SPRING CHINOOK			
	Conifer	1.6	0.38
	Mixed - Low	1.8	0.13
	Grass-Shrub	-0.98	0.03
	All	2.42	0.54
FALL CHINOOK			
	Conifer - Med.	1.5	0.57
	Mixed - Low	3.3	0.12
	Clearing	-2.7	0.04
	Mixed - High	1.7	0.03
	Agriculture	-0.5	0.03
	All	3.75	0.79
COHO			
	(No data)		
CHUM			
	(No data)		
SOCKEYE			
	(No data)		
S.R. CUTTHROAT			
	(No data)		
SUM. STEELHEAD			
	Mixed - High	1.9	0.27
	Mixed - Medium	-2	0.12
	All	-0.1	0.39
WIN. STEELHEAD			
	Conifer - Medium	1.5	0.77
	Mixed - Low	2.1	0.06
	Hardwoods	11.5	0.03
	Conifer - Low	2.1	0.02
	Grass-Shrub	-3.3	0.03
	Agriculture	-1.05	0.01
	Mixed - Medium	2.9	0.01
	All	15.75	0.94

Table 2. Stock status and land use conditions. Threatened salmon stocks in relation to land conditions within a 0.5 km buffer zone along streams. The first column is the salmon species, the second column is the land condition variable included in the equation (only statistically significant land condition variables are included), the third column is the coefficient, the fourth column is the amount by which R-squared is increased by adding the variable to the equation that includes the variables listed above it. All is the R-squared for the equation which includes all the variables.

SALMON STOCK	LAND CONDITION VARIABLE	COEFFICIENT	R-SQUARED
SPRING CHINOOK			
	Conifer - Low	0.8	0.85
	Conifer	1.3	0.1
	Conifer - Medium	0.48	0.03
	Hardwood	1.03	0.001
	Mixed-Med.	0.53	0.001
	All	4.14	0.982
FALL CHINOOK			
	Conifer	1.2	0.2
	Clearing	-2	0.14
	All	-0.8	0.34
COHO			
	Conifer - Medium	2.2	0.66
	Mixed - Low	4.1	0.07
	Mixed - High	3.3	0.04
	Agriculture	-0.9	0.05
	All	8.7	0.82
CHUM			
	Mixed - Low	4.3	0.52
SOCKEYE			
	(No data)		
S. R. CUTTHROAT			
	Mixed- High	4.1	0.55
	Mixed - Low	4.9	0.2
	Agriculture	-0.4	0.04
	Conifer - Low	1.5	0.02
	Clearing	-3.4	0.03
	Mixed	-2.2	0.02
	All	3.7	0.85
SUM. STEELHEAD			
	Conifer - High	0.8	0.24
WIN. STEELHEAD			
	Conifer	1.5	0.23
	Grass-Shrub	-1.2	0.06
	All	0.3	0.29

Table 3. Stock status and land use conditions. Extinct salmon stocks in relation to land conditions within a 0.5 km buffer zone along streams. The first column is the salmon species, the second column is the land condition variable included in the equation (only statistically significant land condition variables are included), the third column is the coefficient, the fourth column is the amount by which R-squared is increased by adding the variable to the equation that includes the variables listed above it. All is the R-squared for the equation which includes all the variables.

SALMON STOCK	LAND CONDITION VARIABLE	COEFFICIENT	R-SQUARED
SPRING CHINOOK			
	Clearing	6.1	0.47
	Mixed - Med.	-2.29	0.14
	Conifer - Medium	-0.53	0.05
	Grass/Shrub	1.13	0.04
	All	4.41	0.7
FALL CHINOOK			
	Grass/Shrub	2.53	0.63
	Mixed - Medium	-1.96	0.03
	Clearing	2.42	0.04
	Mixed	-1	0.03
	All	1.99	0.73
COHO			
	Conifer - Medium	0.53	0.07
	Conifer - High	-0.31	0.07
	Mixed - High	-0.61	0.09
	All	-0.39	0.23
CHUM			
	Conifer - Low	0.38	0.15
SOCKEYE			
	Grass/Shrub	1.14	0.42
S.R. CUTTHROAT			
	(No extinction)		
SUM. STEELHEAD			
	Hardwoods	9.27	0.34
	Grass/Shrub	1.91	0.29
	Mixed - High	-1.25	0.04
	Clearing	2.9	0.04
	Mixed	-1.57	0.04
	All	11.26	0.75
WIN. STEELHEAD			
	Grass/Shrub	3.34	0.59
	Clearing	2.95	0.03
	Mixed	-1.46	0.03
	All	4.83	0.65

Local extinction of stocks: *Clearings and grass and shrub categories are statistically significantly correlated with local extinction of spring and fall chinook, sockeye, and winter and summer steelhead.* In other words, the amount of land in grass and shrub and clearings is positively related to the extinction of those species. In general, forest cover with any amount of fragmentation is negatively correlated with local extinctions with the exception of chum whose extinction is positively correlated with conifer forests with low fragmentation.

A surprising result is that in watersheds where spring and fall chinook remain abundant, chum have become locally extinct. The primary habitat difference between these species is that chum spawn and rear in estuaries and main river stems, while chinook pass through these large water bodies to spawn farther upstream, but rear in the same habitat as chum. This suggests that declines of chum may be related to spawning rather than rearing. We do not have quantitative information to give insight into what this factor might be.

Salmon Stock Status in Relation to Forest Conditions

Chum spawning seems unrelated to forest practices; thus it might be affected by other practices such as gravel removal, agricultural pollution, flood control dams, channel modification of estuaries and main river stems, and overfishing, but data do not allow statistical analyses to test for the importance of these factors. Extinction of steelhead and coho, which spawn and rear in the smaller streams, is statistically (positively) correlated with forest cover.

This analysis suggests that *the relative importance of forest practices on the local extinction of salmon stocks varies with species. For steelhead and coho, forest clearing and the amount of forest cover present are major factors; for chum, forest conditions are a minor factor.* The results for steelhead, coho, and chum are consistent with the fact that they utilize different stream habitats (portions of rivers).

Salmon Stock Status in Relation to Agriculture

Agriculture can have a negative effect on salmon habitat. However, agriculture occupies a comparatively small area within 0.5 km of stream channels in the study area, averaging 8.3 percent. In contrast, on average, 80 percent of the basins are covered by some kind of forest, including all levels of fragmentation.

For stocks of fall chinook that are present and not threatened, there is a statistically-significant but negative correlation between the area of a basin in agriculture and the area that had salmon in the past and still has salmon. However, the area in agriculture explains very little of the variation in fall chinook status. Agriculture is negatively correlated with "threatened" coho stocks, but explains very little of the variation. Agriculture is positively correlated with the area of "threatened" cutthroat stocks, again explaining very little of the variation. There is no significant correlation between area in agriculture and the area occupied by stocks in the past that are now extinct for all species. This may result from the small area that is in agriculture and the small area that makes up the salmon category present in the past and extinct now.

In summary, *although agricultural practices*

The relative importance of forest practices on the local extinction of salmon stocks varies with species.

