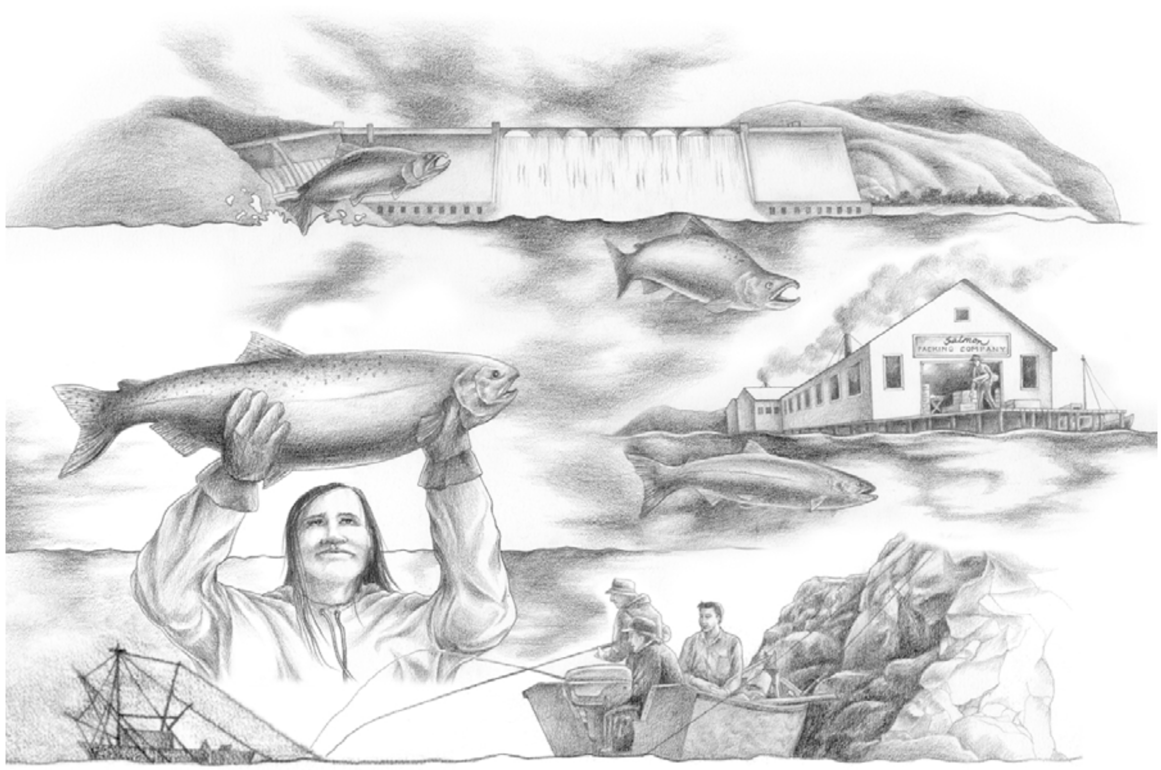
Independent Scientific Advisory Board

Report on Harvest Management of Columbia Basin Salmon and Steelhead



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ISAB Harvest Report
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Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and NOAA Fisheries
851 SW 6th Avenue, Suite 1100
Portland, Oregon 97204
ISAB@nwcouncil.org

Robert Bilby, Ph.D., Ecologist at Weyerhaeuser Company an expert in riparian ecology.

Peter A. Bisson, Ph.D., Senior Scientist at the Olympia (Washington) Forestry Sciences Laboratory of the U.S. Forest Service.

Charles C. Coutant, Ph.D., Distinguished Research Ecologist, Oak Ridge National Laboratory, Oak Ridge, Tennessee, Past President of the American Fisheries Society, with expertise in fish-habitat relationships.

Daniel Goodman, Ph.D., Professor of statistics at Montana State University, an expert in ecological risk assessment.

Susan Hanna, Ph.D., Professor of resource economics at Oregon State University (also an IEAB member).

Nancy Huntly, Ph.D., Professor of wildlife biology at Idaho State University.

Eric J. Loudenslager, Ph.D., ISAB Chair, Hatchery Manager at Humboldt State University, California, an expert in genetics and fish culture.

Lyman McDonald, Ph.D., Consulting Statistician at Western Ecosystems Tech., Inc., Cheyenne, Wyoming, formerly Professor at the University of Wyoming.

Gary Morishima, Ph.D., Consulting Fisheries Scientist, an expert in the biology of Pacific salmon and international fisheries management. (Ad Hoc Member)

David P. Philipp, Ph.D., Principal Scientist at the Illinois Natural History Survey and Professor at University of Illinois, an expert in conservation genetics and reproductive ecology.

Brian Riddell, Ph.D., Senior Scientist at the Pacific Biological Station, Department of Fisheries and Oceans Canada, Nanaimo, British Columbia, an expert in the biology of Pacific salmon and international fisheries management. (Review Lead)

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Executive Summary

This report focuses on the role of harvest management in the conservation and sustainable use of salmon and steelhead from the Columbia River system.[1] With an interest in clarifying how harvest interacts with habitat, hydro, and hatcheries (the other H's) in the Columbia River Basin, the Northwest Power and Conservation Council, NOAA Fisheries, and the Columbia River Intertribal Fish Commission developed a series of harvest-related questions and requested the Independent Scientific Advisory Board (ISAB) produce a report that addresses those questions. The ISAB's review of the current scientific and institutional structure for harvest management leads to answering four questions that encompass the questions posed by the sponsors. The report also provides brief reviews of past management practices, current institutional structures for harvest management of Columbia River salmon,[2] and background information on five topics related to salmon production and harvest management, including an introductory description of harvest management terminology and practices (Section 7e) for people less familiar with this topic. Although harvest management and salmon recovery can be assisted by the use of "best available" science, science alone is not sufficient. Science serves as the basis for harvest management decision making, but management also comprises differing cultural and socio-economic perspectives.

The ISAB is impressed with the management processes that have been developed and the continued efforts to expand the scientific basis for recovery of depressed populations of naturally produced salmon and steelhead. The elements of science, commitment, cooperation, and investment are all evident and progressing in the Columbia River Basin. We remain, however, concerned about the conservation of naturally produced salmonids and the relative effect of harvest on their conservation. Harvest is only one part of this complicated picture, but fishing is frequently targeted as a first management action because it removes mature salmon that could otherwise return to reproduce.

Components of effective harvest management systems

Within the context of this assignment, the *ISAB's vision* of conservation and sustainable use is centered on decision processes that are necessary to ensure that the removal (i.e., total mortality from all sources) of Columbia River salmon does not exceed the productive capacities of

[1] The terms conservation and sustainability involve diverse perspectives and values, resulting in different meanings for different people. The terms embed implicit references to objectives, time horizons, discount rates, and tradeoffs, which take on explicit meaning only when defined for a particular context. Neither term can be defined in the absolute, because each combines economic and social, as well as biological and ecological, elements in varying combinations. The ISAB did not attempt to develop specific definitions of these terms, recognizing the diversity of issues involving salmon and people in the Columbia River Basin.
[2] Throughout this report, when the term "salmon" is used in a general sense, it is meant to encompass salmon and steelhead, "salmonids."

naturally spawning populations over the long-term. From this perspective, effective harvest management systems must have three primary components:

1. A sound scientific foundation for management;
2. Clearly defined priorities and objectives for resource conservation and fisheries management; and
3. The capacity to constrain total fishing mortality on a population to a level that proves sustainable after accounting for all sources of mortality throughout the population's life cycle.

<u>1. Sound Scientific Foundation</u>

Science must effectively inform decision making for harvest management. Science is involved in designing monitoring programs, collection of data, and the development and use of reliable methods of analysis to assess biological status of the populations and fishery impacts. These assessments frequently involve limited data or data that vary in quality though time, and "noisy" data from complex ecological and social systems. Most types of information collected about Pacific salmon involve large variability (and/or limited predictability) due to natural variation in environmental conditions, changing habitat conditions over time, and the complex interactions of biological communities and salmonid ecosystems. A sound scientific basis for harvest management would: (1) provide the best practically obtainable and pertinent data; (2) provide the "best available science"[3] at the time decisions are made; (3) appropriately account for uncertainty, and (4) ensure transparency for the basis of advice, analyses, competent peer review, and a process for regular review and response (learning) as experience is gained.

Given the uncertainties and unknowns that remain in salmon management and recovery, a priority should be placed on ensuring a stronger empirical basis for assessing trends and status in each production unit, and on obtaining key information required to control harvest impacts. Well-designed monitoring programs are required to collect data on fisheries and escapements. A sound scientific basis for harvest management would inform decision-makers of the need for better information as harvest approaches the limits sustainable by the productive capacity of the resources as well as of the trade-offs between uncertainty and costs of management. In the absence of adequate data, managers should reduce impacts on the resource to ensure its continuance and future productivity.

<u>2. Clearly Defined Management Objectives</u>

Effective harvest management requires: (1) definition of the *production units*[4] to be managed; (2) biological conservation targets for each production unit; and (3) objectives and priorities for fisheries and clearly defined risk tolerances.

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[3] The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) requires that harvest management decisions use the "best available science." The MSFCMA contains ten National Standards for fishery management plans, and guidelines for implementing these standards are applied in decision-making processes of regional fishery management councils (see discussion of current institutional structure).

[4] Production unit in this discussion is a spatially defined group of salmon populations and hatcheries that are determined by the responsible agencies as a basis for conservation and management. Typically, each unit would be demographically independent and there could be several such units within an ESU.

Recent identification of independent population units is notable progress in characterizing the resource base, but conservation targets are not as well defined and are often not fully integrated with harvest management capabilities. For instance, although component populations of Evolutionarily Significant Units (ESUs) can be identified, little data may be available to determine the level of harvest that can be sustained by those individual components, and fisheries may be regulated through the use of indicators of population aggregates.

Objectives for harvest management include biological, legal, and socio-economic considerations. Biologically, harvest impacts must be constrained to lie within the productive capacity of the populations that comprise the resource base. Legally, harvest management must comply with international and Indian treaty obligations, as well as requirements set forth in federal, state, and tribal law. Socially, harvest management must distribute the benefits of harvest and responsibilities for conservation in a manner that is acceptable to the public and defensible against legal challenge. The suite of harvest management objectives affecting Columbia River salmon is embodied within management plans and legal requirements, such as the Pacific Salmon Treaty agreements, the Pacific Fishery Management Council's Pacific Coast Salmon Plan, the recently agreed "2005-2007 Interim Management Agreement for Upper Columbia River Chinook, Sockeye, Steelhead, Coho and White Sturgeon (*U.S. v. Oregon* Parties 2005)", and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

In spite of all of the data that have been collected on Pacific salmonids, the reality is that fisheries management is inexact. There are many sources of uncertainty, but science must provide information and advice in the face of both risk and uncertainty. Risk can be minimized and future options preserved in a dynamic and unstable environment by maintaining a genetically diverse mix of component populations and their habitats. A sound harvest management decision process would protect a minimum spawning population size in each unit, given the current and potential future range of environmental conditions and the range of error in assessments.

3. Capacity to Constrain Total Fishing Mortality

The capacity to constrain harvest of Columbia River salmon requires: (1) consistent quality-assured data for pre-season planning and in-season monitoring; (2) clear management objectives and timely in-season decision processes; and (3) management accountability.

With a multitude of institutions having regulatory authority over Columbia River basin fish, there would seem to be ample opportunity to constrain total fishing mortality through both regulations and enforcement. Unfortunately, the distribution of responsibility for achieving the biological conservation targets for individual production units is fraught with such controversy that the aggregate result is often less satisfactory than required.

The capacity to constrain harvest of Columbia River salmon is determined by the institutions involved in regulating fisheries throughout the migratory ranges of individual production units. The institutional structure of harvest management is extremely complex, involving many private, local, regional, state, tribal, federal and international entities. Because many jurisdictions typically affect the harvest of Columbia River salmon, fishery management decision processes must be sufficiently coordinated to collect consistent biological data and accomplish management objectives for production units of interest. These entities operate within their own jurisdictions, but often have overlapping authorities and responsibilities.

The ISAB recognizes that some of the limitations on constraining harvest mortality are due to basic inability to scientifically sort out population dynamics and total mortality for individual populations involved in multiple, mixed-stock fisheries. For an escapement objective for each salmon population to be achieved, not only must management define the desired number of spawners for each population, it must also regulate multiple fisheries to achieve them. This level of harvest management control in salmon fisheries is unrealistic because most fisheries simultaneously exploit a mixture of salmon populations and the actual catch by stock is usually unknown. Additionally, errors in pre-season forecasts, changes in return timing, variation in the response of fishermen to opportunities, and weather all confound our ability to accomplish management objectives for individual production units. Further, in the context of managing fisheries, it is important to differentiate what is known about salmon and our capability to control harvest impacts on specific populations. The latter is referred to as management control error and is frequently not fully accounted for in planning.

Concerns

The issues involved with harvest management are complicated, with many agencies and salmon populations involved and numerous legal requirements and historical complications (past impacts of development, mitigation and legal backgrounds including the massive hatchery production, conflicting objectives, limited historical data, etc.). Significant progress, however, is being made in several areas important to harvest management, such as the definition of independent population units, development of criteria for population and ESU viability, establishment of the Pacific Salmon Treaty and the role of the PFMC in limiting ocean fishing impacts, the renewed in-river fishing agreements, and recent efforts to integrate analysis of the 4-Hs in determining salmon production. While the ISAB has been favorably impressed with the development of biological science and management processes, three fundamental components of harvest management are noted as significant concerns. These include:

1. insufficient quantitative data for analyses by production units;
2. very limited evidence of stock assessment analyses by production units to provide a biological basis for production goals and trends in status; and
3. limited evidence of accounting for uncertainty in management plans with the exception of reference to precaution in the National Standard Guidelines established under the MSFCMA.

Given the severe limitations of historical data, the complex interactions of the 4-Hs, and the number of salmon production units listed under the ESA, managers should clearly reflect on the appropriateness of harvest rates, their ability to control fisheries, and their ability to explain the status and trends in Columbia River salmonids. A serious commitment to acquiring the empirical data for annual stock assessments, achieving the target spawning escapements (or exploitation rate), and explaining deviations is essential to function within the complex management processes involved with Columbia River salmonids. Establishing this empirical basis will serve to reduce management uncertainty and debate between agencies, focus attention on actions most necessary to recovery listed-species, and account for harvest impacts when fishing occurs. The ISAB has emphasized the need for improved quantitative information in two other recent reports: the review of subbasin plans (noting the lack of rigorous stock assessments in many subbasins) and the supplementation review (noting the information needed for assessments). Improving the information quantity and quality will not, however, stop debates over harvest. Conflicts in harvest opportunities between hatchery and natural stocks, between species, and between cultural and socio-economic values will continue. The value of improved information in this context, though, is that accurate assessment of harvest impacts may enable: (1) compensatory actions in the other H's (i.e., integration of mortalities through the life cycle of the salmon); (2) reconsideration of management objectives (e.g., are time scales of recovery realistic?); and (3) review of the relative values and costs associated with this harvest impact.

Recommendations

Based on our review and questions posed by the sponsors, the ISAB presents four recommendations:

1. Core Monitoring Data

There is an essential need for a core set of quantitative data to be monitored annually in all production units or, at least, in a sub-sample of units that may be used as representative indicators of productivity and trends in abundance over time. With the obvious importance of defining recovery goals and then monitoring progress to recovery, establishing quantitative indicator systems within ESUs is required for a credible harvest management system. A monitoring framework with probabilistic sampling designs should be required for each ESU and population unit defined by the Technical Recovery Teams, as well as for stocks that are not listed. These data collected annually provide for the critical analytical assessments necessary to advise management and selection of recovery actions. The ISAB strongly cautions against the collection of data without parallel careful design, use, and evaluation.

2. Documented Assessments

While the ISAB reviewed many reports, biological opinions, scientific papers, and management plans, there were very few quantitative and documented analytical assessments of individual production units or ESUs. Such assessment reports would typically provide the basis of biological advice on Pacific salmon that subsequently becomes the basis for harvest management planning. Detailed assessments must be documented and peer reviewed to provide quality control to the scientific basis of management planning.

3. Accounting for Uncertainty

While many documents refer to uncertainty, there were very few examples of actually estimating uncertainty or accounting for it in a management plan. Analysts likely know much less about the production dynamics of Pacific salmonids than is assumed, and uncertainty is very likely to be much greater than appreciated or accounted for. Guidelines for the estimation and accounting of uncertainty in management targets and in-season management control should be developed and applied. All sources of fishing mortality must be accounted for and a level of risk tolerance established through public consultation. While the ISAB was impressed with the intensive process used for salmon management, we also recommend analysts review whether current levels of harvest impact are consistent with the quality of data and level of uncertainty in the biological and management processes, and provide the expected likelihood of recovery for these listed species.