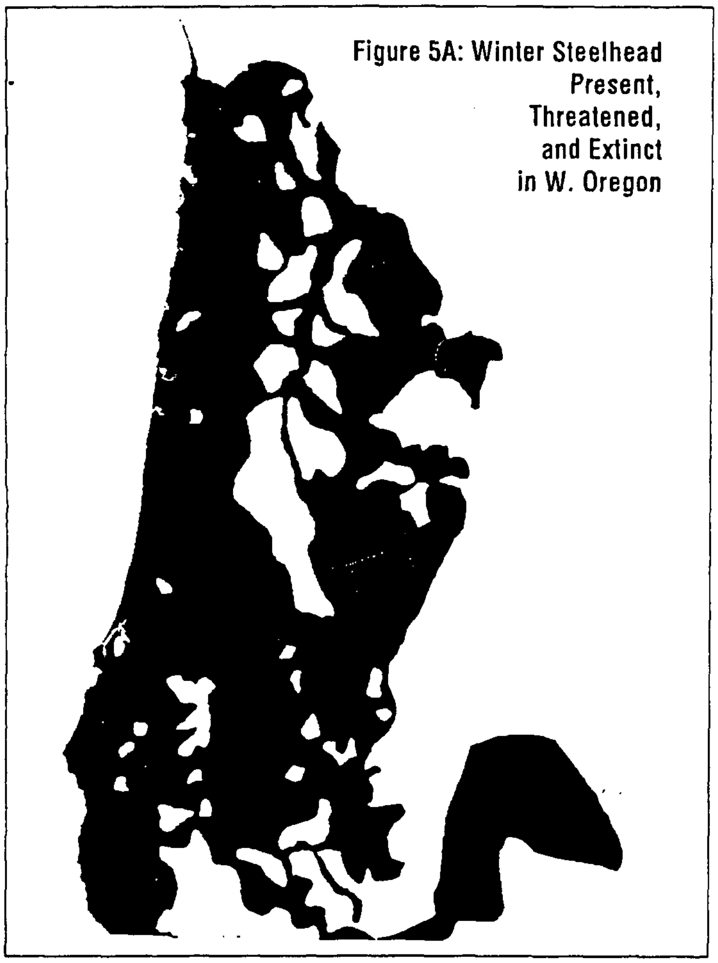

Figure 5A: Winter Steelhead Present, Threatened, and Extinct in W. Oregon

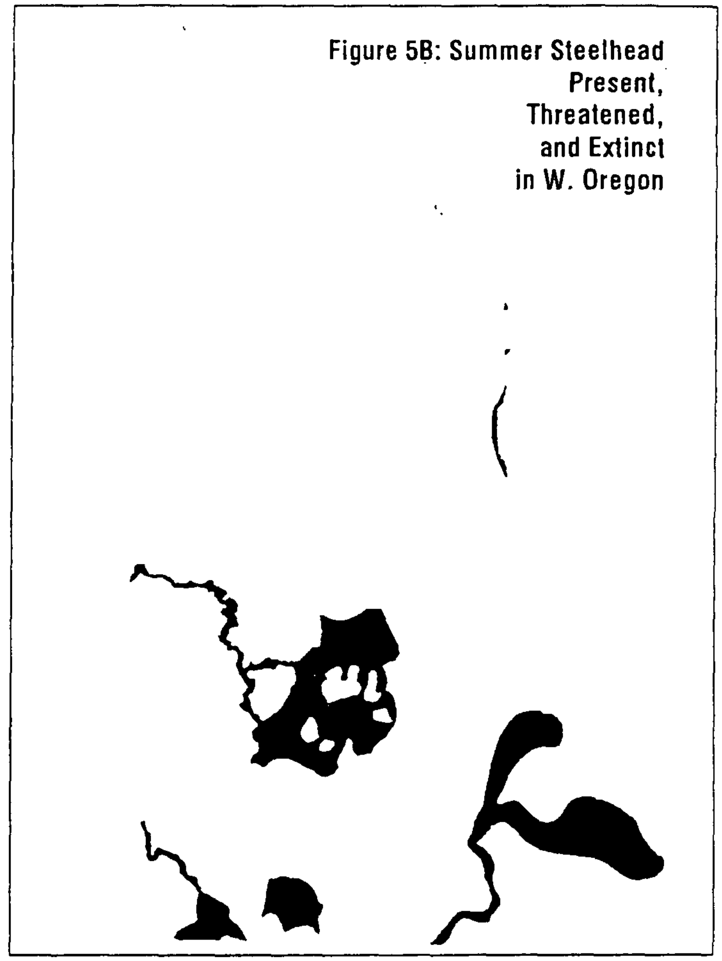

Figure 5B: Summer Steelhead Present, Threatened, and Extinct in W. Oregon

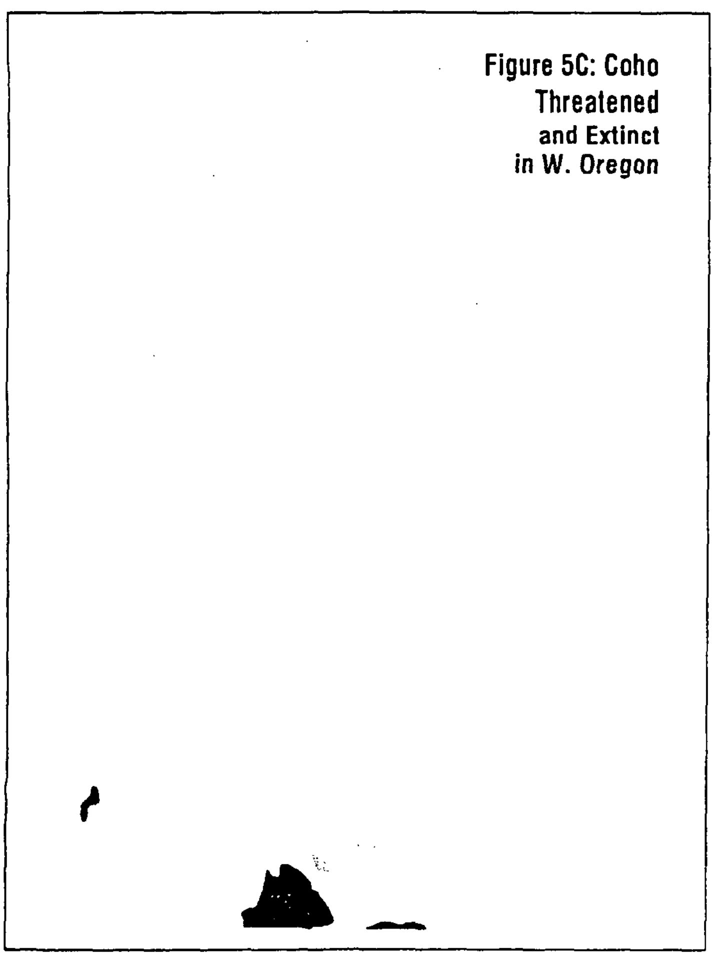

Figure 5C: Coho Threatened and Extinct in W. Oregon

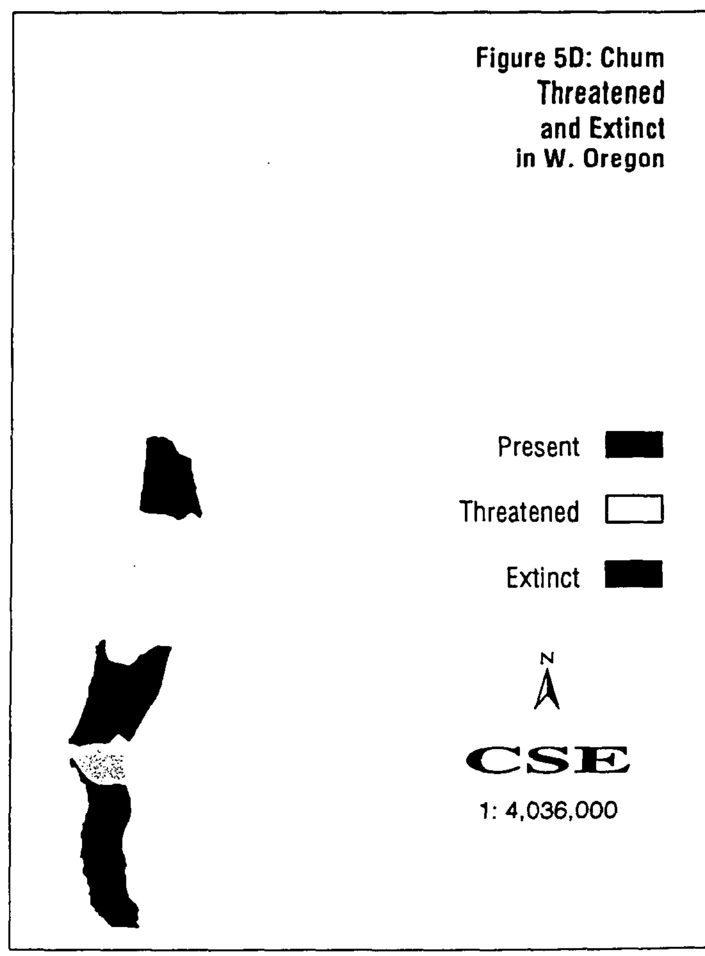

Figure 5D: Chum Threatened and Extinct in W. Oregon

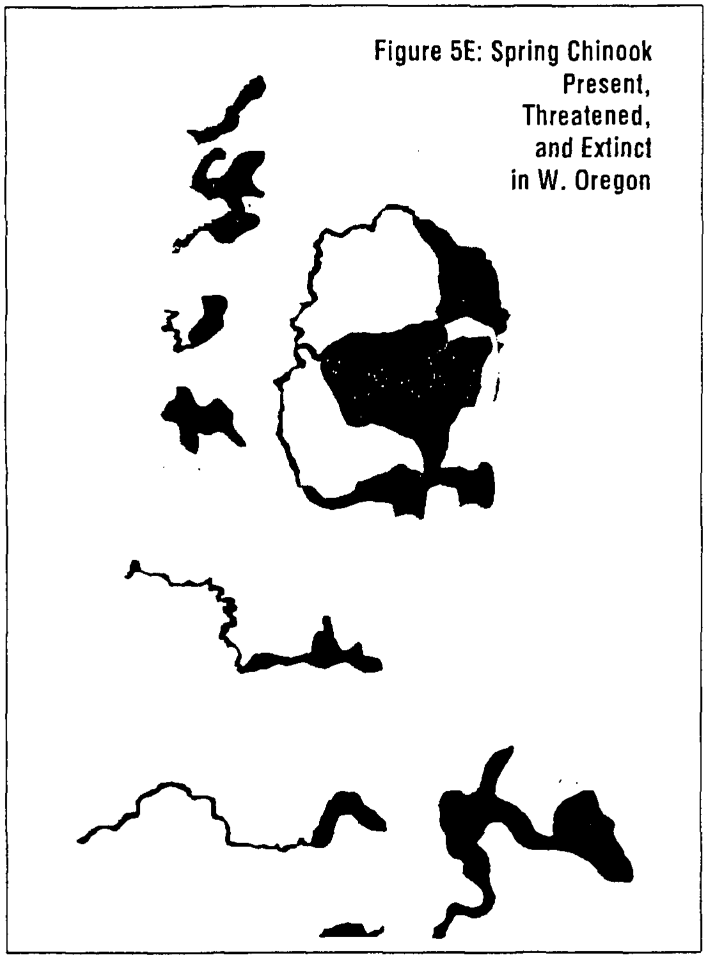

Figure 5E: Spring Chinook Present, Threatened, and Extinct in W. Oregon

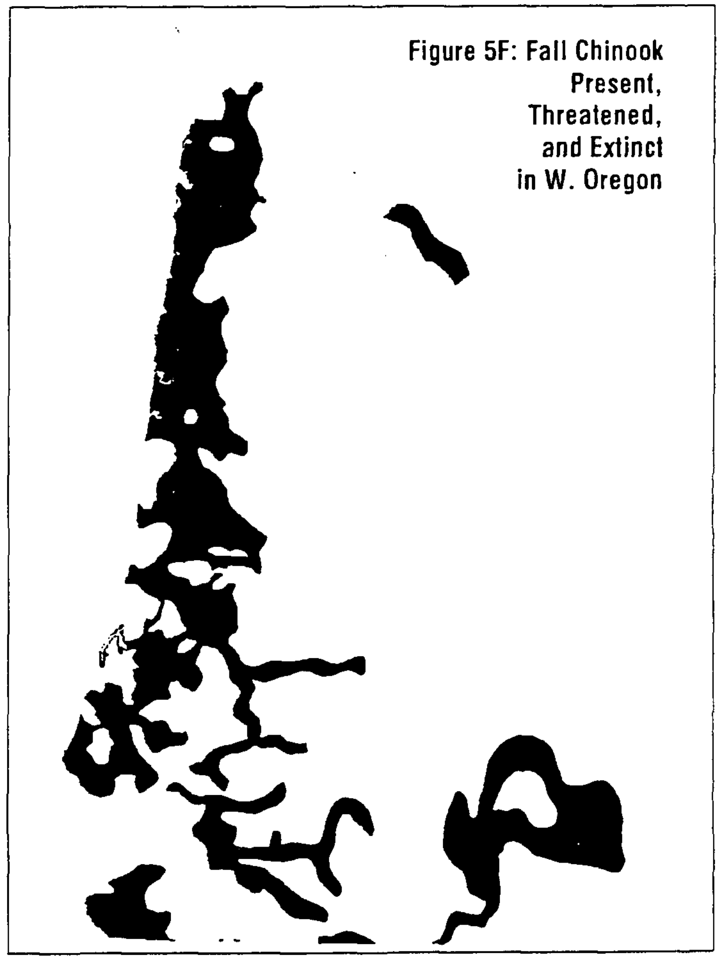

Figure 5F: Fall Chinook Present, Threatened, and Extinct in W. Oregon

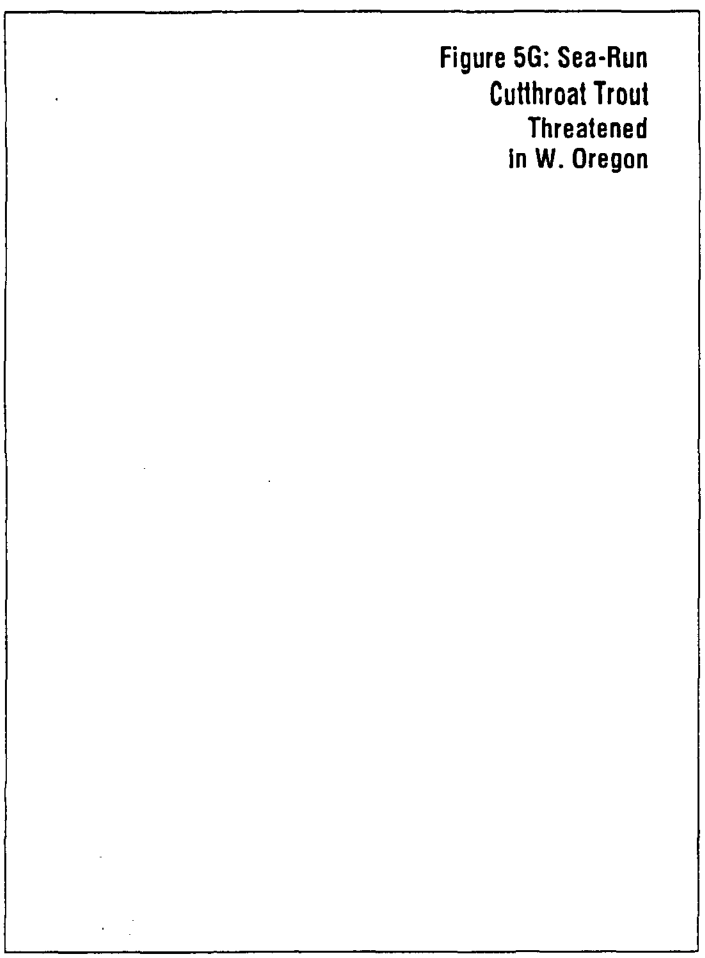

Figure 5G: Sea-Run Cutthroat Trout Threatened in W. Oregon

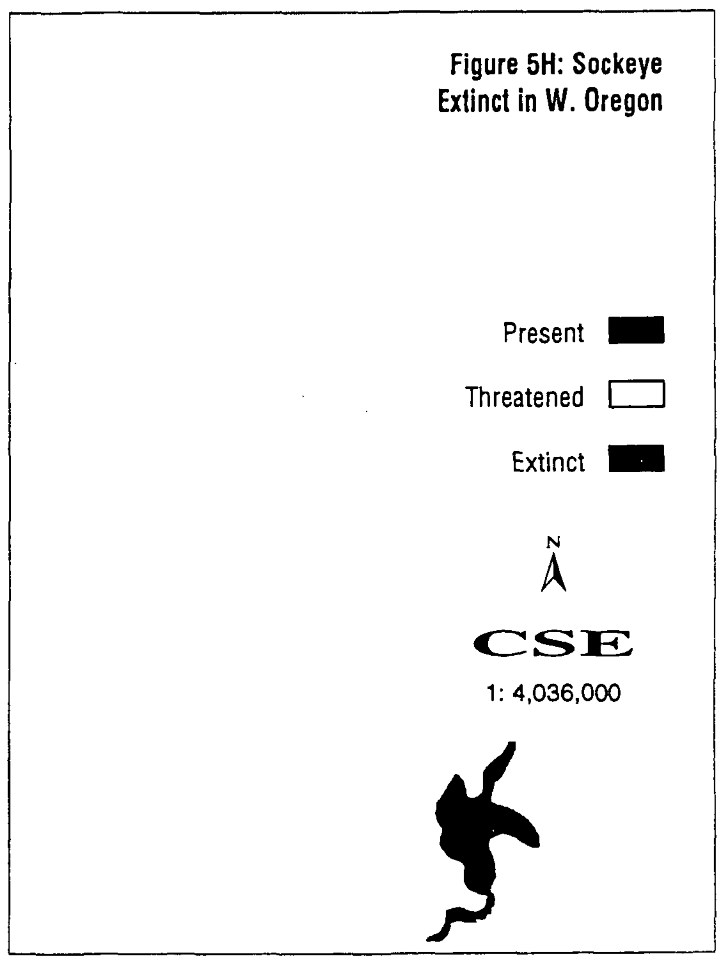

Figure 5H: Sockeye Extinct in W. Oregon

can have a number of negative effects on salmon habitat, agriculture occupies a small percentage of the study area, and present data at the basin scale show little statistical correlation with the status of salmon stocks.