4. Adaptive Management in Salmon Recovery

Given the limitations in historical data, the limited progress on recovery planning, the inherently large uncertainty, and the complexity of management processes involved in harvest management of Columbia River salmonids, the ISAB recommends application of adaptive management principles in salmon recovery. Although the ISAB acknowledges potential problems with implementing a truly adaptive program in such a complex environment, the ISAB believes that a systematic approach to testing alternative actions with an emphasis on achieving secure spawning escapement levels should again be seriously considered. Such alternative actions may include stepped harvest rates weighted to protect minimum spawning levels, manipulations of hatchery production and/or the hydrosystem flows, and testing of incentives for recovery.

Recommendation 4 may also be an appropriate action for addressing how the Columbia River Basin should assess and adapt to the risks of climate and ocean changes on Columbia River salmonids. As discussed in Section 7d of this report, the ISAB anticipates significant increases in understanding of climate and ocean changes and cycles in relation to salmon and other natural resources in the next few years, and significant increases in the uncertainty of production forecasts in the short to medium term. Harvest managers and the harvest industry need to be in close touch with this understanding and adjust their procedures accordingly for conducting assessments, setting allowable harvests, and harvesting fish.

ISAB Reply to Sponsors' Questions

1. Contrast current and past harvest practice, addressing whether harvest rates and total fishing mortality on Columbia River stocks have increased, decreased, or remained constant?

Fishery impacts on Columbia River salmon have been reduced since the mid-1980s due to harvest management measures taken to respond to a variety of factors. The reductions have not been equal across species but three examples are presented in Appendix C to illustrate reductions in fishery impacts on Columbia River salmon and discuss underlying reasons: (1) Upriver Bright Fall Chinook (URB); (2) Coho; and (3) B-Run Steelhead.

2. Does current harvest management adequately manage and protect ESA listed naturally spawning populations?

This question cannot be definitively answered until recovery objectives are established for ESA-listed populations, determinations are made as to which component populations within ESUs must be protected to maintain their viability, and quantitative risk tolerances are adopted. Until then, ambiguities will continue to surround interpretation of the phrases "adequately manage and protect" and "ESA-listed naturally spawning populations." Under the current system of ESA administration, NOAA Fisheries and the U.S. Fish and Wildlife Service have the responsibility to determine whether or not management measures are "adequate" to protect ESUs. In the absence of approved recovery plans and a quantitative risk standard, and a comprehensive quantitative methodology for assessing risk and factoring the uncertainties into that assessment, agencies have considerable latitude in implicitly defining "adequacy" in their jeopardy findings and the annual guidance they provide for harvest management.

The current focus on "adequacy" should be squarely placed on whether management measures are sufficient to make predictable progress toward population recovery on the basis of those factors that are reasonably well-characterized, and maintain options, avoid irreversible damage, and monitor status with respect to factors that are very uncertain. Because of the potential for rapid adjustment of harvest, and given the existence of systems that collect and analyze data in a timely manner to monitor impacts, harvest management measures can be adjusted both annually and in-season. Consequently, harvest management is much more likely to be capable of preserving options for recovery than other types of measures that may be involved, such as habitat improvements or modification of flows and dam passage facilities. This greater flexibility, however, carries the liability that harvest management may be called upon to bear a greater share of the conservation burden in a crisis situation. It is essential to note, though, that if the predominant limiting factor to recovery is not harvest, then those other factors must be addressed, or the value of reduced harvest will be temporary and not sufficient for recovery.

3. What are the consequences of mark-selective fisheries on the accuracy and precision of forecasting and on consideration of harvest regime options? Are there practical measures that could be implemented in the short- or long-term to address the challenges posed by mark-selective fisheries?

Generally, mark-selective fisheries can be expected to increase uncertainty in harvest management of natural (unmarked) stocks, in terms of both precision and bias. The consequences of mark-selective fisheries are situational. Depending on the location and intensity of harvest, mark-selective fisheries may or may not have a significant effect on a variety of harvest management tools, such as estimation and forecasting of in-season run size. The reports of the Pacific Salmon Commissions Selective Fishery Evaluation Committee identify and discuss potential effects of mark-selective fisheries on harvest and management tools (ASFEC 1995). Additionally, a report in preparation by the Expert CWT Panel convened by the Pacific Salmon Commission in June 2004 will address this issue in depth.

Two important factors should be recognized when dealing with mark-selective fisheries. First, the capacity to conduct mark-selective fisheries depends upon continued investment in hatchery production and mass-marking. There are significant ecological risks associated with developing fishing strategies that depend on sustained hatchery production that should not be cavalierly dismissed (e.g., density-dependent competition and/or predator dynamics involving interactions of hatchery and naturally produced juveniles). Second, the costs of mass-marking, double index tagging, and sampling/reporting programs for catch and escapement will likely strain agency budgets and result in reduction of services or other programs, such as data collection, research, or enforcement. If investments are not made to improve sampling and reporting programs, management uncertainties will increase and impose costs to compensate.

4. Are analytical tools sufficient to adequately track future harvest rates? If not, what tools or performance standards will be most effective for managing fisheries? Are there opportunities to use PIT tags to improve management capabilities and reduce uncertainty?

Harvest management of Columbia River salmon involves a number of data collection systems that monitor impacts and analytical tools to evaluate results. The determination of "adequacy" of these tools, however, is situational and beyond the capabilities of ISAB to evaluate in this report. An independent analysis may be helpful to provide an in-depth evaluation of current tools and methods and to develop recommendations for improvement.

To-date, much of the information employed for the management of Columbia River salmon is derived from analysis of coded-wire tag (CWT) data. Analysis of CWT recovery data must frequently involve statistical inference because this technology is based on group marking and single recoveries (sacrificial sampling is required to recover data) of individual members of a group. These characteristics require assumptions and interpretation to address questions of interest to managers and researchers. Coded-wire tag technology is over thirty years old.

Newer technologies are now available and capable of providing data and information that is unattainable from coded-wire tags. One of these technologies is the passive inductive transmitting (PIT) tag that can potentially provide data for estimation of natural and release mortality rates, migration patterns and rates, and growth rates. Additionally, since data from PIT tags can be recovered without mutilating the fish, market values of the fish are not affected, thereby eliminating the barriers to processor and fishermen cooperation. The region should begin planning of long term monitoring of life history parameters, including harvest mortality, of hatchery and wild fish by use of PIT tags. The potential application of PIT tags in harvest management is being considered by the Coded-Wire Tag Expert Panel of the Pacific Salmon Commission, which will be reporting in the summer 2005.

ISAB Report on Harvest Management of Columbia Basin Salmon and Steelhead

1. Introduction

Salmon contribute to ecosystems, cultures, and economies of Native and non-Native Americans in the Pacific Northwest. Juvenile and adult salmon and steelhead are keystone species in both freshwater and marine environments. Adult salmon returning from the ocean provide important nutrients to watersheds, and juvenile salmon in freshwater are dominant members of many aquatic communities. Each year, the salmon resources of the Columbia River Basin are included in extensive fishery management processes upon which numerous peoples and communities depend. Native Americans, for thousands of years, have relied on salmon for food and celebrate salmon in their culture. As the status of Pacific salmonids has declined, however, questions have been raised about the present biological and scientific basis for their conservation, and, in particular, whether or not harvest management overall is consistent with recovery in the Columbia River, most particularly for those listed under the Endangered Species Act (ESA). The discussion about harvest, though, is not only about fish and statistics; any discussion of harvest inherently includes scientific and humanistic issues. The history of Pacific salmon in the Columbia River Basin exemplifies the conflict between conservation, non-Native fisheries, cultural and food values of Native fisheries, and competing economic developments in the Columbia River Basin (i.e., the other 3-H's: Hydro, Habitat, and Hatcheries). This report addresses the fundamental topic of what now constitutes a sound scientific basis for harvest management of Pacific salmonids originating in the Columbia River Basin.

Harvest, and harvest-related mortality such as bycatch or sport fishing catch-and-release mortality, is only one of several sources of the total mortality experienced by a salmon population over its life cycle. Harvest is a human activity, highly visible, and considered controllable (i.e., annually managed and subject to regulation). Furthermore, harvest largely affects salmon that have survived to maturity and are returning to their natal rivers to spawn. Harvest, therefore, can have a significant and immediate effect on the numbers of adults returning to spawning populations. Achieving a desired abundance and distribution of spawning salmon is a matter of balancing all sources of mortality throughout the life cycle of a salmon population. There are a limited number of animals in any population that can be killed and still have the population sustain a desired status. How those deaths are "allocated" through the life cycle, through environmental variation, and in relation to various activities that are the cause of the mortality, is, however, a management question of considerable complexity.

With an interest in clarifying how harvest interacts with other H's in the management of Columbia River Basin salmon, the ISAB's sponsors, the Northwest Power and Conservation Council (NWPCC, aka Council), NOAA Fisheries, and the Columbia River Intertribal Fish Commission (CRITFC) developed a series of harvest-related questions and requested that the ISAB produce a report that answered those questions. The Council asked 14 multipart questions. Those questions were combined into three broad topics: (1) does harvest management adequately manage and protect naturally spawning populations; (2) are there opportunities for more selective-type fisheries, and can artificial production be used to help reduce mixed-stock fisheries; and (3) are there sufficient management tools, including institutional arrangements, in place to adequately manage ocean, near-shore and inland fisheries. NOAA Fisheries asked the ISAB to contrast current and past harvest practices, provide practical advice on mark-selective fisheries for hatchery-origin fish, and consider how PIT tags might be useful to improve management capabilities and reduce uncertainty. CRITFC asked the ISAB to identify data needs and describe the current accuracy and precision of estimates used in management decisions, and then to identify achievable, short-term actions to better achieve integration and implementation of harvest measures.

The ISAB's goal for this report was to explain clearly: the biological basis and management processes involved in providing and controlling harvest, how uncertainty in information and parameter estimates can be accounted for in decision making process, and to explain how harvest may be integrated with recovery objectives. For those less informed about the technical basis for this topic, the report includes a brief Primer (Section 7.e) as background to salmon assessment methods and harvest management processes.

This report has focused on the technical issues associated with harvest management and integrating harvest with the total mortality of salmonids throughout their life cycle. Subtopics include the challenge of managing for smaller population groups given current assessment technologies, the role of salmon in the ecosystem, the assessment of harvest within a life cycle and recovery context, and challenges arising from the complex institutional arrangements responsible for making harvest management decisions. To provide context, the review includes a summary of our current understanding of the effects of climate variability on the marine environment and the interplay of harvest, hatchery production, and varying ocean regimes.

This report was produced by an extensive ISAB effort over the last two years. The review was informed by briefings, analyses contained in agency reports, material in the primary peer-reviewed literature, and some independent analysis of data. Representatives from the Pacific Fishery Management Council and Columbia River Inter-Tribal Fish Commission briefed the Board on ocean and in-river harvest management. NOAA Fisheries' Sustainable Fisheries Division briefed the ISAB on their approach to consultations for harvest pursuant to their responsibilities under the Endangered Species Act (ESA). ISAB members and Dr. Gary Morishima (ad-hoc committee member) presented on the Pacific Salmon Treaty and analytical tools used to develop and evaluate harvest levels.

Synopsis: The ISAB is impressed with the management processes that have been developed and the continued efforts to expand the scientific basis for management and recovery. The elements of science, commitment, cooperation, and investment are all evident and progressing in the Columbia River Basin. We remain, however, concerned about the conservation of naturally produced salmonids and the relative effect of harvest on their conservation. Harvest is only one part of this complicated picture, but fishing is frequently targeted as a first management action because it removes mature salmon that could otherwise return to reproduce.

The issues involved with harvest management are complicated, with many agencies and salmon populations involved and numerous legal requirements and historical complications. Significant progress is evident in several areas important to harvest management, such as the definition of independent population units, criteria for population and ESU viability, establishment of the

Pacific Salmon Treaty and role of the PMFC in limiting ocean fishing impacts, the renewed in-river fishing agreements, and recent efforts to integrate analysis of the 4-Hs in determining salmon production. While the ISAB has been favorably impressed with the development of biological science and management processes, three fundamental components of harvest management are noted as significant concerns. These include:

4. insufficient quantitative data for analyses by production units;
5. very limited evidence of assessment analyses by production units to provide a biological basis for production goals and trends in status; and
6. limited evidence of accounting for uncertainty in management plans with the exception of reference to precaution in the National Standard Guidelines established under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

The bases to these summarizing comments and our recommendations to address them are the heart of this report.

2. Harvest Management: An Evolving Discipline

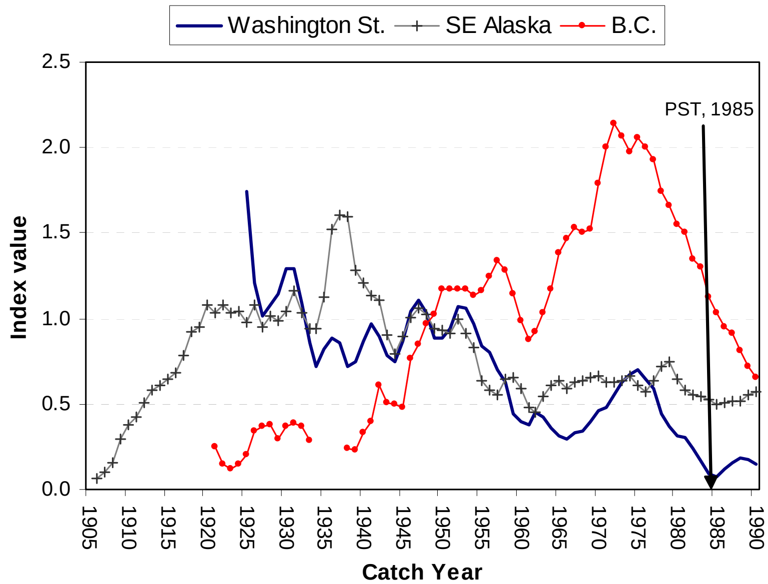
The economic development associated with salmon fisheries and major impacts to salmon populations significantly preceded the knowledge necessary to manage the Pacific salmon resource effectively. In the Columbia River, significant fisheries by non-Native peoples began about 150 years ago and expanded very rapidly. Salmon hatcheries were initiated about 130 years ago, and developmental or anthropogenic impacts (e.g., logging dams, agriculture) on salmon habitat were already being noted 100 years ago. By the 1920s, ocean troll fisheries were well established coastwide and were harvesting large numbers of Columbia River salmon. While some knowledge of salmon biology began in the early 1900's, the establishment of a "modern" management paradigm came much later. For example:

- the first scientific meeting on salmon homing and "stocks" occurred in 1939 (Mouton 1939), and evidence of locally adapted salmon populations and the "Stock concept" was published in 1972 (Ricker 1972);
- the introductory papers on production dynamics of Pacific salmon were published in 1954 and 1958 (Ricker 1954, 1958); and
- an ability to assess populations of Chinook and coho salmon followed development of the coded-wire tag in the early 1960s (Jefferts et al. 1963) and establishment of a coastwide tag recovery program in 1975.

Unfortunately, by the time an empirical basis for salmon management was developed, over-fishing had occurred for many years, habitats had been destroyed, and competitive fishing pressure between nations and user groups was commonly blamed for the declines in salmon abundance. Conservation sacrifices were usually left to the peoples fishing in-river … the last folks in line for the returning salmon.

In hindsight, the period before the 1930's might be considered the era of blissful ignorance. A fish was a fish, the supply was abundant and could be supplemented by hatcheries, and, when there were attempts to increase regulations in rivers, the fishers simply proceeded out into the ocean. Unfortunately, these ocean fisheries soon became highly competitive, and harvest in any one ocean region (management jurisdiction) intercepted salmon bound for other regions of the coast (Figure 1). The controversy over the ocean harvest of Chinook salmon continues today, but has been controlled through the 1985 Pacific Salmon Treaty (www.psc.org).

Figure 1. Trends in the reported catches of Chinook salmon by ocean troll fisheries (1905-1990) in Washington State, British Columbia, and SE Alaska. Trends are relative to the average catches between 1946-1950 to account for differences in landing records and smoothed (3-pt. moving averages) to show time trends more clearly. Historical data compiled by B. Riddell.



The period between the 1930's and 1970 could then be referred to as the era of limited enlightenment. Although a number of theories important to management began to emerge, agencies lacked adequate information to implement them, production from hatcheries expanded significantly, and managers exercised limited restraint on fishing. In addition, in the Columbia River the construction of dams radically altered the salmons' environment.

After 1970, a combination of new information, judicial decisions, and new legislation slowly led to the demonstration of excessive fishing pressure and the need for improved coordination of management agencies for effective conservation of specific Chinook and coho salmon stocks. The development of a coastwide coded-wire tag program involving agencies from California to Alaska provided the fundamental data needed to monitor the distribution of Chinook and coho salmon, annual survival rates, and exploitation patterns in fisheries for specific tagged populations. The coded-wire tag program also provided the first estimates of stock composition in ocean fisheries. These data were primary in the development of fishery management models for Chinook and coho salmon (in the Pacific Salmon Commission and the Pacific States Fishery Council) and currently provide the technical basis for most harvest assessments. The era from 1970-2000 was characterized by the expansion of stock-specific management based on a greatly enhanced empirical basis for management and the development and application of computer models for assessments and management planning.

Even at the beginning of the 21st century, the controversy over how to conserve and rebuild natural production of Chinook and coho salmon and especially the role of harvest continues. The debates are better informed and focused, but no easier to resolve. Groups of salmon in the Columbia River Basin are listed under the ESA, billions of dollars have been invested in recovery of listed-species, mixed-stock ocean fisheries persist, and hatchery production continues to dominate production of Chinook, coho, and steelhead salmon in the Basin, but the long-term preservation of salmon remains tenuous. The ISAB has considered the role harvest management plays in salmon recovery within this historical background.

2a. Evolution of Three Key Concepts

Salmon management along the Pacific coast over the past 50 years has been based on three prominent tenets, but in the past decade, these foundations have been profoundly shaken. These tenets included:

1. the Stock concept[5] … that homing of salmonids to their natal stream allows for the accumulation of genetic differences between local populations and the development of adaptations to those environments. Local populations are more productive (progeny produced per female spawner) in their natal habitats and should be managed separately to maximize annual production and use of freshwater habitats.
2. spawner-recruitment production relationships … mathematical relationships relating the numbers of fish that spawn in a year to the number of progeny produced from those adults. Theoretically, competition for space or food will limit the progeny produced per adult at high population densities (density dependence). Consequently, at some intermediate level of spawning abundance, the difference between the number of progeny produced and the number of animals needed to replace those spawners will be maximized. This number of spawners defined a management goal that, on average, was expected to produce a maximum sustainable yield (MSY) or harvest, given existing environmental conditions.
3. hatchery production and assumptions about ocean rearing capacity … that the number of juveniles reared largely determined the adult return, and that production from hatcheries can increase harvest and mitigate for habitat loss. Ocean conditions were not believed to limit production because the production of salmon had been much greater historically.

The original Stock concept emphasized phenotypic differences between populations, not the genetic processes that provided the rich diversity observed in salmonids. If no morphological or behavioral difference could be identified between spawning populations, then populations were aggregated into larger, more identifiable units for management. Production from these aggregated, natural populations mixed with an expanding production from hatcheries. For many years, the MSY management paradigm was superficially interpreted as sustaining high catch levels. People now recognize that these catches were based on the larger or more productive natural populations plus the hatcheries and that they masked the loss of diversity embodied in smaller or less productive populations. Management focused on maintaining economic gain from these large population aggregates, while diversity within "stocks" was seldom considered. As the impact of these "mixed-stock" fisheries and the large scale of hatchery production were

[5] Formalized for salmon at the 1939 meeting of the American Association for the Advancement of Science.

recognized, some managers began to question how sustainable this paradigm actually was. Finally, over the past decade, the full force of how the ocean can limit salmonid production became evident. Inter-annual variation in ocean conditions can severely limit salmon production, and shifts in ocean conditions can be sudden.

Coupled with these insights has been a growing realization of the uncertainty inherent in managing Pacific salmonids. Unfortunately, the history of salmon management on the Pacific coast has not been to account for or acknowledge uncertainty, but has been to rely on over simplified concepts and attempt to maximize yield from the large stocks and hatcheries, sustain high exploitation rates to meet user demands, and defer management actions due to uncertainty. Uncertainty has frequently allowed one user group to blame another for declines in salmon abundance or an agency to delay conservation actions simply because of inability to "prove" an impact of a fishery or some other development action.

Uncertainty in salmon management and assessment is significant and unavoidable. Pacific salmon have a complex life cycle involving freshwater streams, anadromous migrations to and from the ocean environments, and vulnerability to numerous forms of mortality, including fisheries, during their life span. Typically, three major sources of uncertainty are acknowledged: environmental, production analyses and data, and management error. In practice though, it can be difficult to partition uncertainty among these sources.

2b. Environmental Uncertainty

Environmental uncertainty accounts for variation in production due to climate variability or chance events in the rearing or migratory habitats. Although assessment models frequently generate an estimate of this uncertainty, they typically assume that the variability is random between years and that the background environmental conditions have been stable over time. Clearly, these are simplifying assumptions and are increasingly inappropriate over time, particularly in light of recent evidence for changes in ocean productivity and concerns for global climate change. Predictions of future production or scenarios for salmon recovery require assumptions about future environments. If the future is not represented by conditions in the past, then these predictions have substantially greater uncertainty associated with them. These concerns become increasingly complicated when forecasts involve trends in average conditions and changes in the extent of annual variability associated with climate and/or habitat changes (for example see Ratner et al. 1997, Lawson et al. 2004, Beamish et al. 2004).

The extent of annual changes in marine survival of Chinook, coho, and steelhead salmon has been tracked since the early 1970s using small coded-wire tags that are imbedded in the snout of juveniles and subsequently recovered in fisheries and spawning areas (tagging program described by Jefferts et al. 1963, Johnson 1990). Coronado and Hilborn (1998a,b) provided an extensive review of these tagging programs over time and by geographic area. The results presented in Figure 2 are for representative Columbia River coho groups to demonstrate the annual variations in survival and synchrony between them over time. These data have been updated from Coronado and Hilborn 1998a through recoveries in 2000 (data provided by Hilborn and Magnusson, Univ. Wash., pers. comm.). The magnitude of the between-year variation is substantial, with coho survival rates for individual groups varying from less than 0.25% to over 8%. It is also immediately evident that survival rates may change significantly and very rapidly.

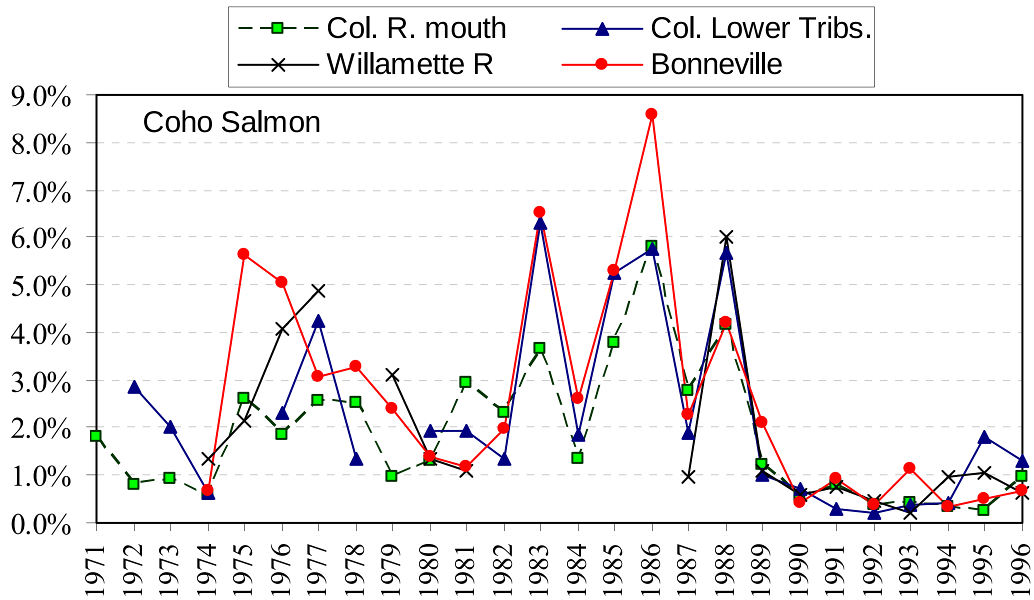


Figure 2. Estimated smolt-to-adult survival rates for coho salmon released from hatcheries in the Columbia Basin by brood year (1971-1996, adult return years 1974-1999). Releases within each of these four groups are averaged within brood years. Data provided by R. Hilborn and A. Magnusson, updated analyses from Coronado and Hilborn (1998a,b).

2c. Uncertainty in Production Assessment

Uncertainty in production assessment by populations (or aggregates of them in a production unit) and necessary data involve both errors in the data collected for the assessment and uncertainty in the estimation of population dynamic parameters. Assessment of a population consists of the determination of its production dynamics (rate of expected production, life history mortality, maturation rates, etc.) and management goals (desired number of spawners, sustainable exploitation rates, etc.) based on historical data. To determine these parameters adequately requires a history of data (catch, numbers of spawners, age classes, and environmental conditions) and usually involves a number of simplifying assumptions concerning error in the data and trends in environmental conditions. In practice, though, error in the data has seldom been estimated or fully accounted for in estimation of model parameters.

As an example of the uncertainties in data applied to "stock" assessment, Figure 3 presents the data for the combined Hanford Reach and Yakima production of Up-River Bright fall Chinook (URB), plus URB above Priest Rapids Dam (spawning years 1964-1991). The data series was fit to a Ricker recruitment function (adjusted for autocorrelation), as described by WDFW (2003, Table 9 and Figure 27). This example was not selected to be representative of all Chinook recruitment curves. The purpose of its presentation was to demonstrate the inter-annual variability in the adult returns (recruits) that may be expected from any number of spawning adults. At the estimated spawning target (~43,000 spawners), the range in observed recruitment has been about twenty fold. It should also be noted that the variability in Figure 3 involves more sources of uncertainty than presented in Figure 2. Figure 3 relates the estimated number of adults spawning to the estimated number of progeny that become vulnerable to fishing and subsequently return as mature adults. Was the variation in recruits due to annual differences in spawning success or due to marine survival variation as presented in Figure 2? In many other populations, significant uncertainty exists in estimates of the parental spawning numbers (in most early spawner-recruitment models the number of spawning parents was assumed to be known without error). Knowing when and where the uncertainty is greatest (parental spawners, juvenile survival, or accounting for catch, etc.) is critical to correctly interpreting historical data and responding appropriately.

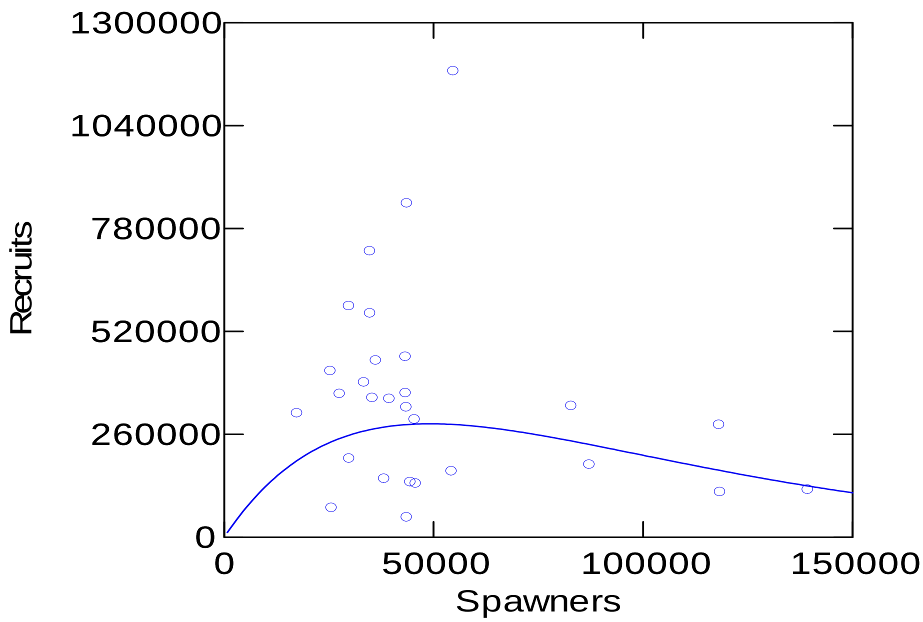


Figure 3. Combined Hanford Reach and Yakima production of Up-River Bright fall Chinook (URB), plus URBs above Priest Rapids Dam (spawning years 1964-1991). Data series with fitted Ricker line (adjusted for autocorrelation) from WDFW (2003).

2d. Uncertainty in Management Control

A source of uncertainty that is frequently overlooked is management control of fisheries. If an escapement goal (the desired number of spawners) could be defined for each salmon population, such an objective would presume that management could regulate multiple fisheries to achieve these goals. With few exceptions, however, such management control is unrealistic. Most fisheries simultaneously exploit a mixture of salmon populations, and the catch from each is usually unknown. Several sources of error interact during the in-season management of a fishery: variation in the return abundance from the pre-season forecast; changes in return timing; variation in the response of fishermen to opportunities and/or weather. In practice, our ability to achieve a specific management target may be much less than acknowledged.

Finally, past management institutions and conflicts have shaped the current management environment. Because Morishima and Henry (2000) have provided an excellent historical perspective, this report will not address those issues. Although Morishima and Henry's paper is focused on ocean salmon fisheries through the late 1990s, more recent data may be acquired to up-date that report from the Pacific Fisheries Management Council (www.pcouncil.org/index.html). In addition, regulatory histories (plus catch and escapements) within the Columbia River may be acquired from the Status Reports, Columbia River Fish Runs and Fisheries 1938-2000 (www.dfw.state.or.us/OSCRP/CRM/reports.html).

For a succinct summary on ESA listings, recovery planning, and the biological opinions prepared to-date, see the Pacific Fisheries Management Council Pre-Season III Report's Appendix A (www.pcouncil.org/salmon/salpreIII05/appdxa.pdf).

3. Current Institutional Structure for Harvest Management Decision Making

In many respects, the contours of the decision process for managing the harvest of Pacific salmon are dictated by the biological characteristics of the resource. Individual populations are characterized by high interannual variability in abundance and productivity. Because of their migratory nature, individual salmon populations are often subjected to harvest decisions made by many different jurisdictions. Most importantly, salmon are semelparous species, that is, they die after spawning, with high homing fidelity to return to their places of origin. Reproductive potential for the next generation is confined to annual spawning escapements of actively migrating mature fish that enter the rivers in concentrated numbers during short time frames.

Fundamentally, harvest management involves decisions that reflect two elements: (1) information regarding the status of the resource and its productive capacity; and (2) a socially determined balance between preservation and utilization of the populations to be harvested, as well as the resources that affect their productivity, such as the quality and quantity of water and spawning/rearing habitat. The decisions made by individual jurisdictions on matters pertaining to harvest, production, and habitat protection respond to the needs of their own constituencies within the constraints of applicable law (see discussion of legal requirements below).

For salmon originating in the Columbia River system, harvest management decisions are made by many different entities in both domestic and international forums. No single entity has the authority and responsibility for ensuring that management objectives are met for a given population, though in principle one entity, NOAA Fisheries, has the authority and responsibility for ensuring that recovery objectives are met for ESUs listed under the ESA. Consequently, cooperation and coordination is required across management jurisdictions. The complexities of harvest management decisions are specific to a salmon population depending upon the pattern of harvest. For example, harvest management of species like chum, sockeye, or steelhead is performed almost exclusively by managers with jurisdiction over in-river fisheries. In contrast, harvest management of Snake River fall Chinook involves in-river managers and ocean fishery managers from California to Alaska. The figure below (Figure 4) illustrates the necessity to coordinate harvest impacts of various jurisdictions that affect Columbia River Upriver Bright Fall Chinook. During 1979-1982 (a "base" period employed by the Pacific Salmon

Commission), fisheries in Washington, Oregon, and the Columbia River (SUS) accounted for 11% of the total fishing mortality of these Chinook, while the majority of the harvest occurred in Canada and Alaska. Although spawning escapement was 53% of the adult production, the number of spawning adults was chronically depressed. The need for a coastwide program aimed at rebuilding of the Upriver Bright and other depressed Chinook stocks became a primary focus for the deliberations that ultimately led to agreement on the 1985 Pacific Salmon Treaty between the United States and Canada.

The time frame for decision making involving harvest management can range from several years for international agreements, like those negotiated by the Pacific Salmon Commission (PSC) to just a few hours for in-season management actions, such as opening or closing a fishery. Typically, harvest management planning decisions are made on an annual cycle coinciding with the availability of information on the status of individual populations and domestic fishery planning process. For Columbia River Chinook and coho salmon, this annual cycle occurs during a two-month period (March-April) when preseason planning processes relating to the Pacific Fishery Management Council (PFMC) are completed.