Salmon Stock Status in Relation to Urban Areas

In urban areas, as in agricultural areas, there have been large changes in salmon habitat: stream channels straightened; trees removed from the riparian zone; pollutants of many kinds entering streams. There may be a significant association between population density and salmon presence and extinction not seen when looking at urban areas alone. *If urban growth continues, effects may cover a large enough area to exert some influence on salmon, but, from the available data, little effect can be seen in terms of the whole study area.* Urban areas cover only an average 3.4 percent of the land in Oregon basins in the study area, and, possibly due to the small area covered, urban areas do not appear as a significant variable in the regression analysis relating land cover to salmon presence and extinction. One could find local urban areas where there is anecdotal evidence of previous presence of salmon and present extinction, but looking at land use across basins, urban areas do not now turn up as a statistically-significant variable.

Major factors known to affect salmon are agriculture, dams, drought fish harvest, forestry, and urbanization.

Other Significant Findings

• Salmon use many habitats including the ocean which can vary in ways that can enhance or decrease salmon survival. Therefore, salmon populations are only partially open to control or influence by people. The best that can be done is to improve those habitats over which we have control and ensure that harvests do not exceed the reproductive capacity of salmon so that human actions are not the bottleneck that limits the abundance of salmon. With this approach, the best one can expect is an improvement in the average abundance of salmon and a reduction or even reversal in the extinction of stocks.

• Of the 26 rivers that flow into the Pacific Ocean in western Oregon south of the Columbia River, there are statistically valid counts of returning adult fish for only two rivers. These counts have been available for approximately the past 50 years.

• Available data in the study area for the number of adult fish returning to spawn on the Rogue and Umpqua Rivers show no consistent pattern in population trends for wild fish (Figures 6A & 6B). Total Oregon landings of ocean caught coho from 1892 to 1993 show a significant downward trend (Figure 7). However, the origin of these fish is unknown.

• Variability, rather than constancy, best characterizes the year-to-year pattern in the number of adult fish returning to rivers to spawn during the past 50 years (Figure 8).

• Models have played an important role in fisheries management, serving as the basis for setting harvest quotas. However, models currently in use are not adequate for realistic, accurate projections of population trends, harvest quotas, or for estimating the effects of human action on fish abundance because they do not consider long-term environmental change directly, either natural or human induced.

• Major factors known to affect salmon are: agriculture, dams and other obstructions, drought, fish harvest, forestry, and urbanization.

• The potential production of salmon in a stream changes through forest succession (age). After riparian vegetation is cleared along a river there is a period of about one

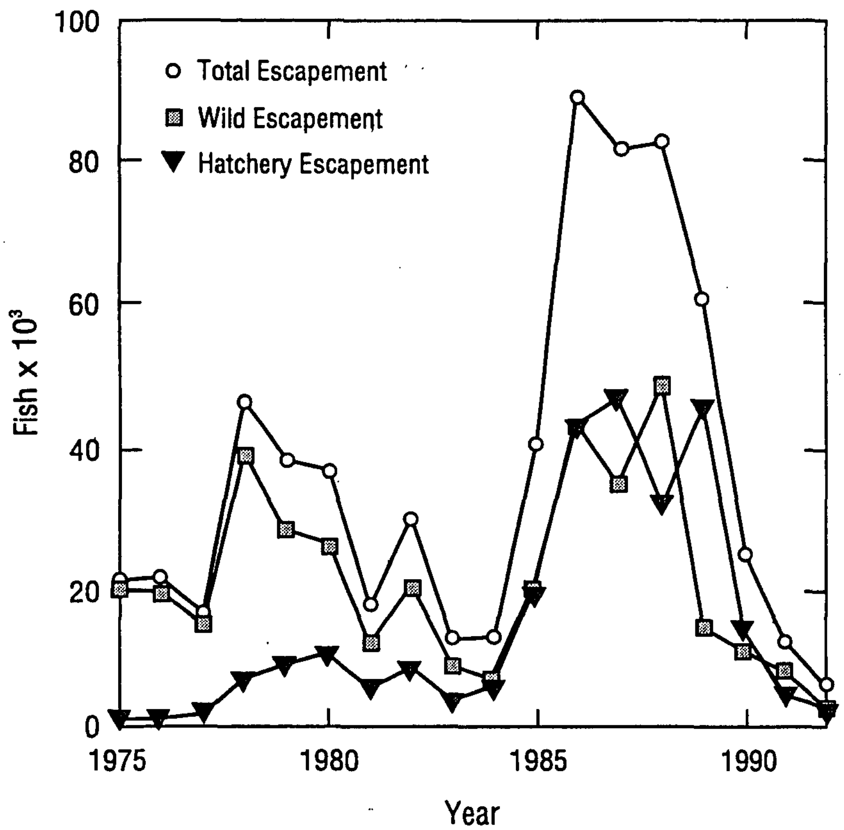

Figure 6A: The escapement of spring chinook into the Rogue River in thousands of fish each year between 1975 and 1992. The graph indicates numbers of hatchery and wild fish, as well as their total.

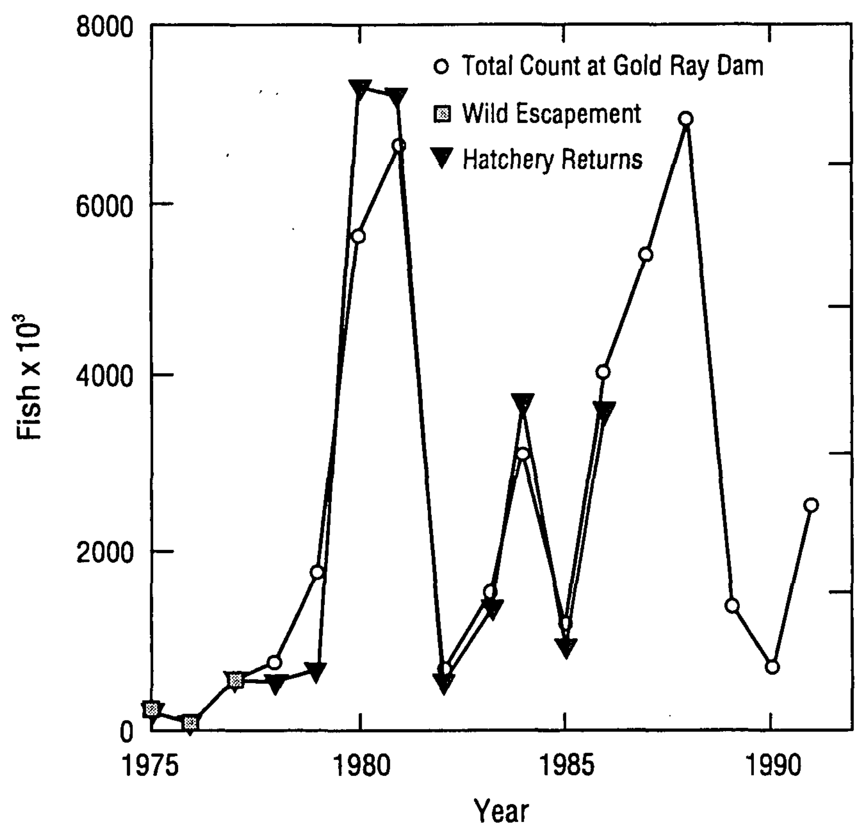

Figure 6B: The escapement of Coho into the Rogue River in numbers of fish each year between 1975 and 1992. Before only wild fish were in the Rogue River. Dam counts were not separated into wild and hatchery, therefore total indicates both. Returns to Cole Rivers Hatchery are estimated at the hatchery which is located above Gold Ray Dam.

to five years when potential salmon production rises (Figure 9). Between about six and 40 years following a clearing, potential fish production falls to a minimum. After about 40 years, potential fish production reaches the range found in mature forests. Areas logged after approximately 1952 but prior to 1972, when the Oregon Forest Practice Rules went into effect, would still be in the stage of lowest potential fish production. Areas subject to logging prior to 1972 may still be limiting the recovery of salmon production, particularly on private land where there was less regulation and greater variation in practice.

• Prior to 1980, summer observation during low flow led to the mistaken conclusion that debris dams pose a barrier to winter salmon migration. Thus there was a large-scale removal of large woody debris (LWD). This removal policy had major, long-term destructive effects on salmon rearing habitats. Areas subjected to LWD removal are still limiting the quality of salmon habitat, a situation which could persist for 50 to 100 years following the removal of the debris (Figure 9).

• This study confirms the importance of the protection of riparian zones along streams for salmon, whether in agriculture, forestry, or urban areas (Figures 10 & 11). In many of the agricultural and urban areas of western Oregon, habitat characteristics required by salmon have been severely damaged

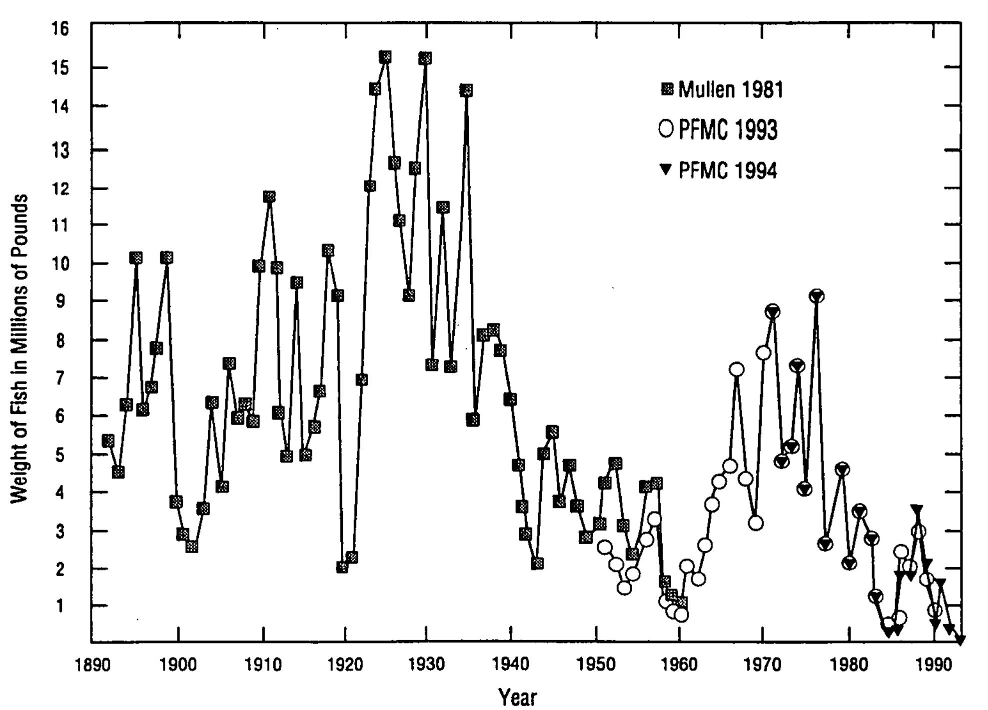

Figure 7: Estimates of commercial ocean troll catch of coho salmon landed in Oregon in millions of pounds from three sources over the period 1892 to 1993. The three sources of the estimates are Mullen (1981), PFMC (1993), and PFMC (1994).

or completely eliminated.

• Historical documentation shows a major simplification of stream channel and floodplain habitats during the period of agricultural settlement and logging in some regions. This simplification resulted in large differences in the amount of woody debris, the volume of pools, and the amount of gravel stored per unit length of stream between logged and old-growth forest reaches. The most important implication in understanding the role riparian zones play in sustaining fish habitat is that long-term restoration of fish runs requires that large fractions of stream channels in western Oregon must be lined with vegetation appropriate to salmon habitats.

• Attempts to restore salmon into watersheds where they have become extinct are gener-

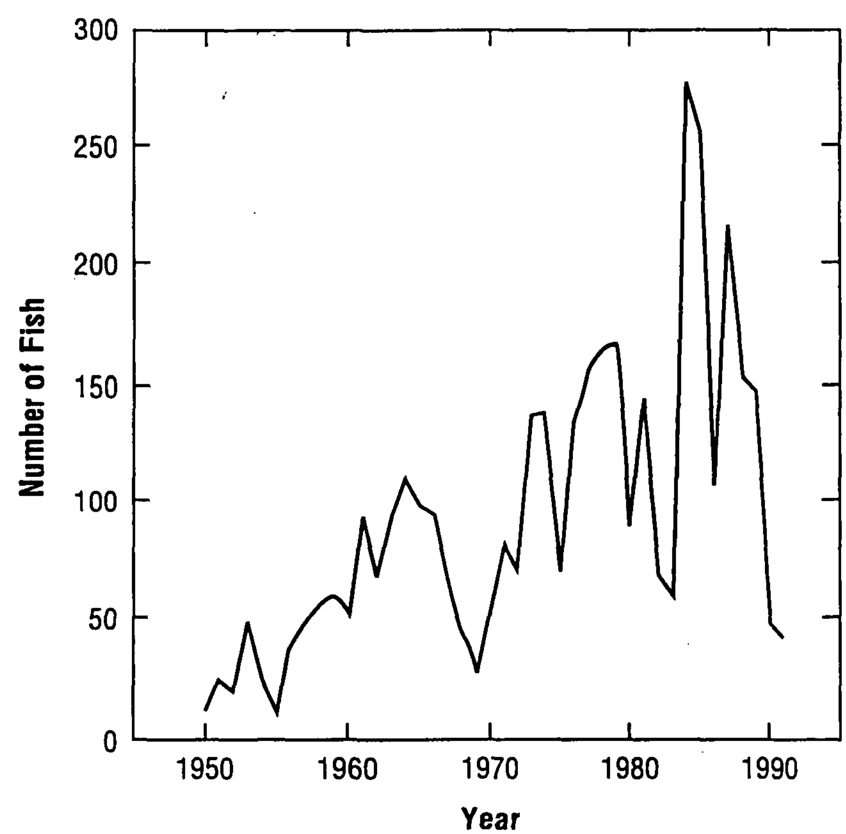

Figure 8: Peak counts (numbers) of chinook salmon on Humbug Creek, which flows into Nehalem River, between 1950 and 1991.

TABLE 4: Sources of Salmon Harvest			
Source of Salmon Harvest	**Metric Tons Per Year (average)**	**Species Included**	**% of Total Harvest**
Commercial Ocean Harvest	2,385 (1952-90)	Chinook, Coho	65
Ocean Sport Harvest	827 (1966-90)	Chinook, Coho	22
Freshwater Sport Harvest	248 (1969-90)	Chinook, Coho	7
Bycatch (legal)	225 (1981-91)	All Salmon	6
Unregulated Ocean Catch (illegal)	*	All Salmon	*
Marine Mammal Predation	*	All Salmon	*
Bird Predation	*	All Salmon	*
Total of All Mortalities (except predation and illegal catch)	3685		100

For each entry, the average total annual harvest is included along with the time period used to make the calculation. The species column indicates the particular (or all) salmon species which were used in making the calculation. [Calculations of annual harvest for each type were made as follows: Commercial ocean: the average annual harvest for chinook and coho between 1952 and 1990 obtained from Pacific Fisheries Management Council (PFMC); Ocean Sport: the average annual harvest of chinook and coho between 1966 and 1990 obtained from PFMC; Freshwater sport; the average annual harvest of chinook and coho between 1969 and 1990 for Oregon coastal rivers obtained from PFMC; Legal bycatch: PFMC estimates that between 25,000 and 100,000 salmon are bycaught in the Oregon commercial fishery. Using an average fish weight of 3.6 kg and using the midpoint of their estimate, or 62,500, we calculate an average annual harvest. Unregulated ocean catch: marine mammals and birds: Data are so incomplete and statistically and scientifically flawed, as discussed in the text, that no quantitative average range of values can be calculated at this time, but the impact of each is clearly minimal. Many studies show no salmon in the stomach contents of marine mammals and birds that are likely predators. In studies that show take of salmon by marine mammals and birds are only from short periods during the year when predation is most likely and/or highest, such as river migrition of salmon co-occurring with nesting seasons of cormorants and with the appearance of pinnipeds in the Columbia River during migration.

ally not successful; apparently, successful migration and adaptation of salmon to new streams require more than a single human lifetime.

- A belief exists that in presettlement times, western Oregon was a continuous cover of ancient forest and that such continuous cover was an important factor in high salmon production. However, Bureau of Land Management maps show that in 1850, approximately 40 percent of the forests were older than 200 years, 62 percent were older than 100 years, 64.5 percent were older than 50 years, and 34.5 percent were mapped as burned (Table 5) (Figures 12A-12D).
- To the best of our knowledge, no studies have been made of how sediment supply is affected by recent technical innovations and regulatory measures in road siting and construction.
- The amount of unregulated catch of salmon on the high seas and illegal ocean catch within treaty waters is generally unknown, but may be significant (Table 4).
- At present, bycatch (the inadvertent taking of salmon in catching other fish) is monitored for only one fishery in Oregon, the whiting fishery.
- Available data show that marine mammals are at most a minor factor in salmon mortality (Table 4).
- An upwelling is a vertical ocean current that brings nutrients crucial to biological production to the surface. Scientists have speculated about connections between the strength of ocean upwellings and the number of returning adult salmon. However, sta-

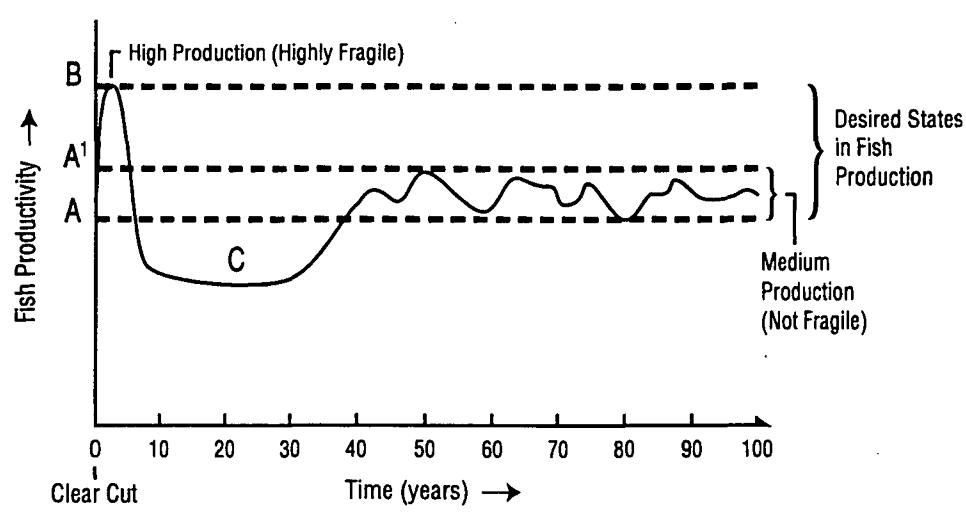

Figure 9: The level of salmon production in a stream during riparian succession over a 100 year period following a clear cut to the stream edge. Normal long-term fish production in a mature forest environment is between A and A^1. Desirable production levels fall within the range of A and B. The portion of the line labeled C is the period of low production between 5 and 40 years following clear cut. (from Wilzbach, 1986).

tistical analysis of available data for adult fish returns to the Rogue River show only a very slight correlation with upwelling indices. Data are available only for 20 years, which may be too short a time to detect correlations.

• Long-term variation in ocean currents may shift conditions that are good for salmon from north (off Alaska and British Columbia) to south (off Washington, Oregon and California) and back again over time.

• The present methods for collection of data about which river is the site of origin for any wild fish caught in the ocean are inadequate.

• Under the Endangered Species Act, there are many more management options available for a stock listed as threatened than for one listed as endangered. Therefore, for legal as well as good resource management reasons, it benefits the government of Oregon and private landowners to prevent threatened stocks from becoming endangered.

• Salmon have one of the most complex life cycles of any vertebrate animal, and some aspects of their habitats vary in ways that are not subject to control by people.

• The present state of science does not allow us to make precise determinations of the genetic differences among stocks of Pacific salmon.

TABLE 5: Forest History. Forest stand age classes of the Oregon Coast Range (percentage by age class). Source: Teensma et al.,1991.

Year	Burned	0–49	50–99	100–199	200+	Total
1850	34.50	1.30	2.20	22.00	40.00	100.00
1890	5.20	23.70	19.60	19.60	46.30	100.00
1920	6.10	4.40	19.80	19.80	49.90	100.00
1940	7.30	33.50	8.70	31.90	18.60	100.00

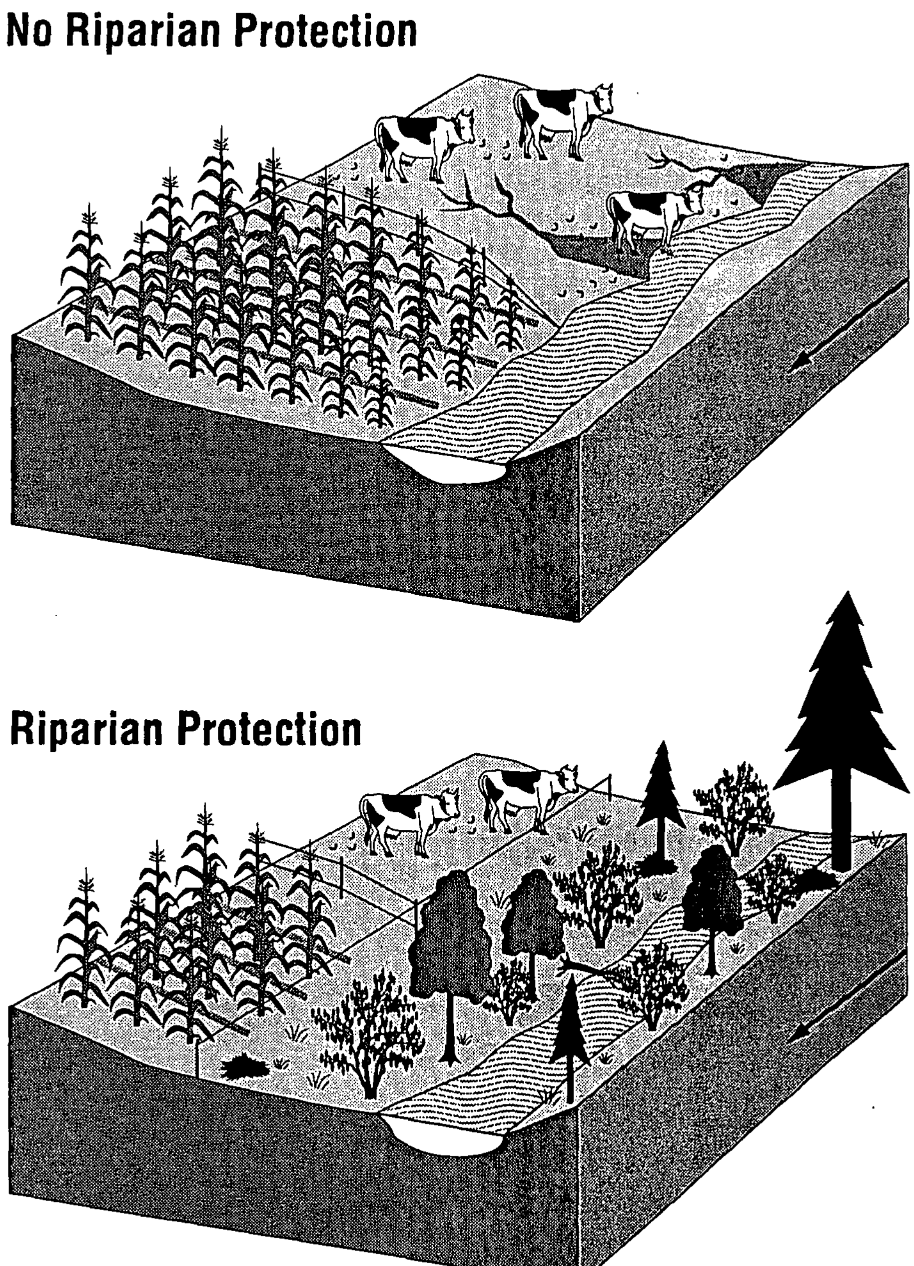

Figure 10: Diagrams of the conditions of streams and riparian zones in agricultural areas with and without riparian zone protection.