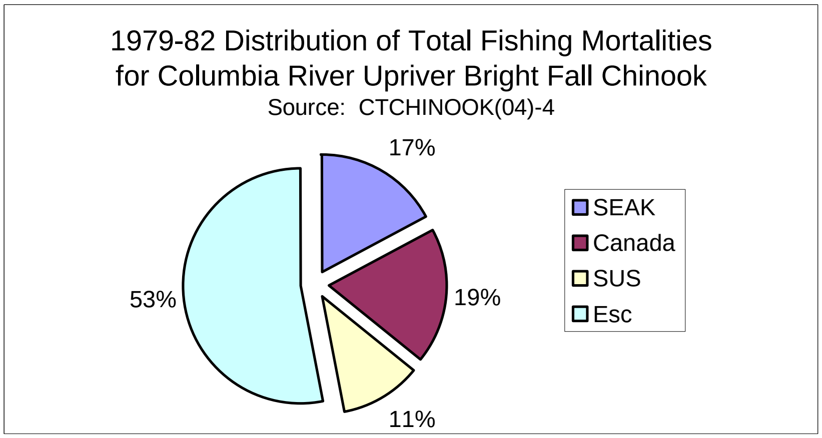


Figure 4. Distribution of total fishing mortality for Columbia River Upriver Bright Fall Chinook (URB). Average annual distribution (1979-82 brood years) of total fishing mortalities, data are expressed as a proportion of the total production, including fishing mortality and spawning escapements. Data from Chinook Technical Committee of the Pacific Salmon Commission (CTCHINOOK(04)-4, 2004) at www.psc.org/publications.htm; SEAK = Southeast Alaska all gears, Canada = all ocean fisheries in BC, and SUS = all salmon fishing gears in Washington and Oregon, ocean and in-river fisheries.

The annual harvest management planning cycle and in-season decisions are based on information that becomes available at different times. For the PFMC, preseason planning for coho and Chinook salmon is based on abundance forecasts that become available from state and tribal co-managers in mid-February. These forecasts are incorporated into planning models employed by the PSC and the PFMC. The PSC Chinook Model is used to develop estimates of abundance indices that determine the allowable level of impact under the PSC's abundance-based management regimes for Canadian and Alaskan fisheries. These expectations are integrated into the PFMC's Chinook FRAM (Fishery Regulatory Assessment Model) for preseason planning of

Chinook fisheries south of the Canada/Washington border. For coho, the PSC and PFMC employ the same model, Coho FRAM. The PFMC's FRAMs are made available to agency staffs and various constituency groups as well as the PFMC's Salmon Technical Team (STT) to evaluate the impacts of proposed regulatory packages. For Columbia River Chinooks, outputs from the PFMC's planning models are incorporated as inputs to in-river models for management planning and negotiation of annual fishing agreements. In April, a full package of agreements for ocean and in-river fisheries that affect Columbia River fall Chinook and coho is developed.

The PFMC adopts recommendations for ocean salmon fishery regulations in April. Ocean fisheries are implemented starting in May. As ocean fisheries are conducted, catch monitoring and sampling programs provide data that are used to evaluate the need for actions to ensure compliance with adopted regulations.

After individual populations are subjected to ocean commercial troll and recreational fisheries, maturing fish return to inside waters and rivers on their spawning migrations where they are commonly subjected to a series of commercial and recreational fisheries. Ultimately, fish surviving harvest by fisheries and in-river mortalities resulting from factors such as dam passage, surviving fish reach the spawning grounds. The timeline for harvest management decision-making affecting Columbia River salmon is presented in Table 1.

Because of these biological characteristics and multi-jurisdictional, socially driven harvest decision processes, harvest management of salmon can be an extraordinary challenge. To effectively manage the resource, harvest management decisions of various jurisdictions throughout the migratory range of individual populations need to be coordinated, or at the very least, be compatible. This coordination is commonly accomplished through two means: (1) communication among scientists responsible for providing scientific advice to decision makers in key forums, and (2) formal agreements among relevant managers.

3a. Many Managers, Many Challenges

<u>In-River (all species)</u>

<u>Tributary Fishery Managers</u>. Harvest management decisions in tributaries of the Columbia River are made by tribal and state managers with primary jurisdiction over individual river systems. These decisions involve both planning and in-season management. Tributary managers include:

Tribal Managers: Confederated Tribes of the Warm Springs Indian Reservation (CTWSIR); Confederated Tribes of the Umatilla Indian Reservation (CTUIR); Nez Perce Tribe (NPT); Confederated Tribes and Bands of the Yakama Nation (YIN); and the Shoshone-Bannock Tribes[6].

[6] A May 1974 order of the Oregon District Federal court determined that tribes must have a meaningful role in fish management (Sohappy v. Smith, No. 68-409). See also Marsh, J.H. & James H. Johnson. 1985. The Role of Stevens Treaty Tribes in the Management of Anadromous Fish Runs in the Columbia Basin. Fisheries 10(4):2-5.

State Managers: The State of Idaho (Idaho Department of Fish & Game, IDFG); the State of Oregon (Oregon Department of Fish & Wildlife, ODFW); and the State of Washington (Washington Department of Fish & Wildlife, WDFW)

Agency staffs provide information on annual status and provide scientific advice for harvest management decisions within their respective jurisdictions. Constituencies of each entity provide advice on socio-economic considerations.

Mainstem fishery managers. Harvest related decisions for planning and in-season management for mainstem fisheries of the Columbia River are made by tribal and state managers and by the Columbia River Compact.

Tribal Managers: CTWSIR; CTUIR; NPT; YIN. The Columbia River Inter-Tribal Fish Commission (CRITFC) coordinates tribal management and enforcement actions for tribal fisheries in Zone 6 (above Bonneville Dam).

State Managers: ODFW and WDFW regulate Columbia River mainstem recreational fisheries.

Tribal and State managers, together with the United States (NOAA Fisheries and USFWS) are in the process of developing a multi-year management agreement for salmon, steelhead, and sturgeon that originate in the upper Columbia River to set forth harvest management constraints and principles along with production plans and objectives.

Scientific advice is provided by agency staffs. Constituencies of each entity provide advice on socio-economic considerations.

Columbia River Compact (Compact): The Columbia River Compact was created by Congress in 1918[7] and is charged by federal and state statutory authority to adopt seasons and rules for Columbia River commercial fisheries. Currently, the directors of ODFW and WDFW (or their delegates) serve on the Compact, representing the Oregon Fish and Wildlife Commission (OFWC) and the Washington Fish and Wildlife Commission (WFWC). In addition, the Columbia River treaty tribes have authority to regulate treaty Indian fisheries, but tribal regulations are also approved by the Compact.

Scientific advice to the Compact is provided by the Columbia River Technical Advisory Committee (TAC), comprised of representatives of state and tribal managers and federal agencies (NOAA Fisheries and USFWS). The TAC reviews forecasts of status, monitors

[7] Neither the State of Washington nor the State of Oregon had the jurisdictional authority to regulate fishing in the Columbia because the river itself formed much of the boundary between the two states. The Compact was authorized under state law in 1915 (RCW 75.40.010, 75.40.020; ORD 50-7.010, 507.030) and approved by Congress in 1918. Article I, Section 10 of the U.S. Constitution provides that "no state shall, without the consent of Congress, enter into any agreement or compact with another state."

abundance and fisheries in-season, and makes recommendations for harvest management to the Compact.

Ocean fisheries (Chinook and coho)

Harvest management decisions affecting Columbia River salmon in ocean fisheries are made by tribal and state managers, Fisheries and Oceans Canada, and the U.S. Secretary of Commerce.

Pacific Salmon Commission (PSC). The PSC was established pursuant to the 1985 Pacific Salmon Treaty between the United States and Canada. Except for sockeye and pink salmon returning to the Fraser River, the PSC has no regulatory or management authority of its own, but is empowered to develop fishery regimes or agreements that will govern the regulation of fisheries by the domestic managers of the U.S. and Canada. The PSC meets twice annually and is focused on development of long-term fishing regimes and matters of coordination and cooperation in salmon management between the United States and Canada.

The primary PSC agreements affecting Columbia River salmon involve Chinook management and a general Pacific Salmon Treaty obligation not to initiate new intercepting fisheries (those that harvest fish produced in the rivers of the other country). Two types of fishing regimes are established by the current (1999) PSC agreement: (1) Aggregate Abundance Based Management (AABM) regimes constrain fishery harvest rates in response to projections for hatchery and natural production combined. AABM regimes apply to Southeast Alaskan (all gear), Northern British Columbia (sport and troll), and West Coast Vancouver Island (sport and troll) fishery complexes; (2) Individual Stock-Based Management (ISBM) regimes. All fisheries that are not managed under AABM regimes are managed under general obligations to reduce harvest rates relative to the 1979-1982 base period for individual stocks that are not projected to meet established spawning escapement goals.

Bilateral Technical Committees provide scientific advice to the PSC. The terms of reference for the PSC Technical Committees require members to serve as independent advisors, not as advocates for agency positions. Information on socio-economic matters is largely provided by the PSC's Northern and Southern Panels.

Tribal Managers. Makah Indian Tribe; Quinault Indian Nation; Quileute Tribe; Hoh Tribe, S'Klallam Tribe. These tribes regulate treaty Indian troll fisheries under the umbrella ocean fishery regulations recommended by the Pacific Fishery Management Council and approved by the Secretary of Commerce.

State Managers. ODFW, WDFW, Alaska Department of Fish & Game (ADFG) in state territorial waters inside three miles of the coastline. The Department of Fisheries and Oceans has the responsibility for regulating Canadian ocean fisheries.

Secretary of Commerce. Under the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) of 1976, the Secretary of Commerce has regulatory jurisdiction over fisheries in the Exclusive Economic Zone from 3-200 miles offshore. The

MSFCMA established eight regional fishery management councils. Two of these, the North Pacific Fishery Management Council (NPFMC) and Pacific Fishery Management Council (PFMC), are responsible for management of Pacific salmon. These Councils develop recommendations for ocean salmon fisheries and provide them to the Secretary for consideration. The NPFMC has deferred salmon management decisions to ADFG under provisions of the Pacific Salmon Treaty. The PFMC is comprised of representatives from the States of Washington, Oregon, California and Idaho, a tribal representative, and representatives of NOAA Fisheries and the US Fish & Wildlife Service. In addition, the NPFMC and PFMC include reciprocal non-voting representatives for coordination. Because of interactions between the PFMC and PSC, the PFMC is required to include at least one member who also serves on the PSC or the PSC Southern Panel. The PFMC considers recommendations of its advisory bodies and makes harvest management decisions through an annual planning process.

The PFMC's Salmon Technical Team (STT), comprised of scientists from State, Federal, and Tribal managers, is responsible for analyzing impacts of regulatory measures and providing scientific advice, both in preseason planning processes and for in-season management actions. Members of the STT serve as independent advisors and not as advocates for the entities they represent. Because of the need for close coordination, there is considerable overlap between the members of the STT and the PSC's Chinook and Coho Technical Committees. The principal focus of the joint PSC-PFMC planning process is on incorporating annual information on the status of salmon populations and the conduct of fisheries into the calibration of fishery planning models used to evaluate the impacts of harvest management measures on individual populations. The PFMC's Scientific and Statistical Committee (SSC) is comprised of independent scientists with various disciplines and is responsible for reviewing methodologies such as models, their parameterizations, and abundance forecasting procedures.

> North of Cape Falcon Forum: The PFMC uses Cape Falcon, Oregon as the southern management boundary for Columbia River Chinook and to implement harvest allocation schedules for non-Indian commercial and recreational fisheries off the coasts of Washington and Oregon (PFMC Pacific Coast Salmon Plan, Section 6.1). For coho, the vast majority of ocean fishery impacts of Washington coastal and Puget Sound coho usually occur in the area north of Cape Falcon. The North of Cape Falcon Forum, sponsored by state and tribal co-managers, convenes the co-managers and representatives of the commercial and recreational fishing sectors during the Council's preseason planning process to determine allocation and conservation recommendations for fisheries north of Cape Falcon (PFMC Preseason Report I, Appendix C).

Advice on socio-economic considerations is provided by the Salmon Advisory Sub-Panel (SAS) and obtained through public hearing processes. The SAS consists of representatives from various sectors (e.g., commercial, recreational, general public) and is responsible for providing recommendations for fishery regulations.

Enforcement advice is provided by state and federal fisheries enforcement staff. Legal counsel from NOAA Fisheries attends all PFMC meetings to provide advice regarding the consistency of PFMC actions with requirements of applicable law.

The PFMC employs an intensive preseason fishery management planning process during March-April each year. Ocean fisheries are managed under the provisions of a long-term Salmon Fishery Management Plan that identifies conservation objectives for individual stocks and allocation requirements between non-Indian fishery sectors. As part of the annual planning process, agreements are made between state and tribal co-managers to govern fisheries inside state territorial waters, to equitably distribute the conservation responsibility and allowable fishery impacts, and to coordinate harvest measures to meet resource management objectives for individual stocks.

3b. Legal Requirements for Harvest Management

Harvest management decisions must comply with applicable law. For salmon, this law includes Indian treaties, agreements of the PSC and obligations under the Pacific Salmon Treaty between the United States and Canada, federal statutes such as the MSFCMA, the National Environmental Policy Act (NEPA), and Endangered Species Act, domestic and state statutes, and applicable case law. Requirements of four areas of law with special significance to harvest management are highlighted below:

Indian Treaty fishing rights. Through treaties with the United States, Indian tribes reserved the right to take fish at their usual and accustomed places. Those places are determined by the federal courts for individual treaty tribe. The courts have determined that treaties entitle tribes to 50% of the harvestable surplus of fish originating in or passing through their usual and accustomed fishing places, prevent laws from being enacted that discriminate against tribal fishing, and restrict the capacity of non-Indian governments to regulate Indian fishing except when necessary for resource conservation.[8] The term “conservation” has a specific legal meaning when applied in the context of treaty fishing; rather than “wise use” connotations of conservation, the courts have ruled that conservation actions must be reasonable and necessary for the perpetuation of a species of fish. To have the largest possible sustained harvest, state, tribal, and federal fishery managers generally rely upon the concept of Maximum Sustained Yield as a standard for regulation of their fisheries.

Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). In addition to the institutional structures of regional councils, the MSFCMA sets forth a set of national standards that must be attained for ocean salmon fishery management:

1. Conservation and management measures shall prevent overfishing while achieving on a continuing basis, the optimum yield from each fishery for the United States fishing industry.

[8] Sohappy v. Smith (302 F.Supp. 899 (1960)) was the first in a series of cases dealing with treaty-protected Indian fishing rights in the Columbia River. Harvest sharing and tribal participation in management were addressed in Sohappy decisions No. 68-409 dated May 8, 1974 and Aug 20, 1975.

2. Conservation and management measures shall be based upon the best scientific information available.

3. To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

4. Conservation and management measures shall not discriminate between residents of different States. If it becomes necessary to allocate or assign fishing privileges among various United States fishermen, such allocation shall be

   a. fair and equitable to all such fishermen;
   b. reasonably calculated to promote conservation; and
   c. carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

8. Conservation and management measures shall, consistent with the conservation requirements of the Act (including the prevention of overfishing and rebuilding of overfished stock), take into account the importance of fishery resources to fishing communities in order to:
   a. provide for the sustained participation of such communities, and
   b. to the extent practicable, minimize adverse economic impacts on such communities.

9. Conservation and management measures shall, to the extent practicable,
   a. minimize bycatch and
   b. to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.

The PFMC has established operational guidelines (National Standard 1) to prevent overfishing and achieve optimum yield (OY). Optimum yield emerged as a management concept about a decade before the passage of the MSFCMA and was included in the Law of the Sea Treaty. Early in its deliberations, the PFMC determined that optimum yield determinations should start from a fixed reference point - maximum sustained yield, and then be modified in response to social and economic considerations.

Currently, NOAA Fisheries describes optimum yield as:

> *"NOAA Fisheries is charged with managing fisheries to provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, while taking into account the protection of marine species and ecosystems. We accomplish this through management, to achieve, on a continuing basis, the optimum yield from each fishery. Optimum yield is defined as the amount of fish which will achieve the maximum sustainable yield, as reduced by any relevant economic, social, or ecological factor. In the case of an overfished fishery, optimum yield has been defined as that amount of fish which will provide for rebuilding of the stock to a level which will support the maximum sustainable yield.*
>
> *Our management decisions must reflect the needs of many different groups, including commercial and recreational fishermen, fishing communities, non-consumptive users, Pacific Islanders, and Native American tribes which have treaties with the United States guaranteeing certain fishing rights which we are obligated to uphold. We must also consider efficiency, minimize costs, avoid unnecessary waste and duplication, and allocate harvest restrictions and recovery benefits fairly among all users, while minimizing adverse economic impacts on fishing communities, consistent with our conservation objectives. To achieve this, we will focus on reducing sources of waste such as overcapitalization and bycatch (all fish harvested but not sold or kept for personal use, including economic and regulatory discards), mitigating the effects of fishery management on fishing communities, and increasing recreational fishing opportunities."*

The PFMC is required to adhere to requirements of fishing regimes established by the PSC and abide by federal decision-making requirements set forth in statutes such as NEPA.