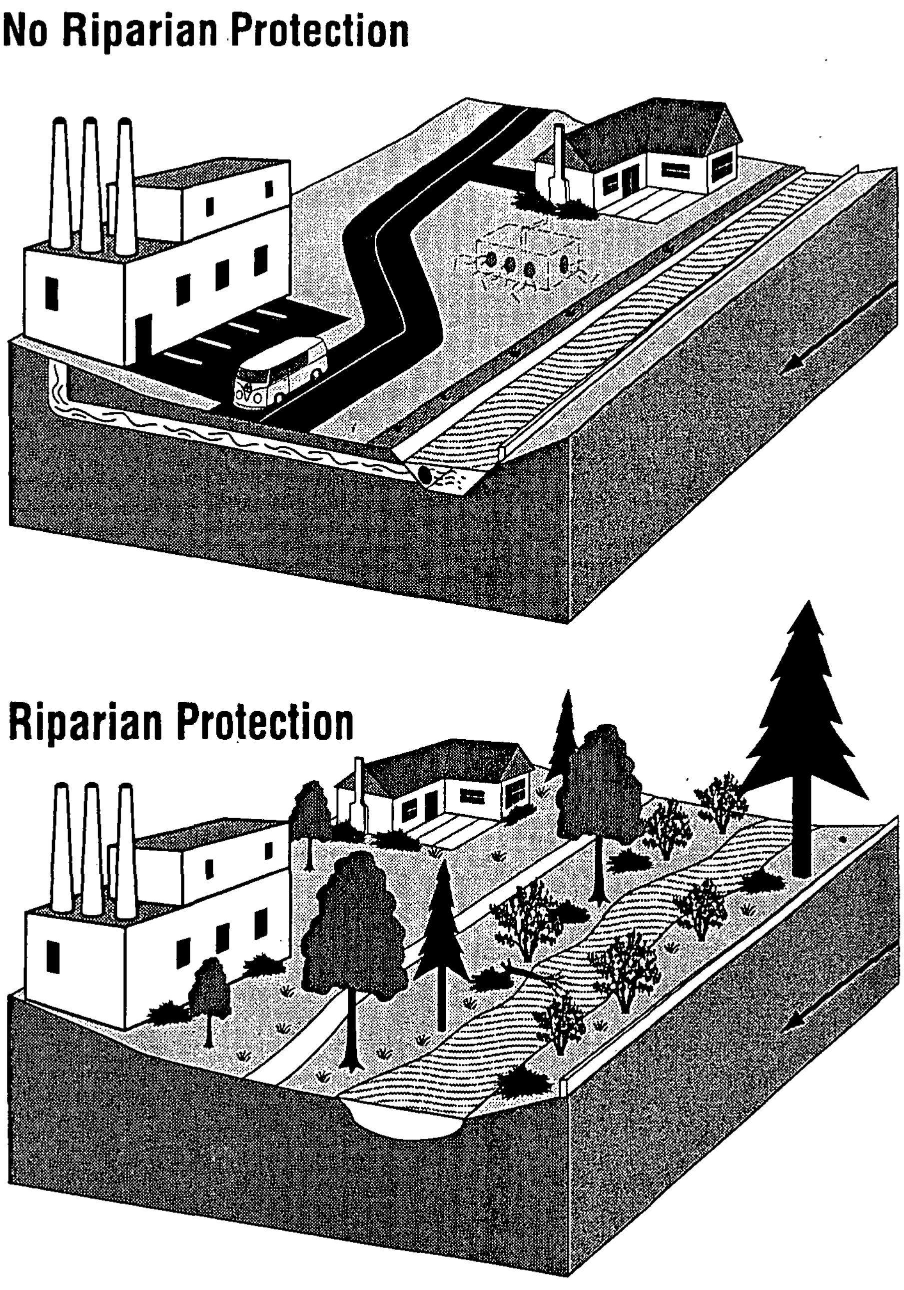

Figure 11: Diagrams of the conditions of streams and riparian zones in urban areas with and without riparian zone protection.

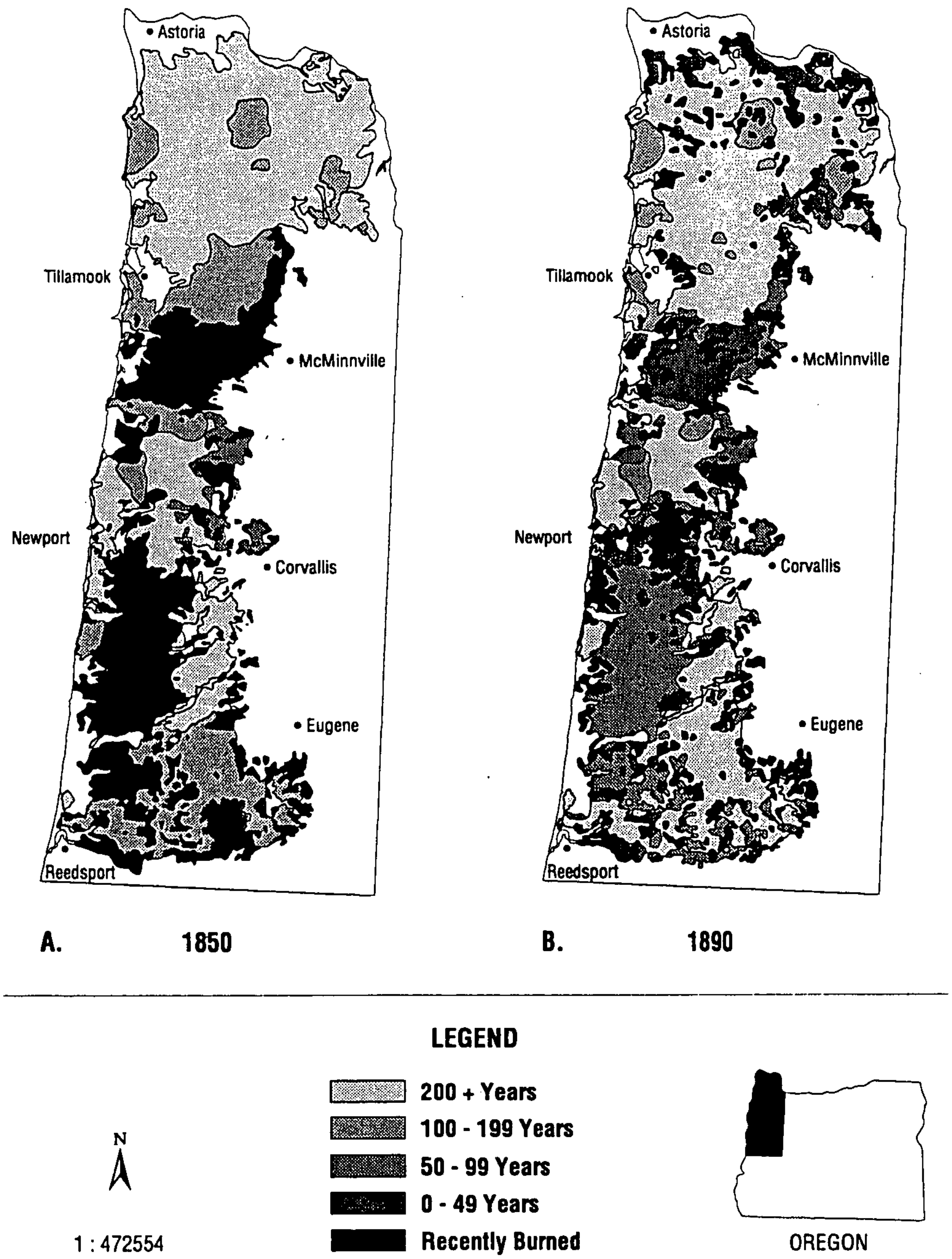

Figure 12 A-B: Forest stand age classes for the Oregon Coast Range
NOTE: This map was compiled from reconnaissance field notes. It was digitized from hand interpolated source materials and may differ spatially from digital mapping compiled from other source data. Prepared by Salem District and Oregon State Office, Bureau of Land Management, Sept., 1991 from United States Geological Survey data collected in 1850.

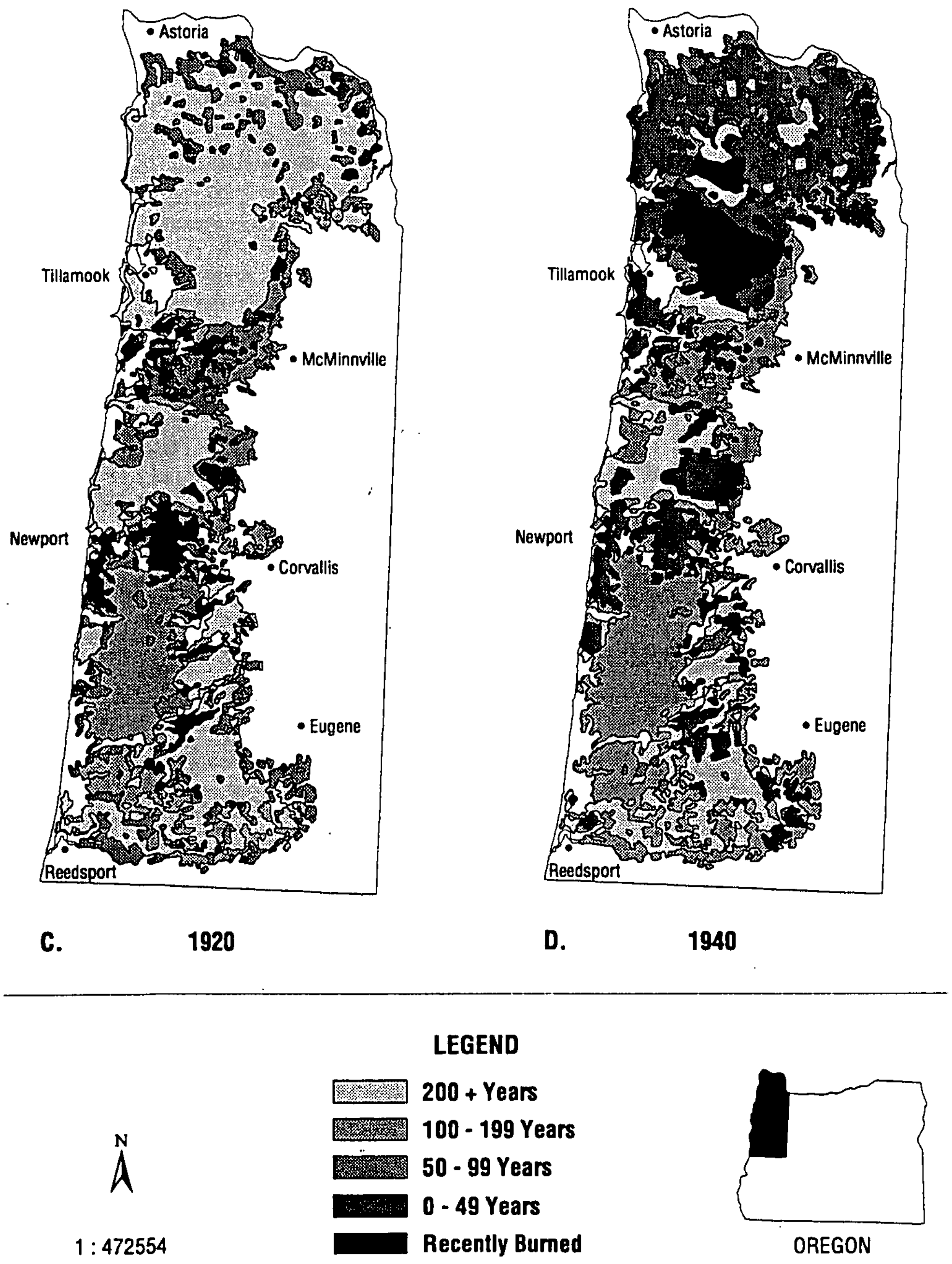

Figure 12 C-D: Forest stand age classes for the Oregon Coast Range
NOTE: This map was compiled from reconnaissance field notes. It was digitized from hand interpolated source materials and may differ spatially from digital mapping compiled from other source data. Prepared by Salem District and Oregon State Office,Bureau of Land Management, Sept., 1991 from United States Geological Survey data collected in 1850.

Table 6 Leading Causes of Changes in Salmon Abundance and Distribution in Western Oregon and Northern California. Causes are separated into major factors, potentially important factors for which insufficient data exists for an appropriate assessment, and minor factors. Numbers following each factor refer to the components listed at the bottom of the page.