<u>The Endangered Species Act (ESA)</u>. Numerous salmon populations from the Columbia River have been listed as threatened or endangered under the ESA. Harvest management actions that impact these populations are subject to consultations with NOAA Fisheries (for anadromous forms) and the USFWS (for resident forms). Harvest management decisions affecting ESA-listed populations must meet a "no jeopardy" requirement of the legislation. The assessment of whether a harvest action will cause "jeopardy" is documented in a "biological opinion" by the responsible agency, and annual guidance letters advise harvest managers how to comply in their implementation. An assessment of the PFMC's recommended fishery regulations with respect to these standards is provided to the Secretary of Commerce as part of the record of decision for proposed harvest management measures.

<u>Columbia River Compact.</u> The Compact must consider the effect of commercial fishing for salmon, steelhead, and sturgeon in the Columbia River on escapement, treaty rights, and sport fisheries, as well as the impact on species listed under the Endangered Species Act (ESA). Although the Compact has no authority to adopt sport fishing seasons or rules, it is an inherent responsibility of the Compact to address the allocation of limited resources among users.

3c. The Decision-Making Process

The annual harvest management process centers around attaining management objectives for individual populations of fish, usually centered on constraining exploitation rates on maturing and mature fish so as to attain desired levels of spawning escapements. Consequently, the following description of harvest management processes will start with ocean fisheries and end with in-river fisheries. A schematic diagram of the process (Figure 5) and time schedule of annual fishery management planning processes (Table 1) follows.

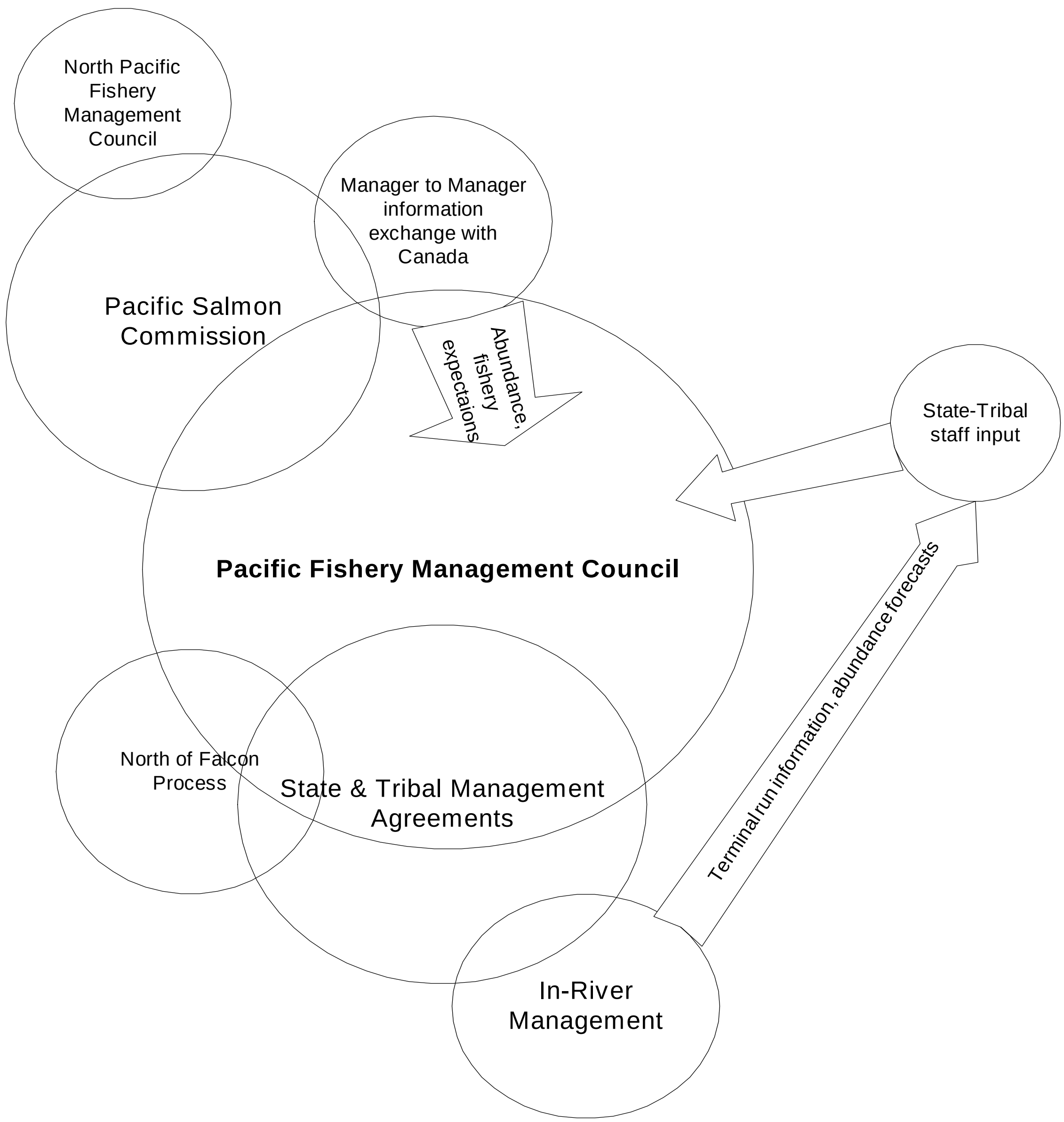


Figure 5. Harvest Management of Columbia Up-River Fall Chinook

Table 1. Annual timeline for harvest management decisions affecting Columbia River salmon.

1. A. Decision timeline for Chinook salmon significantly impacted by ocean fisheries. For coho, PSC and NPFMC not relevant.		
Entities and Timeline	**Scientific Advice**	**Socio-Economic Advice**
Pacific Salmon Commission, Chinook Technical Committee (CTC)	Provided by Bilateral Technical Committees. Evaluation of regime performance Annual calibration of CTC Model Post season review	Regime development reflected in negotiated long-term agreements.
North Pacific Fishery Management Council	Defers to PSC and ADFG	Alaska Board of Fish
Pacific Fishery Management Council January Mid-February Mid-March April May May through following April Nov	Scientific & Statistical Team reviews models and methodologies. Salmon Technical Team (STT) prepares post season review State & tribal co-managers provide abundance forecasts. STT prepares preseason report on abundance expectations and parameterizes planning models, including projected impacts of Canadian and Alaskan fisheries driven by AABM regimes. STT evaluates regulatory packages (in consultation with state & tribal co-managers) in relation to Council objectives and legal requirements; prepares preseason report II for public comment. PSC manager-manager discussions with Canada to obtain preseason expectations of abundance and fisheries. STT evaluates modifications to options and prepares pre-season report III describing expected impacts in relation to PFMC management objectives, documents technical basis for decisions (models & methods) reports. PFMC staff prepares NEPA analysis and submit to Secretary of Commerce for consideration. State & Tribal co-managers monitor fishery and sample fisheries (size, coded-wire-tags, scales, etc.), PFMC and STT take in-season action as necessary and appropriate for compliance with fishery regulations. PFMC's Scientific & Statistical Committee and Salmon Technical Team review planning, models, forecasts, and analysis methods as necessary and appropriate.	Framework Plan requirements Salmon Advisory Subcommittee (SAS) provides recommendations on season structure. Public comment PFMC establishes specific management objectives & guidance to STT, identifies options for public review. Constituency and co-manager meetings (North of Falcon process) PFMC revises options in response to input, receives advice from SAS & public comment. State & tribal co-managers agree on preseason fishing plans for ocean and inside fisheries. PFMC adopts recommendations for seasons & regulations. NEPA statements prepared. Secretary of Commerce evaluates (dis)approves. In-season conference calls involving STT, state and tribal managers, SAS.

1.B. Decision timeline for all species.		
Entities and Timeline	**Scientific Advice**	**Socio-Economic Advice**
In-River Management Early Dec Mid-Dec Jan Feb Feb-May Early July Aug-Sept Mid-Sept	State & tribal staffs monitor run sizes and catches in-season. Columbia River Technical Advisory Committee (TAC) provides analysis and advice to Compact. Meeting and information exchange schedules for the Production Advisory and Policy Committees. Columbia River staffs provide estimates of escapements and run sizes according to the following schedule. Winter season report on sturgeon and smelt management. Post-season reconstruction and preseason run forecasts for spring & summer Chinook and sockeye. Status report on spring Chinook and steelhead. Preliminary post-season fall fishing report. Status report Snake River fall Chinook. Run size forecasts for fall Chinook. Columbia River staffs provide preseason abundance forecasts to STT and PSC Technical Committees. In-season management of fall fishery. Fall season report. Post season spring/summer fishing report.	Columbia River Compact establishes seasons.

3d. The Task Today

Salmon management in the Columbia River is currently dominated by conservation objectives and by the requirements of the Endangered Species Act. Salmon management today faces an increasingly challenging set of constraints and contrasting objectives. For example, while several ESUs are listed under the ESA, mixed-stock ocean fisheries (which incidentally harvest some fish from listed ESUs) continue and managers must respect Treaty fishing rights. While the debate concerning the interactions of hatchery-produced fish and naturally produced fish has never been more acrimonious, hatchery production continues and new means to identify these fish for harvest are being implemented (mass-mark selective fisheries requiring the release of un-marked and usually naturally produced salmonids). Ultimately harvest increases the demand for hatchery production, which in turn may have other negative effects on wild populations (see the ISAB supplementation report, ISAB 2003-3). Although incidental mortalities relative to landed, reported catches have increased in many fisheries, increasing the uncertainty about harvest impacts, precautionary approaches are also being promoted in management guidelines that require reductions of fishing impacts to compensate for this greater uncertainty. Under the ESA, jeopardy determinations are made at the level of the ESU (usually an aggregate of spawning populations), and harvest management typically operates on aggregates of independent populations. Salmon production and allowable harvest rates, however, are determined by the dynamics of each local salmon population in their habitats, and should be managed for their individual characteristics.

The ISAB has attempted to integrate the above discussion of institutional structures for salmon management with the biological basis for production and establishment of management targets (Figure 6). A fundamental issue for salmon management has been the challenge of determining biological productivity (rate of production of mature progeny per spawning female) of each population unit (a demographically independent spawning group) and then controlling harvest impacts to achieve the management objectives for those units. The problems in achieving this include:

- inadequacy of data to identify the independent population units and estimate their individual productivity;
- inherent differences in productivity due to differences in natural habitats and changes in habitat conditions over time;
- practical inability to control the cumulative impact of multiple fisheries on each population unit; and
- high degrees of uncertainty during in-season management processes, and unpredictable changes in environmental conditions through time.

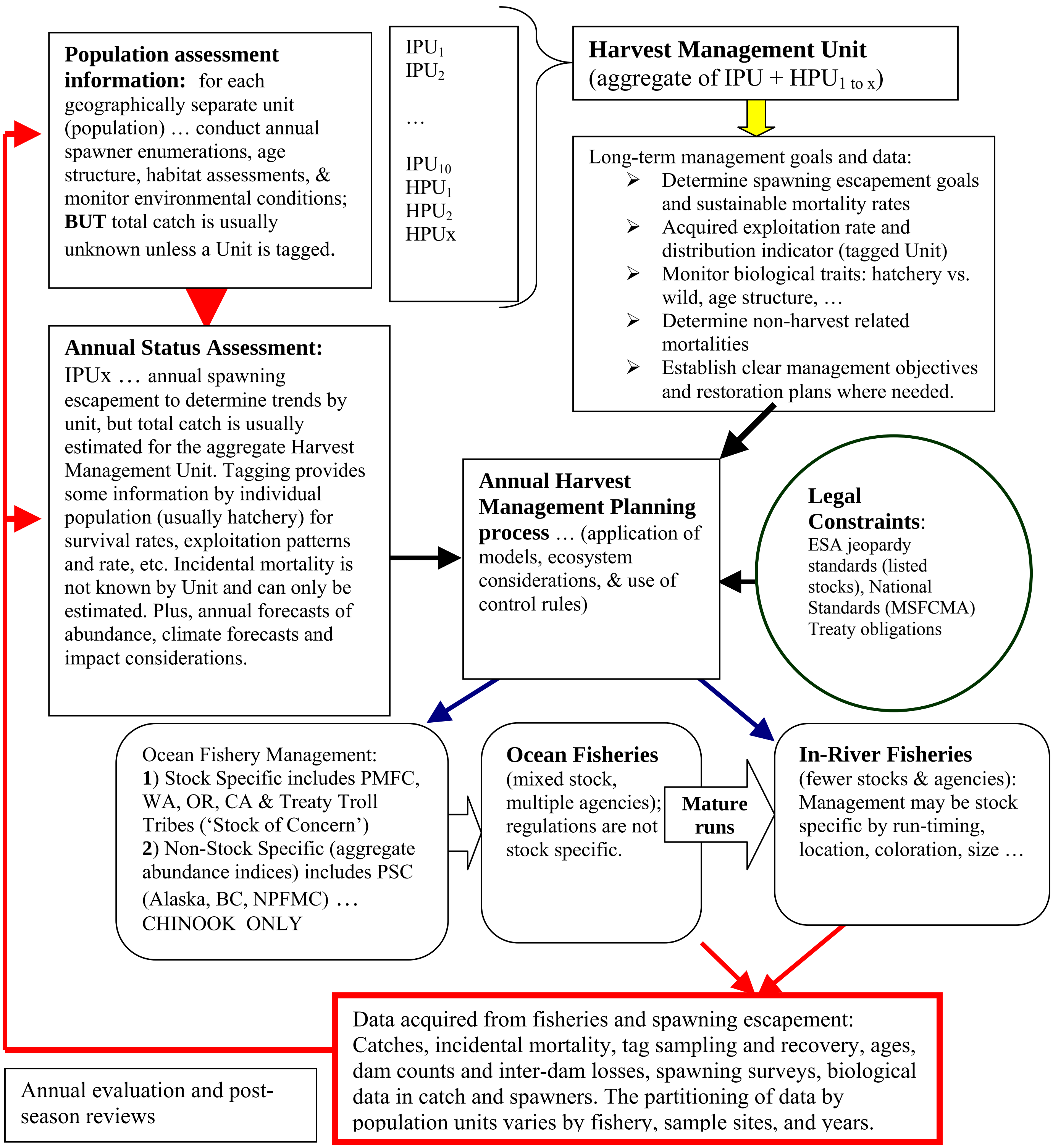
Although the problems associated with multiple units with different “productivity” and multiple fisheries have been recognized for many years (Ricker 1958), in practice, they have seldom been fully addressed in salmon management. The mixing of hatchery-produced salmon with natural salmon is an extension of this basic problem, but one that greatly increases the risk of over-fishing on natural populations. The upper portion of Figure 6 portrays the problem of aggregating multiple population units into “management units” and the establishment of management objectives for these aggregates. The remainder of Figure 6 encapsulates the institutional details presented above as well as the extensive data required for annual evaluation of fishing impacts and the status of the management units. These data must then be integrated with spawning surveys and biological sampling within population units to estimate abundance, productivity, and the spatial distribution of salmon within the management unit.

Each element of Figure 6 may differ between species or sub-groups within a species (e.g., spring, summer, fall Chinook) but the major elements are generally representative of all Pacific salmon. There will, however, be differences between species in the roles of respective management institutions (e.g., varying role of ocean fisheries versus in-river fisheries). Attempting to describe these differences comprehensively would be a large task but it can be effectively illustrated by the major functions of harvest management using three examples of Columbia River Basin salmon runs of varying characteristics:

1. a healthy natural population (Upriver Bright fall Chinook);
2. an ESA-listed Chinook population impacted by ocean fisheries (Snake River fall Chinook); and
3. an ESA-listed Chinook population that is not harvested significantly in ocean fisheries (spring Chinook).

Tables for each example are provided in Appendix A. These tables identify a range of management functions, the responsible institutional entities, areas of responsibility, legal authorities, decision time frames, and relevant scientific issues and questions.

Figure 6. Schematic integrating population assessment and harvest management for Columbia River salmon, details presented for fall Chinook (details for other species may vary). HPU = Hatchery Population Unit, IPU = Independent natural Population Unit. CWT = coded-wire tags. **(Note: Examples of Institutional structure by Harvest Management Units are described in Appendix A.)**



4. ISAB Review

4a. Vision Statement

This report focuses on the role that harvest management plays in the conservation and sustainable utilization of salmon from the Columbia River Basin. The terms *conservation* and *sustainability* are often each given different definitions that result in ambiguous descriptions. This may be expected, because each term involves biological and socio-economic factors. Diverse perspectives and values inevitably become involved such that the terms mean different things to different people. In the United States, political decision-making processes that are guided by a suite of legal mandates determine what is to be sustained, how, and at what cost. Decisions are usually made by governments with advice from constituencies who then decide if the consequences are acceptable. Since fish don't vote, they bear the consequences of human decisions. To be sure, the manner in which fisheries and other aquatic resources have been managed has been fertile ground for controversy.

Within the context of this assignment, the ISAB's vision of conservation and sustainable use is centered on decision processes that are necessary to ensure that the removal (i.e., total mortality from all sources) of Columbia River salmon does not exceed the productive capacities of naturally spawning populations over the long-term. From this perspective, effective harvest management systems must have three primary components:

4. a sound scientific foundation for management;
5. clearly defined priorities and objectives for resource conservation and fisheries management; and
6. the capacity to constrain total fishing mortality on a population to a level that proves sustainable after accounting for all sources of mortality affecting the population throughout its life cycle.