General Factors

Major Factors

Agriculture 1, 2, 4, 5, 6, 8, 9, 10, 18, 21, 22	Fish Harvest 16, 19
Dams 9, 11, 18	Forestry 1, 2, 4, 6, 7, 10, 21, 22
Drought 9, 10	Urbanization 1, 3, 5, 6, 7, 8, 9, 10, 11, 21, 22

Potentially Important Factors

Gravel Harvest 6	Hatchery Fish Interference 19, 20
Irrigation 9, 12	Unfavorable Ocean Condition 13, 14, 15, 16
Legal Bycatch and Noncatch Mortality 16, 19	Unregulated Harvest 16, 19

Minor Factors

Bird Predation 17	Marine Mammal Predation 16, 17

Components of Factors

1. Loss of Riparian Vegetation and Functions	12. Lack of Barriers Over Diversion Canals
2. Pesticide Exposure	13. Reduced Upwelling
3. Industrial Pollutants Exposure	14. Altered Ocean Currents and Flow
4. Increased Sediment Delivery to Streams	15. Decreased Food Abundance
5. Stream Channelization	16. Reduced Escapement
6. Habitat Destruction	17. Reduced Smolt Releases
7. Loss of Woody Debris and Channel Form	18. Barriers to Fish Passage
8. Filling of Side Channels	19. Loss of Genetic Integrity and Diversity
9. Reduced Fresh Water Flow	20. Competition Between Hatchery and WildFish
10. Exposure to Abnormal Temperatures	21. Forest Fragmentation
11. Habitat Area Loss	22. Estuary Degradation

CONCLUSIONS OF THE STUDY

As written, the six charges of the Oregon Bill 1125 assume a decline in salmon. In initiating our study, we made no assumptions. We sought to learn what the available data could tell us about changes in status of salmon.

As explained earlier, a decline in salmon status may result from two different processes: 1) a decrease in geographic distribution - a loss in specific stocks (whose likely result would be a decrease in genetic diversity); and 2) a decline in overall numbers (including a decline in total legal ocean and sport catch).

The two are sometimes treated as if they were the same, but they are not. For example, there could be a loss of many stocks (local extinction), while other stocks remain abundant. The extinction of stocks, which were already at low abundance, might lead to a negligibly small change in total numbers, but a large decrease in genetic diversity. The converse could also be true: there could be a large overall decline in total numbers, but geographic distribution and genetic diversity could be maintained.

In responding to the charges, it is necessary to clarify which of these two phenomena has occurred, or perhaps that both have. It is contrary to the goal of this study to presuppose a decline before examining the available data. Therefore it is necessary to rephrase the charges, replacing "decline" with "change in status".

The following responses by the panel to the first five charges are based on findings presented in the final report. Charge 6 is a request for recommendations and our response to this charge is found at the beginning of Section V.

CHARGE 1: "Identify leading causes, both onshore and offshore, for anadromous fish population declines if that is the case."

Except for sea-run cutthroat, the geographic distribution of salmon has decreased for all species in the study area. Some stocks have become locally extinct, others have so few adults returning to spawn as to be considered endangered. There is no equivalent general trend for total numbers.

Except for sea-run cutthroat, the geographic distribution of salmon has decreased for all species in the study area.

The leading factors for changes in salmon populations as well as the components or results of the factors are listed in Table 6.

Based on available data, it is the opinion of the panel that *agriculture, forestry, urbanization, over harvest through legal catch, impediment construction (dams), and naturally occurring drought are major factors in salmon declines.* Potentially important factors for which adequate data is lacking include unregulated and illegal salmon harvest, gravel harvest, unfavorable ocean conditions, legal bycatch and non-catch mortality, hatchery fish interference, and irrigation. Marine mammal and bird predation are minor factors (Table 6).

CHARGE 2: "Assign the relative importance of forest practices to these declines, compared to other leading causes."

The panel believes that over the long term, forest practices have been a major factor, along with agriculture, dams, drought, fish harvest, and urbanization. If the ODF's Water Protection Rules (riparian rules) are carried out as written, then it is the opinion of the panel that the negative effects of forest practices will decline in the future. Whether or not these practices are adequate or optimal for salmon is not known. Only through continued monitoring and evaluation can that determination be made.

Stream and riparian conditions heavily dependent on forest conditions, set an upper boundary to potential salmon production. For example, clearcutting to the edge of a stream reduces potential salmon production through such processes as increased erosion, simplification of channel shape and form, loss of shade, reduction of woody input, and reduction of supply of food and nutrients required by salmon.

Effects of forest growth and development set a baseline condition for potential production against which water flow exerts an annual variation.

Because water flow, hatchery releases, and ocean troll catches account for 80 to 90 percent of the variation in adult spring chinook returns on the Rogue River during the past 20 years, forest practices could account for only the remaining 10 to 20 percent, or forest practices may influence or vary in a direct way with water flow or hatchery releases. If forest practices contribute less than 20 percent to the year-to-year variation in spring chinook on the Rogue River, this is a comparatively small effect. However, effects of forest growth and development are not likely to show up on a year-to-year time frame. Instead, these effects set a baseline condition for potential production against which water flow exerts an annual variation. This baseline varies itself over time, but at a slower rate than water flow. A degradation of forest conditions that affect riparian and stream habitats would lower salmon potential; restoration of these habitats would increase this potential. It is in this way that forest practices are a major factor.

Which of the major factors are limiting the production of salmon, averaged over the entire study area at present? The answer to this is less clear. We do not know if the actual abundance of salmon is at present limited by the conditions of all stream and riparian zones together, or if some other factors, such as climate, ocean currents, or ocean fishing, are restricting the number of returning adults below the potential level that existing stream and riparian conditions provide. This uncertainty is a result of the lack of adequate statistically-reliable data for the number of returning adults. The period for which data are available on the Rogue and the Umpqua is not sufficiently long to reveal effects of the processes of forest development and ocean dynamics.

Another complicating factor in determining the relative importance of forest practices is that there was a major change in forest practices beginning in 1972 with the implementation of the first Oregon Forest Practices Rules, but this change was not accompanied by adequate measurements to track before and after effects. Also, because forests change over long time periods, the effects of the 1972 new forest practices do not show up in the available data on salmon.

CHARGE 3 "Identify the relative importance of various habitat characteristics in streams in limiting anadromous fish production."

To salmon, the most important habitat characteristics in streams are minimum water flow, food, obstructions to flow that create debris dams and have other effects on *stream shape, and gravel necessary for spawning.*

The riparian zone is the area that lies along the banks of a running water system and interacts with it. It influences the factors cited above by: 1) providing large woody debris (LWD) that, along with embedded boulders and bedrock outcrops, control the shape and water-flow features of stream channels and floodplains and create complex habitats that benefit salmon; 2) providing leaves that fall from trees and shrubs into the stream that stimulate the production of small invertebrates that are food for salmon; 3) regulating the amount of light that reaches the stream, which in turn determines the kind and amount of algal growth important to the salmon's food chain; 4) regulating the movement of dissolved nutrients important to overall stream biological production between the adjacent land and stream; and 5) maintaining stream temperatures within salmon tolerance limits through shading provided by streamside trees. (Figure 13A & 13B)

LWD plays a major role in the development of stream shape and form beneficial to salmon, including features such as off-channel rearing backwaters, side channels

LWD plays a major role in the development of stream shape and form beneficial to salmon.

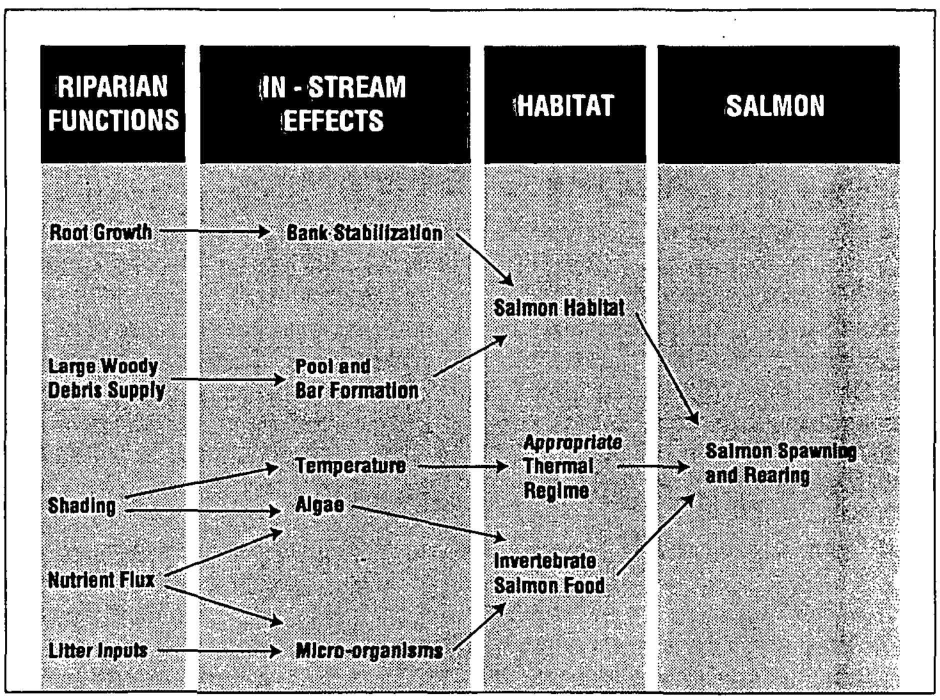

Figure 13A: Relationship of riparian zone functions, their effects, and salmon.

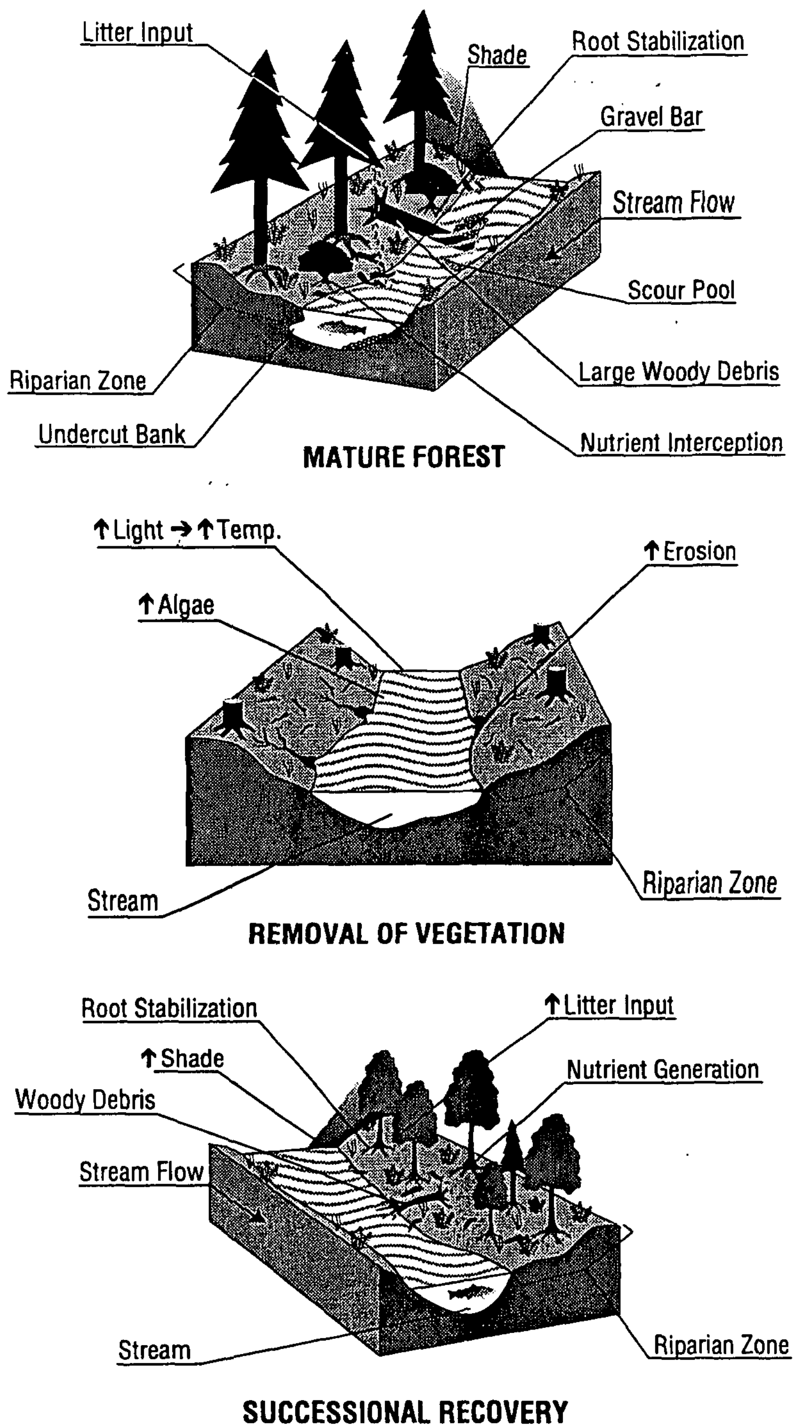

Figure 13B: Riparian zone conditions and dynamics within three states: mature forest, removal of vegetation, and recovery. Figure representation not to scale.

in floodplains, and pools and riffles in small main-stream channels. LWD provides obstructions upstream from which gravel bars and scoured out pools can form. Both are necessary physical habitat features for salmon. In western Oregon and northern California, the most important fraction of woody debris is large decay-resistant conifers.