This report first describes these components and then (Section 4b.) comments on the adequacy of their status for the Columbia River Basin.

<u>Sound Scientific Foundation</u>

Science must effectively inform decision making for harvest management. Science is involved in designing monitoring programs, collection of data, and the development and use of reliable methods of analysis to assess biological status of the populations and fishery impacts. These assessments frequently involve limited data, data that varies in quality though time, and "noisy" data from complex ecological and social systems.

A sound scientific basis for harvest management would:
1. provide the best practically obtainable and pertinent data;
2. provide the best available science[9] at the time decisions are made; and
3. ensure transparency for the basis of advice, analyses, competent peer review, and a process for regular review and response (learning) as experience is gained.

Given the uncertainties and unknowns that remain in salmon management and recovery, a priority should be placed on ensuring an empirical basis for assessing trends and status in each production unit and on obtaining key information required to control harvest impacts. Well-designed monitoring programs are required to collect data on fisheries and escapements. A sound scientific basis for harvest management would inform decision-makers of the need for better information as harvest approaches the limits sustainable by the productive capacity of the resources and of the trade-offs between uncertainty and costs of management. Fishery and escapement data, biological data on the exploited populations, and basic data on production capacities are the fundamental building blocks of a sound scientific foundation for harvest management. These are necessary to: (a) identify and quantify mortality from all sources affecting a given population throughout its life cycle, (b) provide biological goals for management, and (c) provide clear early signals of non-sustainability should it occur. For example, the monitoring program should be capable of differentiating causes of a decreasing trend in spawning numbers; is it due to over-fishing, reduced productivity in freshwater, and/or a period of reduced ocean production? In the absence of adequate data, managers should reduce harvest impacts on the resource to ensure its continuance and productivity.

Clearly Defined Management Objectives

Effective harvest management requires:
1. definition of the **production units**[10] to be managed;
2. biological conservation targets for each production unit; and
3. objectives and priorities for fisheries and clearly defined risk tolerances.

In spite of all of the data that have been collected on Pacific salmonids, the reality is that fisheries management is inexact. There are many sources of uncertainty. Ultimately, science must provide information and advice in the face of both risk and uncertainty. Risk can be minimized and options preserved in a dynamic and unstable environment by maintaining a genetically diverse mix of component populations and their habitats. In the absence of accurate information on productivity and exploitation for specific component populations, a sound harvest management decision process would employ a precautionary approach to protect a minimum spawning population size in each unit, given the current and potential future range of

[9] The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) requires that harvest management decisions use the "best available science." National standards and guidelines have been developed and are being applied in decision-making processes of regional fishery management councils (see discussion of current institutional structure).

[10] Production unit in this discussion is a spatially defined group of salmon populations and hatcheries that are determined by the responsible agencies as a basis for conservation and management.

environmental conditions[11] and the range of error between estimates and true values.

Capacity to Constrain Total Fishing Mortality

The capacity to constrain harvest of Columbia River salmon requires:

1. consistent quality-assured data acquired for pre-season planning and in-season monitoring;
2. clear management objectives and timely in-season decision processes; and
3. management accountability.

This capacity is determined by the institutions involved in regulating fisheries throughout the migratory ranges of individual production units. Because many jurisdictions typically affect the harvest of Columbia River salmon, fishery management decision processes must be sufficiently coordinated to collect consistent biological data and accomplish management objectives for production units of interest. The capacity to constrain harvests to levels sustainable by the inherent productivity of production units depends upon common acceptance of management objectives and responsibilities. It also depends upon having accountability in decision processes involving a variety of necessary components, including sound scientific information, stakeholder participation, and enforcement. Walters (1995) discusses institutional requirements for sustainability. The current institutional structure for managing Columbia River salmon is described and evaluated in reference to these requirements in Section 3 of this report.

4b. Indicators of effective harvest management systems

Indicators of performance of the harvest management system for Pacific salmon are derived from these three requirements for effective management: sound scientific foundation, clearly defined objectives, and institutional capacity to constrain total fishing mortality.

Performance Indicator 1: Is the Scientific Foundation sound?

Although Pacific salmon have been studied extensively, scientists and managers continue to learn about population structure, population processes and production dynamics, and about the extent of inherent variability in the environment as it affects natural populations. Generally, the scientific community knows less than is expected or understood by the public. The ISAB notes, however, that progress in science that supports harvest management is evident and likely to continue. The ISAB found the use of technical information in setting harvest limits to be incomplete, especially for biological opinions related to harvest impacts on ESA-listed species.

The scientific basis for assessment and harvest management consists of empirical information, statistical analysis of that information, developing inferences, and providing sound advice for

[11] page 6, NW Region Sustainable Fisheries Division report (Dygert and Bishop 2004): "With respect to the abundance criterion, the VSP report provides guidelines for developing "viable" and "critical" abundance levels to serve as benchmarks for assessing the status of populations."

the development of annual management plans, and recommending research. The empirical basis must:

1. identify the spatial units or organization of salmon production and their habitats;
2. provide the data necessary for assessment and planning;
3. enable the determination of sustainable levels of use (includes all sources of anthropogenic related mortality) to ensure conservation;
4. provide for annual monitoring and assessment of the production units to enable documented annual advice on abundance trends, population status, and limits to be addressed in fishery management plans.

Significant progress is being made in the delineation of production units for salmonids. The NOAA status reviews (www.nwfsc.noaa.gov/trt/brtrpt.htm) and the work of the Technical Recovery Teams (TRT, www.nwfsc.noaa.gov/trt/) have identified independent demographic units for salmon production. (See Background Section 7.a, Sustaining Diversity.)

The empirical bases for assessment and for determining management goals in production units are data quality and availability, their use in analyses, and the inferences drawn from these analyses (e.g., spawning escapement goals and/or target exploitation rates). In essentially all cases for Pacific salmonids from the Columbia River Basin, the quality of historical data has severely limited its use for assessment of individual populations and estimation of production rates.

Problems with the data include:

- data were typically collected only after years of over-fishing;
- the origin of the fish caught in each fishery is frequently unknown (and individual populations are usually caught in numerous fisheries);
- the actual number of spawning fish to associate with catch is frequently unknown; and
- the age of fish caught and/or spawning is seldom monitored annually.[12]

Unfortunately, these types of problems are quite common along the Pacific coast when agencies attempt to estimate production (progeny) from the number of adults (spawning abundance, stock) in the parental year (i.e., spawner/recruitment analyses as described by Ricker 1954 or Beverton-Holt 1957; see Primer in Salmon Harvest Management, Section 7e). The problem was common enough that Hilborn and Walters (1992) concluded that: *"We think that bad stock-recruitment analyses have been a significant factor leading to over-exploitation and stock collapse for some major fisheries." (pg. 287)*

Ironically, these limitations of historical data may not have been as serious a limitation in the Columbia River Basin as they may have been in less disturbed environments. The extensive alternations of habitat in the Columbia negate a basic assumption (a consistent habitat base) of stock/recruitment analyses and restrict where such analyses have proven somewhat informative (i.e., in Lewis River wild fall Chinook, Coweeman tule fall Chinook, and Hanford Reach Bright fall Chinook). In most other Columbia production units, these data limitations have contributed to the difficulties in defining biologically based recovery goals and management targets.

12 Similar comments and concerns were expressed by the ISAB during our Supplementation report, Chapters 3 and 4, ISAB 2003-03.

Over the past decade, however, there has been notable attention to the scientific basis for recovery of depressed salmon abundance and for improving assessment and management. The ISAB notes particularly:

- the inclusion of life history diversity in consideration of natural populations, the value of meta-population processes (i.e., maintain diverse inter-connected populations within freshwater habitats);
- increased recognition of ecosystem values (see Background Section 7.b, Freshwater Ecosystems);
- definition of criteria for viable salmon populations including threshold values to delimit viable (Box A2) and critical (Box A3) population abundances (McElhany et al. 2000);
- means to assess viability of individual populations (McElhany et al. 2003);
- attention to regional monitoring programs; and
- the application of risk assessment frameworks for salmon conservation (Kareiva et al. 2000, NMFS-NWFSC 2001, ISAB/RP 2005-5).

The latter risk frameworks are efforts to integrate the 4-Hs (Hydro, Hatcheries, Habitat, and Harvest) in the Columbia River Basin. The ISAB emphasizes that this integration is crucial to effective harvest management of Columbia River Basin salmon. The most recent and related model reviewed by the ISAB and ISRP was the "All-H Analyzer" that the Northwest Power and Conservation Council staff proposed to use to establish numerical objectives for anadromous fishes, including natural returns, hatchery escapement, and harvest at the subbasin, province, and basin levels. While the review was critical of the current version of AHA, the review noted:

> *"…the ISRP&AB emphasize that there is a clear need for quantitative analysis, including disciplined use of analytical and exploratory modeling, to improve fish and wildlife management in the Columbia River Basin, particularly the integration of natural and hatchery production with habitat actions at the subbasin level. We strongly agree with the Council staff's observation that a major problem within the Columbia Basin is the lack of clearly articulated objectives integrated across the four Hs at the subbasin, province, and basin levels. Without these objectives, it is difficult to prioritize project implementation and monitoring activities. A key to developing these objectives is a comprehensive, integrated analysis of habitat, hatchery, hydrosystem and harvest actions." (ISAB/RP 2005-5, Feb. 2005)*

The ISAB notes that many of the elements of a sound scientific foundation are being progressively developed. Realistically, though, the complex interaction of human activities with Pacific salmonids in the Columbia River Basin and the changing environmental conditions (e.g., see Background Section 7.d, Climate Change) suggest that the foundation will continue to develop for years to come. For example, the recent initiative to mass-mark all Chinook, coho, and steelhead produced in federally supported hatcheries has been promoted as a means to support recovery of naturally produced salmon while providing for the selective retention of marked salmon to support fisheries (mass-marked selective fisheries). If, however, a limiting factor to recovery of natural salmonids is competition with the massive numbers of hatchery fish produced in the Columbia River Basin, then this initiative may actually prove to be detrimental to recovery (for example, see Sweeting et al. 2003, Levin and

Williams 2002, Levin et al. 2001; also see Background Section 7.c, The Hatchery Paradigm and Ocean Carrying Capacity). Furthermore, the current implementation plans for mass marking and selective fisheries will severely compromise some important aspects of data collection that bear on the estimation of harvest mortality rates. The issue of mass-marking and selective fisheries is addressed further in Question 3 below. Without research programs directed to evaluate this issue, however, the value of mark-selective fisheries will remain uncertain, particularly as the mortality of released fish (i.e., incidental or non-reported mortality) becomes a significant component of the total mortality attributed to harvest.

The biological basis for assessments and estimation of spawning escapement goals or recovery goals ultimately provides advice for the development of the fishery management plans. Currently, the development of harvest regulations requires advice on limitations imposed by the constraint to protect listed ESUs (Evolutionary Significant Units, or component populations) that must be considered during the development of fishing plans to access other harvestable production. For Columbia River Basin listed ESUs, this becomes a challenging task involving multiple listings and numerous fisheries both in the ocean and within the river.

For each listed species in the Columbia Basin, the Pacific Fishery Management Council Salmon Pre-Season III Report's Appendix A (www.pcouncil.org/salmon) lists the ESU, populations representing the ESU in the Salmon Fishery Management Plan (FMP), ESA Consultation Standards (guidance provided annually by NOAA Fisheries), and the fishery management measures intend to comply with the Standards. Text in the PFMC Salmon Pre-Season III Report's Appendix A provides a succinct statement of how listed species are treated under the salmon fishery management plans (table numbers refer to tables in the Pre-Season III report).

> *"Since 1989, NMFS has listed 16 Evolutionarily Significant Units (ESUs) of salmon under the ESA (Table A-1). As the listings have occurred, NMFS has initiated formal section 7 consultations and issued biological opinions (Table A-2) that consider the impacts resulting from implementation of the Salmon FMP, or from annual management measures, to listed salmonid species. NMFS has also reinitiated consultation on certain ESUs when new information has become available on the status of the stocks or on the impacts of the Salmon FMP on the stocks. Some opinions have concluded that implementation of the Salmon FMP is not likely to jeopardize the continued existence of certain listed ESUs. Other opinions have found the Salmon FMP is likely to jeopardize certain listed ESUs and have identified reasonable and prudent alternatives that would avoid the likelihood of jeopardizing the continued existence of the ESU under consideration. The consultation standards referred to in this document include (1) reasonable and prudent alternatives, (2) conservation objectives for which NMFS conducted section 7 consultations and arrived at a no-jeopardy conclusion, and (3) NMFS requirements under section 4(d) determinations.*
>
> *Amendment 12 to the Salmon FMP added to the list of stocks in the salmon management unit the generic category "species listed under the ESA" and the respective escapement goal to "manage consistent with NMFS consultation standards or recovery plans to meet immediate conservation needs and long-term recovery of the species." Amendment 14 to*

the Salmon FMP specified those listed ESUs and clarified which stocks in the Salmon FMP management unit were representative of the ESUs.

NMFS, in a March 4, 2005 letter to the Council, provided guidance on protective measures for listed species for the 2005 fishing season. The letter summarized the requirements of NMFS' biological opinions and 4(d) rules which are to be applied to the 2005 management season. The ESA consultation standards and the exploitation rates (or other criteria) projected for the 2005 management measures are presented in Table A-3. Some listed stocks are either rarely caught in Council-area fisheries (e.g., spring chinook from the upper Columbia and Willamette rivers) or already receive sufficient protection from Salmon FMP and ESA consultation standards for other listed ESUs (e.g., Central Valley spring chinook). NMFS has determined that management actions designed to limit catch from these ESUs, beyond what will be provided by harvest constraints for other stocks, are not necessary." (Salmon Pre-Season III Report for 2005, Appendix A)

In reviewing the scientific basis for management objectives the ISAB encountered two notable issues:

1. identifying the production units used in management planning to represent listed ESUs (i.e., the correspondence between production units and ESUs), and
2. understanding the technical and analytical basis of the biological opinions.

Although Table A-3 of the Pre-Season III report relates "stocks" represented in the salmon FMP, it does not identify the populations used in the assessment of these stocks such that an assessment's technical basis is reviewable. To address this, the ISAB collated a large table of ESUs, component populations identified by the NOAA technical review teams, indicator stocks and assessment methods, and the harvest management units for ocean and in-river management (Appendix B). While this table was informative in organizing our understanding, it also clearly demonstrates the paucity of quantitative assessments that form the basis of harvest management for both listed and other production units within the Columbia River basin.

The technical bases for some biological opinions were not apparent and their adequacy for achieving recovery was uncertain. To permit an action that results in "take" (including harvest) from a listed population, the ESA requires a determination that the take is incidental to the proposed action (and not the primary purpose of the action) and that the anticipated level of take will not "jeopardize the continued existence" of the population. Regulations interpret "jeopardize the continued existence" to mean "appreciably reduce the species likelihood of surviving and recovering in the wild."

Because fishing is not completely selective, individuals from listed populations may be caught during the course of harvests intended to target other populations. Because the harvest in the first place is deliberate, and the take of the listed population is owing to failure of selectivity, the degree to which this is "incidental" is a matter of interpretation.

The level of harvest mortality that results for the listed population can be quite high -- rates in the 20% to 50% range can be encountered. A healthy, productive salmon population can sustain such harvest mortality, so managing the fishery on the aggregate with a view simply to maintaining the gross level of production of the more productive components will lead to these sorts of harvest mortalities on weak (less productive) or listed stocks. Endangered populations often are not as productive as their healthy counterparts, so the level of harvest based on the aggregate of populations may be excessive and not sustainable by the weaker component populations. Similarly, because hatchery production may give rise to productivity levels considerably higher than the natural production of the same species, a fishery managed to access the hatchery component of the population may not be sustainable by the natural component.

Another common characteristic of salmon population dynamics that is relevant to biological opinions, even for normal healthy populations, is a high degree of temporal volatility. Between good years and bad years, the productivity can vary through a ten-fold range, or more. As a result, the assessment of sustainability of a proposed harvest level is inevitably subject to a large degree of temporal uncertainty. The uncertainty owing to real process variation will be compounded by uncertainty owing to measurement error in the estimation of the productivity, implementation error owing to imperfect control of the fishing activities themselves, and uncertainties having to do with effects of other factors, such as attempts to mitigate for other components of mortality or productivity.

The regulatory determination through a biological opinion, therefore, of whether or not a proposed harvest level is compatible with survival or recovery of a listed population, will be ill-defined unless it is guided by hard quantitative standards for what constitutes an appreciable reduction in the probability of survival and recovery, as well as how the determination should factor in the various pertinent uncertainties. At present such quantitative standards have not been stated for the regulatory determinations. Biological opinions have been generated for permitting incidental harvest of various listed salmon ESUs using a variety of kinds of data, of varying degrees of completeness and reliability, and analyzed by a variety of statistical and modeling methods. To date, these determinations related to harvest have been conducted in a relatively collegial atmosphere with the regulated community, and the decisions have not been contested at a disruptively vigorous level (in contrast to those related to operation of the federal hydro system). Whether or not this kind of acceptance of a loosely defined process will continue in the future is an open question. It would be prudent for NOAA Fisheries and the Fish and Wildlife Service to develop more explicit, quantitative, standardized methodology, if only as a defensive precaution. Certainly, many other aspects of regulation of listed salmon have come under very intense and rather costly debate.

NOAA Fisheries and the Fish and Wildlife Service have been aware for some time of the ambiguities in the existing legislation and harvest regulation, and joint efforts have been underway to attempt to develop more complete and standardized guidance. It would be good to ensure communication between the salmon decision-making apparatus and these guidance efforts to capitalize to the extent possible on current thinking. For example, clear statements of critical population sizes for populations or ESUs (based effective population sizes, Waples 2002 a,b) and threshold exploitation rates necessary to limit harvest mortalities to achieve these critical spawning numbers (these rates will vary with productivity, poor salmon survival will require reduced exploitation rates). If critical population sizes are not achieved within a generation, then immediate responses could be built into a harvest management planning in order to maintain spawning population sizes and the potential for recovery within an agreed time frame. Documentation of the technical bases for decisions should be peer reviewed, understandable, available to the public, and include adaptive response mechanisms if recovery does not proceed along an expected recovery trajectory. While the ISAB recognizes that elements of these points are contained in some biological opinions, the technical assessments and recovery targets are not readily apparent.

In May 2005, the National Marine Fisheries Service (NMFS) released the "Biological Opinion on Impacts of Treaty Indian and Non-Indian Fisheries in the Columbia River Basin in Years 2005-2007 "(F/NWR/2005/00388). This opinion complements assessments for ocean fisheries and addresses the proposed fisheries to be conducted pursuant to the 2005-2007 Interim Management Agreement for Upper Columbia River Chinook, Sockeye, Steelhead, Coho and White Sturgeon (*U.S. v. Oregon* Parties 2005). The parties to the 2005-2007 Interim Management Agreement are: the States of Oregon, Washington and Idaho, the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Yakama Indian Nation, the Shoshone-Bannock Tribes, the Bureau of Indian Affairs, the U.S. Fish and Wildlife Service and NMFS. In reviewing the biological status of these resources NMFS concluded that:

> *" … given all the factors for decline—even taking into account the corrective measures being implemented—it is still clear that the affected ESU's biological requirements are currently not being met under the environmental baseline. Some of the ESUs are responding favorably to improved natural conditions and actions taken to reduce human-induced mortality. However, the survival and recovery of the species depends on their ability to also persist through periods of low ocean survival. Thus circumstances are such that there must be a continued improvement in the environmental conditions (over those currently available under the environmental baseline). Any further degradation of the environmental conditions could have a large impact because these ESUs are already at risk. In addition, efforts to minimize impacts caused by dams, harvest, hatchery operations, and habitat degradation must continue." (p. 85, Section 2.2.7 Summary)*

Table 29 of this biological opinion specifies incidental take limits and expected incidental take (as proportion of total run size) of listed salmonids for non-Indian and treaty Indian fisheries under the 2005-2007 Interim Management Agreement. Table 30 presents a schedule of harvest rates that vary with abundance of certain upriver stocks. Fisheries will be limited by the incidental takes specified for an abundance level in order to achieve critical spawning abundance levels and maintain progress towards recovery targets. The Interim Management Agreement for 2005-2007 continues to rely on a management framework very similar to that proposed in the 2001 Agreement. Apart from the modification designed to accommodate a change in management period (for summer Chinook), the 2005-2007 Agreement proposes to extend the harvest rate schedule considered in 2001-2005 Interim Agreement. Based on these considerations, NMFS concluded that continued reliance on the harvest rate schedule in the 2001-2005 Interim Agreement and the impacts associated with the proposed 2005-2007 fisheries are not likely to appreciably reduce the likelihood of survival and recovery of Snake River fall Chinook. This assessment appears to continue the ISAB's concern commented on above and does not appear to be well supported by the analysis provided.

Performance Indicator 2: Are there clearly defined management objectives?

While the process components of Indicator 2 appear adequate and functional, the biological components for some production units do not, and need to be more explicitly stated to guide management. Inadequacy of the biological component may again reflect limitations to the historical data combined with the extent of depression in abundance for some production units. For example, significant progress has been made in identifying the independent production units, but conservation and recovery goals for them remain undefined. Further, criteria for defining a viable ESU are still under development (see ISAB 2005-3), and whether such recovery goals provide adequate production to meet socio-economic aspirations for harvest, and how quickly these goals can be met is unknown. The ISAB also notes that the functioning of the complex management process seems largely dependent on the cooperation of dedicated individuals rather than a formal structured and integrated management process.

As noted in Section 4a, the interpretation of clearly defined management objectives encompasses: definition of the production units[13] to be managed; biological conservation targets for each production unit; and objectives and priorities for fisheries including socio-economic aspects, and clearly defined risk tolerances. Considerable effort goes into defining management objectives both at the long-term policy level and for annual harvest planning.

Production units to be managed and their associated conservation targets are defined in fishery management plans of the PFMC and for the in-river management.

The Pacific Coast Salmon Plan (FMP) provides the framework for marine harvest management by the Pacific Fishery Management Council. Chapter 3 of the FMP identifies salmon management units and conservation goals for “stocks” that are significantly affected by the PFMC’s actions, specifies criteria and procedures to prevent over-fishing, and contains additional information regarding stocks listed under the ESA and by-catch. Chapter 5 of the FMP specifies management objectives and considerations for fisheries, including allocation among commercial and recreational fishing sectors and across geographic areas. This section contains nine "overall" fishery management objectives that can be paraphrased as:

1. set ocean exploitation rates consistent with ESA consultation or recovery standards, or rebuilding plans;
2. fulfill Indian treaty obligations and other federally recognized fishing rights;
3. maintain fishing seasons that support established commercial and recreational fisheries while meeting allocation objectives in a fair and equitable manner;
4. minimize incidental catch mortality;
5. manage for optimum yield that encompasses the quantity and value of food produced, recreational value, and the social and economic values;
6. manage fishing effort fairly and evaluate alternative effort management systems;
7. with effort management, support enhancement of salmon abundance to facilitate economically viable and socially acceptable seasons for all fisheries;

[13] Production unit in this discussion is a spatially defined group of salmon populations and hatcheries that are determined by the responsible agencies as a basis for conservation and management.

8. achieve long-term coordination with other salmon management entities and consistency with the Pacific Salmon Treaty;
9. promote safety at sea in the recommendation of fishing seasons.

Fishery management measures to constrain harvest within allowable limits are described in Chapter 6 of the FMP. The FMP does not explicitly state risk tolerances. Instead, the PFMC addresses uncertainty recognizing that the consideration of risk has many components, including risk to the salmon, risks to the commercial and recreational fishing sectors, risk to the capacity to meet legal obligations, and risk to safety of the fleet. These considerations are taken into account during the annual planning process that leads to the adoption of recommendations for fishing plans in light of the status of individual "stocks", which was discussed in Section 3 of this report. For instance, uncertainty can be reflected in risk-averse assumptions used in the planning process (e.g., conservative projections of abundance, area closures to reduce contact rates on sub-legal sized fish or around river mouths, gear restrictions, incidental fishing mortality rates, buffers for effort response projections, timing of openings to reflect market demands or weather conditions). For listed ESUs, biological risk is considered by NOAA Fisheries when establishing jeopardy standards, providing annual guidance letters to the PFMC, and issuing Biological Opinions on recommendations for annual fishing plans. Ocean fisheries are monitored in-season and management actions are taken to ensure compliance with requirements set forth in regulations.

Within the Columbia River, management plans are developed for the spring, summer, and fall seasons. These plans identify the salmon production units and their associated management objectives and constraints. Guidance is sometimes provided through multiple-year agreements between state, tribal, and federal co-managers, but plans are implemented annually to reflect expectations for terminal returns for specific populations. As with the FMP, risk tolerances are rarely specified in the Columbia River management plans. For listed ESUs and component populations, biological risk is considered explicitly in biological opinions. Uncertainty is taken into account in-season when regulations are established in response to data on production status and fisheries, so as to constrain fishery impacts within allowable levels.

Socio-economic objectives for fisheries are usually not specified in the Columbia River management plans. Instead, the Columbia River Compact, like the PFMC, takes those considerations into account during the deliberative processes that establish in-season fishery regulations. The plans and in-season management actions are informed by legal requirements pertaining to the regulation of Treaty Indian fisheries through what are commonly known as the Conservation Necessity Principles,[14] which limit the capacity to restrict the exercise of treaty fishing rights. These principles grew out of a process to redress a lengthy history of policies and regulations adopted by the States of Washington and Oregon, which had the effect of discriminating against treaty-protected fisheries. Under state regulation, non-Indian commercial and recreational fisheries had been allowed to take virtually all the harvestable fish, so the

[14] These principles have been embodied in a series of US Supreme Court cases dating back to the 1960's - they were repeated in the US v Washington ruling and incorporated into Secretarial Order 3206 (American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the Endangered Species Act) which was signed by the Secretaries of Commerce and Interior in June 1997. The Order sets forth policies and procedures to harmonize administrative responsibilities of NMFS and FWS under the ESA with tribal sovereignty and reserved rights.

remaining fish were needed to protect spawning escapements. Because Indian fisheries were the last in line, they were called upon to bear the brunt of the burden for perpetuating the resource.

To protect the rights that tribes reserved in their treaties, the United States filed suit against the State of Oregon (U.S. v. Oregon) and Washington (U.S. v. Washington). The states' arguments that Indian fishing had to be closed for *conservation* did not prevail. The courts understood that a dead fish is a dead fish regardless of who catches it and recognized that the states' regulatory practices had been based on non-Indian societal values and wise-use notions of conservation. The courts determined that only fish in excess of the spawning escapement needs for future propagation could be taken and required the states to regulate fisheries so as to ensure that tribes would have the opportunity to take a specified share of the resource at their usual and accustomed fishing grounds and stations (in their treaties with the United States, the Columbia River tribes reserved the right to take fish at their usual and accustomed grounds and stations). The courts also acknowledged that only the tribes had the right to determine the best and wisest use of their share. To protect against future discrimination against treaty Indian fisheries, the courts established a strict definition for the term *conservation*. That definition led to the Conservation Necessity Principles as a concise statement of legal standards to be satisfied before treaty-protected Indian fisheries can be restricted for conservation purposes, the restrictions:

- are reasonable and necessary for the conservation of the species at issue;
- are necessary because the conservation purpose cannot be achieved through reasonable regulation of non-treaty activities;
- are the least restrictive measures available to achieve the conservation purpose;
- as stated or as applied, do not discriminate against treaty activities; and
- are necessary because voluntary tribal conservation measures are not adequate to achieve the conservation purpose.

Policy commitments such as these provide guidance for ESA consultations on fisheries, particularly when the government seeks an appropriate balance between trust obligations and the imperative of meeting the conservation needs of the listed species. This policy commitment and guidance related to treaty rights was reiterated in other documents and correspondence, including the All-H paper (Federal Caucus 2000) and subsequent consultations on harvest (page 103, Biological Opinion on Impacts of Treaty Indian and Non-Indian Fisheries in the Columbia River Basin in Years 2005-2007, F/NWR/2005/00388, May 2005).

Performance Indicator 3: Is there adequate institutional capacity to constrain total fishing mortality?

Since a multitude of institutions have regulatory authority over Columbia River basin fish, there would seem to be ample opportunity to constrain total fishing mortality through both regulations and enforcement. This multitude, though, presents difficult challenges for coordination and the aggregate result has often been less satisfactory than needed. A portion of the limitation to constraining total fishing mortality is due to the inability to scientifically sort out population dynamics and total mortality for individual populations involved in multiple, mixed-stock fisheries. Therefore, while there is apparently adequate institutional processes developed, the ability to constrain total mortality on specific production units remains less than necessary, unless very broad-based harvest reductions are implemented in times and areas where the stock is expected to be present.

Cooperation and coordination across management jurisdictions to attempt to achieve management objectives for individual production units has developed because no single entity has the authority and responsibility for ensuring that management objectives are met for a given population. The need to coordinate harvest impacts on a given production unit involves many separate management jurisdictions and is accomplished through the joint efforts of scientists responsible for providing scientific advice to decision makers and through formal agreements among managers. Attainment of management objectives (spawner escapements or target exploitation rates) for individual production units, however, is problematic.

For an escapement objective for each salmon population to be achieved, not only must management define the desired number of spawners for each population, it must also regulate multiple fisheries to achieve them. This level of harvest management control in salmon fisheries is unrealistic because most fisheries simultaneously exploit a mixture of salmon populations, and the actual catch from each is usually unknown. Additionally, errors in pre-season forecasts, changes in return timing, variation in the response of fishermen to opportunities and weather all confound our ability to accomplish management objectives for individual production units. Further, in the context of managing fisheries, it is important to differentiate what is known about salmon and our capability to control harvest impacts on specific populations. The latter is referred to as management control error and is frequently not fully accounted for in planning.

The capacity to constrain harvest of Columbia River salmon is determined by the institutions involved in regulating fisheries throughout the migratory ranges of individual production units. The institutions involved with salmon include many private, local, regional, state, tribal, federal, foreign, and international entities. These entities operate within their own jurisdictions, but often have overlapping authorities and responsibilities for a range of functions, including harvest management, regulation, habitat protection, flow control, permitting, enforcement, and research.

Institutions for harvest management exist to execute a suite of legal mandates and constraints that apply to directed harvest, by-catch, protection, and recovery. Meeting these objectives entails the performance of several different management tasks: the implementation of management plans that contain multiple objectives for salmon conservation and fishery participation (as listed above under Performance Indicator 2); the assessment of population status to provide the basis for annual decision making; the design of regulations to control and distribute fishing mortality; the coordination of decisions under state, state-tribal, federal, and international authorities; the implementation and enforcement of regulations; the monitoring and evaluation of regulatory performance.

Ultimately, the effectiveness of harvest management institutions in constraining harvest depends on whether the jurisdictions affecting the harvest of Columbia River salmon have decision processes that are sufficiently coordinated to:

- collect consistent biological data;

- accomplish management objectives for individual production units;
- accept common management objectives and responsibilities;
- adequately account for uncertainty in information and management control;
- be transparent and accountable, including sound scientific information, stakeholder participation, and enforcement.

As described above, the biological data needed to provide a sound scientific foundation for harvest management include data on the fishery and escapement, estimation of exploitation rates on populations, and status relative to their production capacities. These data should allow identification and quantification of all sources of mortality affecting a given population through out its life cycle, provide biological goals for management, and provide clear signals of non-sustainability. Problems related to continuing uncertainties about population dynamics and to the limitations of fishery and biological data were discussed in this section above. The data question pertaining to the effectiveness of salmon harvest management institutions is whether the data collection processes of various jurisdictions are sufficiently coordinated to ensure that data are consistent and complete across jurisdictions and time. Data consistency is in fact a problem over multiple jurisdictions as well as over time, creating a need to develop standards and protocols for data collection. These are being developed and should gradually improve regional evaluations. The US Chinook Technical Committee of the PSC developed draft data collection standards several years ago, and the Coho Technical Committee has recently begun a similar initiative.

The management objectives and responsibilities of the many jurisdictions involved in Pacific salmon harvest management are defined by applicable law, including Indian treaties, international agreements, and federal and state laws, and interstate compact. Various fora exist (flow chart, Figure 6) to address the translation and coordination of legal guidance into common understandings of objectives and responsibilities for harvest management. The interaction of harvest management with recovery of listed salmon populations, however, introduces additional ambiguity about management objectives for lack of accepted and well defined quantitative jeopardy standards for survival and recovery. The institutional landscape of harvest management and recovery actions is sufficiently connected through the ESA consultation process, though, to implement survival and recovery objectives once defined. Ocean fishery harvest management is already connected to jeopardy standards through guidance letters from the Secretary of Commerce and records of harvest management decisions submitted to the Secretary of Commerce.

The harvest management decision process, as illustrated in the timeline for harvest management decisions for Columbia River salmon (Table 1), is transparent to the extent that it is a public process, subject to notice and comment, and open to public observation and participation. The process involves scientists in data collection, analysis, recommendation and evaluation to an extent unmatched in other marine fisheries. Stakeholders are formally involved as advisors. Scientific information forms the basis of both advice and decision-making. Limits on transparency are caused by the complexity of the analyses and decision process, the multiple stages of data analysis and interpretation, and number of groups involved, overwhelming reliance on "gray literature," unclear processes for documenting and justifying critical assumptions, and unclear processes for archiving and providing access to fundamental original data, and intermediate steps in complex analyses. This reflects the complexity of the legal, cultural, economic and biological context of the fisheries.