When streamside vegetation is removed, the effects on salmon habitat are negative, except that immediately after clearing, sunlight reaching the water surface increases, and this results in a short (approximately zero to five years) rise in the growth of the kinds of algae that form the base of an important food chain for young salmon and leads to a peak in salmon production (Figure 9). This increase in salmon production is unstable, however, because of the many negative effects of clearing riparian vegetation, which include: 1) Production of other algae, which do not serve as an appropriate base of the salmon's food chain, due to the continued input of increased light; 2) A dramatic increase in stream temperatures, depending on water flow and stream width, after removal of shade. Elevated temperatures can be a serious stress on salmon eggs, newly hatched salmon and salmon fry, especially during summer periods of low flow; and 3) A simplification of channel banks and the destruction of shelter for rearing and protection of fish from predators due to removal of streamside vegetation, leading to a widening of channels that are more prone to warming by sunlight.

CHARGE 4: "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."

In response to this charge we have applied: 1) regression analysis of the presence and extinction of local stocks in comparison to land use and land conditions; and 2) an analysis of trends in the return of adult salmon before and after 1972.

The regression analysis of salmon stock status and land use/land conditions does not indicate that forest practices have been a factor in the status of all species of salmon. Maps of the combined presence and local extinction of chinook and chum support the suggestion that chum spawning seems unrelated to forest practices but might be affected by other practices; possible causes include gravel removal, agricultural pollution, flood control dams, channel modification of estuaries and main river stems, and overfishing.

Steelhead and coho, which spawn and rear in the smaller streams, are very much affected by forest cover.

Steelhead and coho, which spawn and rear in the smaller streams, are very much affected by forest cover. This analysis suggests that for these two species, relatively speaking, forest cover is an important factor in past local extinction. For chum, however, which does not use heavily forested habitats at present, local extinction appears weakly correlated with forest cover. Factors that affect spawning and rearing in estuaries, main stems of rivers, or the ocean habitat, seem to be more important for chum. The results for steelhead, coho, and chum are consistent with the differing stream habitats these species utilize.

This analysis suggests that the relative importance of forest practices on the local extinction of salmon stocks varies with species. For steelhead and coho, forest clearing and the amount of forest cover present are major factors; for chum, forest conditions are a minor factor.

In order to discern the effectiveness of the 1972 forest practice rules, adequate monitoring for more rivers over a long time should have been implemented.

The analysis of trends was applied to two data sets: counts made at dams on the Rogue and Umpqua Rivers; and counts of spawners on coastal rivers (peak counts). The analysis of trends for counts at the two dams examined trends based on the entire data set available and also based on data only from 1972 to 1991. Available data on adult spring chinook returns to the Umpqua and Rogue Rivers indicate that the 1972 establishment of forest practice rules has had no detectable effect on the returns of spawning adults salmon to Oregon coastal rivers (Table 7). This is of particular interest because the first Oregon forest practice rules went into effect in 1972.

The results from analyses of the peak count data are so mixed that no general trend can be found except that chinook trends over the last 40 years tend to be upward, trends for coho tend to be downward, and there seem to be no trends for chum. Given the statistical unreliability of the peak count method, the panel believes that no useful conclusion about trends can be obtained from those data.

Failure to find a statistically-significant, overall improving trend since 1972 does not indicate one way or the other if the 1972 forest practice rules increased potential spawning and rearing-capacity of streams in the study area. In order to discern the effectiveness of the 1972 forest practice rules, adequate monitoring for more rivers over a long time should have been implemented.

CHARGE 5: "Identify the extent to which forest practices are limiting the recovery of depressed anadromous fish populations." Much has been learned from research during the past 30 years at the local level of a stream or small watershed. This research makes clear that riparian forests play a major role in the potential production of salmon, as discussed in the answer to Charge 2.

Areas logged after approximately 40 years

TABLE 7: Population Trends: Pre and Post 1972 for Wild and Hatchery Fish

	Spring Chinook		Fall Chinook		Coho		Summer Steelhead		Winter Steelhead		Sea-run Cutthroat	
	Pre-'72	Post-'72	Pre-'72	Post-'72	Pre-'72	Post-'72	Pre-'72	Post-'72	Pre-'72	Post-'72	Pre-'72	Post-'72
Total Wild and Hatchery Fish												
Dam												
Gold Ray	-	↑	-	↑	↓	↑	↓	-	-	-		
Winchester	↑	↓	↑	-	-	↑	↑	-	-	-	-	↓
Wild Fish Only												
Gold Ray		-										
Winchester	↑	-			-	↑	-	-	-	-		

Pre and Post 1972 trends in returning adults counted at Gold Ray Dam on the Rogue River and Winchester Dam on the Umpqua River by species. An up arrow indicates a statistically significant upward trend; a down arrow indicates a statistically significant downward trend; a dash indicates no significant trend; and a blank indicates no data available. Trends were determined using the Daniel's test; see text for further explanation.

ago and before 1972 are still in the stage with the lowest potential fish production, based on Figure 6. It is possible that these areas could still be limiting the recovery of salmon.

The routine removal of LWD on a large scale prior to 1980 had major, long-term negative effects on rearing habitats for salmon, and areas subjected to this removal of LWD would still be limiting the recovery of salmon stocks.

Because appropriate data are lacking on the history and present status of riparian zones, the extent to which forest practices presently limit all depressed stocks throughout the study region is more difficult to characterize. The correlations of the status of salmon stocks with land conditions provide some insight into this question. These results suggest that, *where forest practices have led to the elimination or serious damage to riparian and stream habitats, then forest practices would be important in limiting the recovery of steelhead, coho, sea-run and resident cutthroat and chinook, but would be less so for chum.*

Both the proposed FEMAT standards and new ODF Water Protection Rules, if implemented as stated and if accompanied by adequate monitoring, will result in an improvement of the riparian zone and salmon habitat. In areas where riparian zones were not previously logged or negatively affected and which now receive riparian rules protection, forest practices will be a lesslimiting factor than before to salmon populations. The degree to which they will be less limiting we do not know. Only through monitoring and evaluation can that determination be made.

RECOMMENDATIONS

CHARGE 6: "Make recommendations as to how forest practices can assist in recovery of anadromous fish populations."

The response to Charge 6 is organized in four sections: 1) actions to improve salmon habitat related to forest practices; 2) actions to improve salmon habitat or enhance salmon survival not directly related to forest practices; 3) measurement needs related to forest practices; and 4) measurement needs not directly related to forest practices.

ACTIONS TO IMPROVE SALMON HABITAT RELATED TO FOREST PRACTICES

- Continue to regulate forest operations to protect riparian habitat.
- Continue to create incentives for habitat restoration in conjunction with forest operations.
- Develop a management strategy for an *adequate* loading of LWD such as bringing logs to areas that lack sufficient large streamside trees. Measurement must be part of this strategy, including before and after monitoring, to determine the ecological effectiveness and cost effectiveness of different methods.
- Assess how recent technical and regulatory innovations in forest road construction have affected sediment supply to streams.
- Maintain permanent forest roads at a level sufficient to avoid major washouts or chronic erosion.
- Where possible, close as many previously constructed logging roads as is feasible.

The routine removal of LWD on a large scale prior to 1980 had major, long-term negative effects on rearing habitats for salmon.

• Monitor and evaluate on a continuing basis the effectiveness of ODF's Water Protection Rules (riparian rules) to determine if riparian zone buffers are adequate for the protection of salmon and their habitat. *It is the opinion of the panel that these rules may not provide sufficient loading of LWD to the stream channel, especially in the short term in secondary forests.*

Actions to Improve Salmon Habitat or Enhance Salmon Survival Not Directly Related to Forest Practices

• Increase the amount of riparian zone restoration, and conduct experiments to test the ecological effectiveness and cost effectiveness of various techniques.
• Use native species in riparian zone restoration. Exotic plant species can create more problems than they solve.
• Allow occasional seasonal flooding of floodplain areas where this does not threaten human life or property.
• Develop water protection (riparian) rules for streams running through agricultural and urban areas.
• Reform water rights provisions to prohibit the use of diversion dams that can temporarily block salmon passage or significantly reduce water flow.
• Give priority to supporting the persistence of endangered stocks over attempts to restore extinct stocks; restoration efforts should be focused on the habitats of threatened and endangered stocks.
• Develop watershed-based management, either through establishment of new watershed-level agencies or through formal coordination of existing agencies.
• Develop a set of realistic, pragmatic mathematical or computer models for forecasting adult returns and setting harvest levels. These models should be used with adequate monitoring.
• Remove marine mammals only where they pose a local problem to a specific threatened or endangered salmon stock. Removal should happen only after thorough study has established that removal is necessary and is done in accordance with the Marine Mammal Protection Act.
• Contingent on the outcome of a more thorough study, convert some salmon hatcheries from providing fish for sport and commercial harvest to breeding highly-endangered salmon stocks. The exception would be on rivers selected primarily for the production of commercial catch, if this is found to be cost-effective.
• Conduct risk assessment as part of management planning; decisions must be made based on the awareness that some factors are beyond human control.
• Formulate adaptive policies that change with fluctuations in environmental circumstance, advances in scientific knowledge, and evolution of public preferences.
• Acquaint the public with the different policy implications of the three major policy options discussed in the next section of this report: managing for conservation of biological diversity, managing for sport fishing, and managing for commercial fishing.

Measurement Needs Related to Forest Practices

• Inventory conditions of riparian zones for stream reaches where salmon spawn and rear. Where funds are limited, focus the inventory on habitats of threatened and endangered stocks.
• Inventory riparian zones tree species abundances, individual tree sizes and ages, and amounts of LWD.
• Make quantitative measurements of envi-

ronmental conditions before and after forest harvesting such as: stream temperature, water chemistry and other water properties, gravel and sediment accumulations, light levels, fish abundance, and species diversity.

- Test the FEMAT and ODF Water Protection rules (riparian rules) against each other by applying each on selected streams. Compare costs, ecological effectiveness and timber production, with before and after monitoring.
- Monitor the status of woody debris by conducting stream surveys before and after forest operations:
  - measure simple length and diameter of material in the stream above a certain diameter and indicate placement;
  - note large debris dams and estimate their size;
  - repeat at five-year intervals.
- Monitor the status of understory light levels before and after forest operations:
  - lay out transects along edges of stream courses at the same time woody debris is being measured;
  - take spot measurements of photosynthetically active light along the transect with a light meter;
  - note time of day, cloud cover, and time of year to insure measurements are comparable over time.
- Monitor water temperature before and after forest operations:
  - repeat at periodic intervals.
- Monitor fish populations before and after forest operations:
  - develop a reliable and statistically valid method to monitor fish populations in relation to the other factors that are monitored.
- Develop a sample design that covers variation of conditions and forest operations. It is not necessary to measure and monitor every site. Statistically reliable information can be obtained from a small number of monitoring sites, if designed correctly.

Measurement Needs Not Directly Related to Forest Practices

- Assess the present gravel supply and stability of the landscape as a result of bedrock type and topography.
- Record location of timber cuts and silvicultural treatments by geographic location, rather than by county.
  - enter these records into GIS along with all inventory data.
- Establish a series of permanent measurement plots to monitor changes in forest conditions, using standard statistical sampling procedures.
  - establish a series of permanent forest plots on which the species, height, and diameter of trees are measured.
  - add to the number of plots when new policies are planned, to provide baseline measurements.
- Update GIS maps of land cover and land use at a minimum of five-year intervals.
  - maps should include major cover types and amounts of fragmentation. This is especially important in watersheds where there are fish data.
- Develop methods for rapidly surveying channel habitat conditions and application of such data in a geographic information system (GIS).
- Conduct research to reconstruct forest history within watersheds and make maps showing ages of stands, especially on the Rogue and Umpqua Rivers where detailed fish data are available.
  - analyze fossil pollen records to reconstruct presettlement vegetation history.

-analyze forest stands and historical records to reconstruct logging history.

- Analyze the effects of agriculture, specifically water diversion from salmon habitat, earthen dams that act as a barrier to salmon passage, and agricultural runoff, on salmon.
  - record by watershed the quantity of water removed per month for agricultural irrigation and urban water use.
  - record by watershed physical changes in stream structure due to urban and agricultural practices.
  - record by watershed chemical changes in streams due to urban and agricultural practices.
  - generate a map that shows the area of watersheds where agricultural diversion ditches are unscreened or have damaged screens.
    - update all of the above at regular intervals.
    - make all of the above information in GIS format.
- Map and maintain maps of the geographic status of salmon stocks.
- Analyze data on salmon abundance in coastal rivers using econometric techniques and multivariate statistical analysis to increase the forecasting ability for each river.
- Conduct a survey of the databases available that address the fresh water invertebrate food base of rearing salmon.
- Continue monitoring abundance of returning adults on the Rogue and Umpqua, including an estimate of age structure.
  - expand this monitoring to either of the following:
    - long-term monitoring of additional rivers;
    - a short-term program on each major river to determine through statistical analyses if returns on one river can be forecast from returns or water flow from another river with sufficient accuracy for planning.
- Establish statistically-valid monitoring of salmon abundance on rivers where peak counts are made, eventually replacing the peak count method. A variety of new methods are available to monitor fish. These range from sonar devices such as those used in Tokyo Harbor to visual counts from low-altitude aircraft. Continue both kinds of measurements until it is determined that:
  - peak count data, in spite of violating basic sampling procedures, provides reliable information;
  - a relationship between the valid method and peak counts is established, so that one can be used to forecast the other; or
  - the peak count is shown to be inconsistent with the valid method and therefore rejected.
- Develop a better definition of the minimum viable population for salmon through new research or a synthesis of existing information.
- Conduct historical, archeological, and anthropological studies to estimate the range of adult fish returns on rivers in the study area prior to 1950.
- Conduct a study of present and past ocean and watershed conditions for salmon.
- Sample salmon populations in the ocean to determine age structure.
- Conduct more complete monitoring of bycatch in all fisheries.
- Investigate the amount of unregulated catch of salmon on the high seas and illegal catch of salmon within international treaty waters.
- Estimate salmon noncatch mortality in commercial fishing and include these estimates when setting annual legal harvest quotas. Efforts should be made to develop catch methods and equipment which minimize this mortality.

- Conduct counts of fish returning to specific rivers and caught commercially in the ocean.
  - obtain counts for wild fish by restricting ocean catch to terminal fisheries for rivers in which the fish spawn. This is one way to link wild populations with ocean catch.
  - continue to use coded wire tags to assess hatchery fish by river of origin.
- Conduct a short-term research project on marine mammals to obtain a statistically-valid sample of pinnipeds' stomach contents to determine the percentage of diet that is salmon and the distribution of salmon consumption throughout the year.
- Obtain statistically-reliable estimates of pinniped population sizes.
- Recalculate the relationships between water flow, hatchery release, ocean troll catch, and ocean upwelling every year based on the findings of *Forecasting Spring Chinook Runs* (Sobel and Botkin 1994) and make these calculations part of the method to set harvest quotas. Deviations from past relationships may serve as a warning that some other environmental factor is beginning to change in a way that might influence salmon returns. Recalculations correct for a "moving" background of other effects and will make projections more accurate.

POLICY & OPTIONS

A common impression implied as much as stated in discussions of salmon and their habitats in the Pacific Northwest, is that every stream must be treated in exactly the same way as all others, especially if new regulations are to be developed. In this study, we suggest three policy options that allow for geographic differentiation in the use of streams and watersheds: managing for biodiversity; managing for sportfishing; managing for commercial harvest, or some combination of these options.

While these three goals are sometimes treated as if they were the same, they are in fact quite different and can be achieved by different methods.

A *biological diversity* option requires: 1) maintaining minimum viable populations of all stocks considered legally threatened and endangered; and, 2) maintaining (to the extent possible) the present diversity of stocks. The emphasis of this goal is on geographic distribution and genetic variability, rather than total number of salmon.

The *sport fishing* option would provide a surplus of salmon above that required for biological diversity and place an emphasis on 1) production of wild fish; and 2) production of fish on specific rivers that have been favored in the past for recreational fishing.

A *commercial fishing* option would provide a surplus of salmon above that required for biological diversity and place an emphasis on total abundances for commercial fishing, without particular regard to the spawning location of the fish or whether they are wild or produced by hatcheries.

Each of these options requires specific actions. The first, biological diversity, is a legal requirement in any case. More explicitly, the ESA requires that "critical habitat" for endangered species be determined and all federal agencies avoid actions that adversely impact these habitats. If most or all salmon stocks are determined to be threatened or endangered, the requirements to protect those species will provide the most stringent constraints on management options. This would provide a baseline or floor for other management options. Either or both of the other two options can be performed in addition to the first option. The discussion of these options in the main report is lengthy; those interested are referred directly to that report.

Biodiversity is the implicit criterion of the ESA.

The Biodiversity Option

Biodiversity is the implicit criterion of the ESA. To meet this goal one has to determine 1) the minimum number of salmon of a given species that is required to maintain a viable population for a reasonable period of time, and 2) how many of the existing stocks or populations need to be protected. Past attempts to reintroduce salmon in the Pacific Northwest, where they have become locally extinct, have generally not been successful. If the goal is to improve salmon stocks within a human lifetime period - on the order of 30 years - then efforts are best put toward aiding stocks that still exist but are at extremely low abundances, rather than reintroducing salmon where native stocks are now extinct.

Actions that would aid in achieving the Biodiversity Option include:

- Convert some hatcheries from their present intended purposes of providing a large number of fish for harvest to enhancing only threatened and endangered stocks.
- Monitor ocean catch so that the stream of origin can be determined. Restrict ocean fishing to terminal fishing (fishing only at the mouth of a river).
- Restrict commercial and sport catch geographically, so that threatened and endangered stocks are not harvested. We are aware that attempts have been made to do this, but with variable success.
- Give highest priority to restoration of riparian and stream habitats of threatened and endangered stocks.
- Monitor the geographic status of stocks to provide a more accurate assessment of which stocks are endangered, threatened, and relatively abundant.
- Control water flow to maintain sufficient levels during periods of low flow. Existing dams could be used to control flow. Restricting water off-take for agricultural and urban use could increase stream water levels.
- Extend water protection (riparian) rules to agricultural and urban areas.
- Protect critical areas of riparian habitat from disturbances such as gravel removal.
- Integrate monitoring as part of management, so that all new actions include measurements of conditions before, during and after an action.
- Develop accurate models on which to set harvest levels in order to provide for a sustainable and healthy fishery.
- Conduct further experiments on how the emergence of new stocks might be fostered in rehabilitated watersheds.

The Sport Fishing Option

This option would require an excess production of fish above that needed to meet the ESA. The sport fishing option would provide 1) sufficient biological production to allow reasonable sport fishing catches and 2) sufficient geographic diversity so that sport fishing can simultaneously occur in various coastal rivers.

Sixty-two percent of the total economic value from sport fishing comes from only five watersheds; the Rogue, Tillamook Bay, Umpqua, Nestucca, and Nehalem. The percentage increases to 84 with the addition of five more rivers: the Alsea, Elk, Chetco, Salmon and Siletz. Adding the Siuslaw and Coquille raises the total percentage to 90.

There are two possible approaches to achieving a sport fishing goal: 1) treat all basins equally and try to meet multiple needs simultaneously on every river; or 2) select a subset of the rivers - those now preferred by sport fisherman - and concentrate restoration and other actions in their watersheds.

The first approach has a variety of legislative advantages, one being that it would not affect the present economic value of land. However, from an environmental and planning perspective, this approach presents obvious limitations.

The second approach has several environmental and planning advantages. One way to achieve a sport fishing option would be to select a set of rivers, with public input, that would be given the status of "sport fishing rivers".

Actions that would aid in achieving the sport fishing option include:

- Restore stream and riparian habits on sportfishing rivers.
- Control water flow to maintain sufficient levels during periods of low flow (especially in summer and fall, through November).
- Establish a form of water protection (riparian) rules for agricultural and urban areas on sport fishing rivers.
- Use water flow in previous years as a factor in forecasting return of adult fish.
- Investigate the relationship between other environmental factors and the variation in water flow to improve the forecasting of future adult returns.
- Adjust for the changes in land value that would occur when some rivers are categorized for sport fishing and some are not by making use of transfer development rights.
- Conduct economic analyses for the watersheds that provide the majority of economic value of recreational sport fishing, the economic value for agriculture, forestry, gravel mining, forms of recreation other than fishing, urban uses, etc.

The Commercial Fishing Option

Like the sport fishing option, this option requires an excess production of fish above that needed to meet the ESA. The commercial fishing option could be implemented in conjunction with the sport fishing option.

Actions that would aid in achieving the commercial fishing option include:

- Acquaint the public with the possibility that fish for commercial catch might be produced via mariculture (essentially the farming of salmon).
- Evaluate and implement methods of mariculture best suited for selected areas in Oregon.
- Locate and conduct mariculture in ways that would not interfere with any stocks now listed or likely to be listed as threatened or endangered.
- Assess the extent to which present commercial fishing is subsidized by existing practices such as hatcheries and stream restoration, and estimate the comparative cost of mariculture. Then determine whether the state would

Sixty-two percent of the total economic value from sport fishing comes from only five watersheds; the Rogue, Tillamook Bay, Umpqua, Nestucca, and Nehalem.

prefer to continue to provide these subsidizes without compensation from commercial fisherman, or if some kind of charge would be passed on to the commercial fisherman who catch the fish produced.

SUMMARY

We began this report by describing a set of common beliefs about salmon and their habitats. Now we can return to these beliefs and ask: Which of these beliefs are unfounded and which have a basis in current scientific knowledge?

The first set of beliefs we described was about conditions prior to European settlement: there was a superabundance of salmon; the forests of western Oregon and northern California were essentially composed of large, ancient trees; and this extensive old-growth was essential to the abundance of salmon. We know from anecdotal accounts and catch records for the Columbia River and from the commercial ocean fishery since the 1870s that salmon were more abundant in the last part of the 19th century and the early part of the 20th century than they are now. No such information exists for the study area, nor is there any present attempt to obtain it. From the available scientific information, no consistent trends in fish abundance are apparent. However, there has been a large decrease in the geographic distribution of salmon, with summer steelhead extinct from 44 percent of its historic range in the study area to coho extinct from 4 percent of its historic range in the study area. In addition, from historic maps, we have learned that in 1850 the forests of western Oregon were not continuous old-growth and that approximately 60 percent of the trees were less than 200 years old. Although salmon may not have required continuous old-growth, recent work has demonstrated the importance of mature forests to salmon, especially in the riparian zone. Another belief - that the forests and salmon were at a steady state prior to European settlement - is false. We now know that these natural systems are in a constant state of change and that some of these changes, such as occasional episodes of riparian succession, are important to salmon.

We have found that some human actions commonly believed to account for the decline in salmon, overfishing and habitat destruction in forest areas, are accurate. In addition, habitat destruction from agricultural and urban influences are major contributors to a decline in salmon. Some other factors which have not received much attention but we believe, based on limited information, may be important contributors to a decline in salmon are: hatchery fish interference, gravel harvest, irrigation, legal bycatch and noncatch mortality, unfavorable ocean conditions, and illegal salmon catch. Contrary to the beliefs of some, marine mammals and birds are at most minor factors in the salmon debate.

This project took a broad regional approach, considering ecosystems on which salmon depend. There is a growing demand in our society for this kind of approach, moving away from the former goals of resource management, which was to maximize the production of a single product. This broad perspective is demanding, especially of new kinds of data. However, this perspective also led to new insights which we believe can be helpful to the people of Oregon.

Salmon are an integral part of the human and natural environments of western Oregon and northern California. In a very real way,

OVERVIEW

the salmon of western Oregon and northern California are integrators of the array of environmental and social-cultural conditions and factors that define the life, indeed, the welfare of the state. In their migrations salmon encounter a variety of land and stream ecosystems, from sea level to mountain top, as well as all degrees of human-caused change of the land, from the most primitive wilderness areas to the most modified urban, industrial and agricultural areas. Salmon travel across all types of land use and economic endeavors; across virtually all jurisdictions and ownerships, including federal and state government authorities, Native American land, industrial and private land; and among all climatic conditions. In addition, they encounter coastal and open-ocean marine environments, where there are legal (regulated) harvests within treaty areas, unregulated commercial harvests outside of these areas, and bycatch in both. The ocean environment also experiences variations in upwelling and is directly affected by global atmospheric and oceanic circulations.

While salmon and their habitats are integral parts of complex ecological systems, they are also components of complex sociological, political, and economic systems. Any consideration of the management of the fish and their habitats must be undertaken within socio-political and socioeconomic contexts. These contexts involve the public's expectations of the fish and related resources, their motivations for seeking to manage the fish as a resource, and the political, economic and institutional responses to those motivations. These motivations include market forces, treaties or agreements with nations and tribes, federal, state and municipal legislation, and the administrative practice of government agencies. It is within this broad and at times seemingly baffling context that our study has taken place. It is hoped that this report contributes to a clearer understanding of salmon and their habitat and to what is needed now and in the future if we are to see these wild and unique fish continue to survive and hopefully thrive in North American ecosystems.