An important component of accountability is enforcement. The effectiveness of harvest management implementation depends in large part on the extent to which harvest regulations can be enforced. This makes enforceability of regulations an important consideration to their design, requiring that they be clear and unambiguous. Marine harvest management conducted under the auspices of the Pacific Fishery Management Council is advised on matters of enforcement by its Enforcement Consultants committee, comprising representatives of state and federal fishery enforcement authorities. Enforcement of in-river harvest regulations is overseen by tribal and state conservation enforcement authorities.

5. ISAB Recommendations

Although harvest management and salmon recovery can be assisted by the use of best available science, science alone is not likely sufficient. Freshwater habitats and salmon runs have been so altered in the Columbia River Basin that conservation and restoration of naturally produced Pacific salmonids will require strong social commitment, cooperation between agencies, and extensive and continuing financial investments. The ISAB is impressed with the management processes that have been developed and the continued efforts to expand the scientific bases for recovery. Ironically, the elements of science, commitment, cooperation, and investment are all evident and progressing in the Columbia River Basin. There remains, however, extensive concern for conservation of naturally produced salmonids and the effect of harvest on their conservation. Harvest is only one part of this complicated picture, but fishing is frequently targeted as a first management action because it removes mature salmon that could otherwise return to reproduce.

Among the many resource use conflicts within the Columbia River, salmon harvest is often thought by non-experts to be the predominant human impact on salmon. As a result, while there will be varying public support for allowing fisheries on listed ESUs and component populations, there will be less understanding about the impact of the hydro-system, habitat loss, and hatcheries on these same fish. The issues involved with harvest management are complicated, with many agencies and populations involved and numerous historical complications (past impacts of development, mitigation and legal background including the massive hatchery production, conflicting objectives and limited historical data, etc.). Significant progress, however, is being made in several areas important to harvest management (as noted earlier in section 4b) such as the definition of independent population units (NOAA TRT's and State agencies), definition of population and ESU viability, establishment of the Pacific Salmon Treaty and role of the PMFC in limiting ocean fishing impacts, and the renewed in-river fishing agreements. In spite of these actions, harvest is likely to remain a concern because:

- there has been limited evidence of progress toward recovery (until very recently);
- the basis for annual variability in salmon returns is not well understood or explained to the public;
- hydro and habitat issues are seen as very long term issues and not easily managed;

- hatcheries are commonly used and understood to support harvest, particularly with the recent development of mass marking and selective fisheries;
- ocean mixed-stock fisheries in Canada and the United States continue; and
- harvest management systems are poorly understood.

Many of these sources of concern could be addressed through an effective communication plan to improve public understanding of how allowable harvest levels are established and how effective modern management processes can be in achieving their management goals. In this understanding, it would also be important to identify the inter-connections of the 4-H's and how lack of attention to any one "H" limits progress in the others. An excellent current example is the development of mass-marking of hatchery fish and mark-selective fishing to increase the harvests of hatchery fish while maintaining fishery impacts on unmarked fish (usually naturally produced salmonids) within allowable rates. One goal of this plan is to assist recovery of listed species; but if habitat is not restored, then there may not be the productive capacity to sustain the natural returns. In addition, if juvenile hatchery fish compete with natural fish, adult recovery may not result due to continued limitations during juvenile rearing.

While the ISAB has been favorably impressed with the development of biological science and management processes, we note significant concern for three fundamental components of harvest management. These include:

1. a paucity of quantitative data for analyses by population units (core data);
2. very limited evidence of assessment analyses by production units to provide a biological basis for production goals and trends in status; and
3. limited evidence of accounting for uncertainty in management plans with the exception of reference to precaution in the National Standard Guidelines.

(While precaution is not explicitly referenced in the MSFCMA, it is implied through overfishing prohibitions in National Standard 1 (OY). Precaution is referenced, however, in the National Standard Guidelines issued by NMFS, in which it states that specification of OY should be done using a precautionary approach. That statement is the motivation for the technical guidance provided in Restrepo et al. (1998) and the more recent Report of the NMFS National Standard 1 Guidelines Working Group (2003).[15])

Recommendation 1. Core Monitoring Data: The ISAB has commented previously (ISAB 2003-3) on the essential need for a set of core quantitative data to be monitored annually in all production units or, at least, in representative units that may be used as "indicators" of productivity and trends in abundance over time. Given efforts to restore habitat productivity and annual variation in flow, variability in ocean productivity, inter-annual climate variation, and varying levels of exploitation over time … how would an agency account for a declining trend in spawning numbers without credible data sets that provide for analysis? Is a declining trend due to the environment or exploitation rates? Data sets for many production units in the Columbia River proved to be very difficult to locate and frequently involved major assumptions, such as fixed age-at-return or use of constants in the estimation of spawning numbers. With the obvious importance of defining recovery goals and then monitoring progress to recovery, establishing

[15] Report of the NMFS National Standard 1 Guidelines Working Group, Nov. 2003; available at: www.nmfs.noaa.gov/directives/

quantitative indicator systems within ESUs is essential for a credible harvest management system. A monitoring framework with sampling designs should be required for each ESU and production unit defined by the TRTs and by agencies managing stocks that are not listed. Programs to monitor specific populations have typically used coded-wire tags to identify exploitation patterns, and to estimate exploitation rates and survival after release. Tagging could, however, also involve PIT tags or active acoustic tags to allow fuller life-cycle monitoring.

<u>Recommendation 2. Documented Assessments</u>: While the ISAB reviewed many TRT reports, biological opinions, scientific papers, and management plans, there were very few quantitative and documented assessments of individual production units or ESUs, including both natural and hatchery production. Such assessment reports would typically identify the methodology, delineate the spatial limits of the production unit, provide the historical data used in the analyses, conduct quantitative analyses to estimate biological management targets (target number of spawner, sustainable exploitation rate, etc.), identify limitations to the data and analyses, and identify advice for management (e.g., current status or trend in abundance, forecast of expected returns, and recommend management actions). In both the recent reviews of subbasin plans and during this review, very few examples of thoughtful population assessments were evident. Consequently, the ISAB has to question the basis of biological advice on Pacific salmon that subsequently becomes the basis for harvest management planning. Furthermore, the ISAB strongly cautions against the collection of data without parallel careful design, use, and evaluation. Collection of the data is, of course, the first priority, but only by using data and assessing the dynamics of a production unit can errors be detected and corrections made. Detailed assessments must be documented and peer reviewed to provide quality control to the scientific basis of management planning.

<u>Recommendation 3. Accounting for Uncertainty</u>: While many documents refer to uncertainty, there were very few examples of actually estimating uncertainty or accounting for it in a management plan. With limited historical data and changing habitats through time, analysts likely know much less about the production dynamics of Pacific salmonids than is assumed. The effect of environmental variability between years is inherently large, environmental conditions are not stable over time, biological communities and ecosystems are complex, and the parameters estimated from spawner/recruitment analyses should be expected to apply at best as a long run average, and at worst to be significantly biased because they represent a sample representing too small a time period from a process with long-term variation. None of the data collected in the natural environment is collected without error, and errors in achieving an in-season management target are seldom accounted for. Overall, uncertainty is very likely to be much greater than appreciated or accounted for, and predictability less.

It should be understood that there is a relationship between data quality, uncertainty, and managing to a target value. To apply uncertainty in a harvest management context, the analyst needs an estimate of the uncertainty, a management target value, and a specified level of risk tolerance. If data quality is poor, uncertainty is expected to be large, and the management adjustment to ensure a high probability of achieving the target would also be large (i.e., the impact of poor data would be borne via reduced fishing opportunity). With poor data quality and no management adjustment, the salmon stock would be at increased risk due to the uncertainty of staying within the management target. Historically, this latter scenario likely accounted for frequent over-fishing of the salmon resources.

The ISAB recommends that guidelines for the estimation and accounting of uncertainty in management targets and in-season management control be developed and applied in the management of listed ESUs. All sources of fishing mortality must be accounted for and a level of risk tolerance established through public consultation. While the ISAB was impressed with the intensive process used for salmon management, we also recommend analysts review whether current levels of harvest impact are consistent with the quality of data and level of uncertainty in processes, and provide the expected likelihood of recovery for these listed species.

<u>Recommendation 4. Adaptive Management in Salmon Recovery</u>: Given the limitations in historical data, the inherently large uncertainty in salmonid ecosystems, and the complexity of management processes involved in harvest management of Columbia River salmonids, the ISAB recommends application of adaptive management principles in salmon recovery. Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. It is most effective if active management is employed. Programs are designed to experimentally compare selected policies or practices by evaluating alternative hypotheses about the system being managed, and monitoring systems are established to continually assess these alternatives (see Walters 1986, Lee 1999). Adaptive management is not just adjusting to the outcomes of trial and error (see Lee 1999) but involves a more rigorous set of strategies and a comprehensive planned set of adjustments conditional on various outcomes. In complex biological and social systems such as the Columbia Basin, the challenge is frequently one of maintaining the agreed design (i.e., a response) when impacts on the social and cultural systems increase. Given the limited progress in developing agreed recovery plans, the ISAB believes that a systematic approach to testing alternative actions with an emphasis on achieving secure spawning escapement levels should again be seriously considered.

A similar approach has previously been envisioned, but not implemented, with the development of the PATH process in the mid-1990s, but little application resulted from that effort (see Marmorek and Peters, 2001; and papers in the Canadian Journal of Fisheries and Aquatic Sciences Vol. 58, issue 12). There are, however, potential problems with implementing an adaptive management program in a complex ecological and cultural system such as the Columbia Basin that may explain this inaction. Examples of potential problems include:

1. the inherent variability in natural ecosystems and the difficulty of planned manipulation of large systems;
2. this variability also results in “noisy” character of data collected and leads to the need for large perturbations to detect response and isolate causal factors - social values and perceptions of risk may work against the ability to generate strong signals through adaptive management actions; and
3. costs of monitoring and evaluation are often difficult to support over the longer term.

Despite these potential problems, given the extensive financial investments in the basin already and the potential future costs of not achieving recovery, adaptive management should be re-considered. The basic process to implement an adaptive management approach would be to establish initial recovery targets through a set of agreed management actions, with a specified risk tolerance, and for a specified number of years. If progress to that goal is not achieved in a limited number of years, then an alternative set of actions, identified in advance, would be implemented with a more stringent requirement to achieve recovery and lower level of risk. As the system responds to actions taken, insight is gained which can be used to reduce uncertainty between alternative future actions and to direct monitoring programs to priority information needs. An important but indirect value in this process is a positive feedback for maintaining a strong monitoring and assessment program. Furthermore, the management actions should be sensitive to variation in marine productivity. Spawning abundances should be protected so that there remains a high likelihood of not "going backwards" on recovery except when rare configurations of marine conditions overwhelm the biological response.

Recommendation 4 may also be an appropriate action for addressing how the Columbia River Basin should assess and adapt to the risks of climate change on Columbia River salmonids. The ISAB considered a recommendation concerning preparation for climate change but decided that such considerations would require more time and were likely beyond the current task of reviewing harvest management. At this juncture, it seems sufficient to note evidence that oceanic cycles affect salmonid productivity and harvest opportunity at yearly and decadal scales, and that global climate appears to be on a warming trend that may affect long-term sustainability of both production and harvest. The ISAB sponsors may wish to consider a broader assignment concerning climate change impacts and longer-term forecasts of its impacts.

As will be discussed in Section 7d of this report, the ISAB anticipates major increases in understanding of climate change and climate cycles in relation to salmon and other natural resources in the next few years, as well as significant increases in the uncertainty of production forecasts in the short to medium term. Harvest managers and the harvest industry need to be informed of this increased understanding and to be prepared to change their procedures accordingly for conducting near-term and long-term assessments, setting annual quotas, and harvesting fish.

6. Questions Posed to the ISAB

The following four questions were developed by the ISAB from the many questions posed to it by NOAA, NWPCC, and CRITFC. The sources of original questions contained in each of these four are noted in parentheses.

1. **Contrast current and past harvest practices (NOAA Fisheries question), addressing whether harvest rates and total fishing mortality on Columbia River stocks have increased, decreased, or remained constant (CRITFC question)?**

Fishery impacts on Columbia River salmon have been reduced since the mid-1980s due to harvest management measures taken to respond to a variety of factors. Three examples are presented in Appendix C to illustrate reductions in fishery impacts on Columbia River salmon and discuss underlying reasons: (1) Up-River Bright fall Chinook (URB); (2) coho; and (3) B-run steelhead.

- The URB example discusses the need for coordinated, collaborative management to meet stock-specific management objectives, provides information on how harvest management strategies affect fishery impact rates, and illustrates the importance of having information on productivities and differences in exploitation patterns of component populations. Based on analysis of coded wire tag (CWT) data by the Pacific Salmon Commission's (PSC) Chinook Technical Committee, adult equivalent brood year exploitation rates on URBs have decreased from about 80% in the mid 1980s to 45%. Less data is available to evaluate changes in fishery impacts on the Snake River fall component of URBs, but indicate that adult equivalent brood year exploitation rates have fallen from around 70% to 20%. In-river, harvest rates of URBs and Snake River fall Chinook exhibit different patterns. The URB harvest rate has declined from approximately 60% in the mid 1980s to less than 30%; spawning escapement goals have consistently been achieved and have been substantially exceeded in recent years. In comparison in-river harvest rates on Snake River fall Chinook have decreased from about 60% in the mid-1980s to about 20%. Dam passage mortalities of URBs and Snake River fall Chinook are significant (e.g., accounting for a mortality rate occasionally exceeding 30% on URBs since 1986).

- The coho example discusses the importance of interpreting changes in fishery impact rates within the context of fishing patterns and management responses to adjust to changes in legal requirements. Columbia River coho are predominantly produced by hatcheries constructed to mitigate for damage associated with dam construction. Exploitation rates on Columbia River coho are not based on analysis of CWT data, but rather on an index derived from catches and escapements. This index indicates that total exploitation rates have fallen from over 80% in the mid-1980s to about 50%. The decrease in exploitation rates is even more dramatic for ocean fisheries, which have declined from about 80% to less than 20%. These decreases have been triggered by conservation concerns for commingled naturally spawning stocks from the Oregon coast and remnant populations in the lower Columbia River. Because of mark-selective fisheries in recent years, reductions in exploitation rates on naturally spawning coho from the Columbia River are greater than indicated for hatchery fish.

- The B-Run steelhead example provides a contrast to the URB and coho examples both in terms of fishing patterns and the quality of information available for harvest management. Separation of B-Run fish from commingled hatchery and wild fish is based on assumptions regarding the timing of passage at Bonneville Dam and fish size; this example illustrates some difficulties, ambiguities, and inconsistencies that can result from management by assumption. This stock is not significantly impacted by ocean fisheries. Available data indicate that in-river harvest rates have declined from over 30% in the mid 1980s to less than 10% since the mid 1990s.

2. Does current harvest management adequately manage and protect ESA listed naturally spawning populations (NWPCC question)?

This question cannot be definitively answered until recovery objectives are established for ESA-listed populations and determinations are made as to what component populations within ESUs must be protected to maintain ESU viability, and quantitative risk tolerances are adopted. Until then, ambiguities will continue to surround interpretation of the phrases "adequately manage and protect" and "ESA-listed naturally spawning populations." Under the current system of ESA administration, NMFS and FWS have the responsibility to determine whether or not management measures are "adequate" to protect ESUs. In the absence of approved recovery plans and a quantitative risk standard, plus a comprehensive methodology for assessing risk and factoring the various uncertainties into that assessment, agencies have considerable latitude in implicitly defining "adequacy" in their jeopardy findings and the annual guidance they provide for harvest management. That discretion, however, carries the obligation to disclose and fully document the data and methods employed in their analyses in Biological Opinions. This discretion also creates more scope for litigation. NOAA Fisheries issued a report in November 2004 describing its approach to establish jeopardy standards for ESA-listed salmon.[16] Section 4b of this report provides comments and perspectives on the adequacy of the scientific analyses underlying jeopardy standards for harvest management.

In addition to ESA jeopardy standards, harvest management is also guided by statute (such as the National Standards contained in the Magnuson-Stevens Fishery Conservation and Management Act), legal standards (e.g., Indian treaty fishing rights providing for conservation of individual stocks and allocation of harvestable surpluses), and administrative processes such as those employed by the PFMC. The PFMC provides an annual preseason assessment of projected fishery impacts in Appendix A of its Preseason Report III for ocean salmon fisheries as part of the administrative record. Finally, challenges to the adequacy of plans in protecting ESA-listed populations can be filed in judicial proceedings.

When evaluating the adequacy of harvest management actions in protecting ESA listed populations, it is important to understand that harvest is related to productivity through complex interactions of escapement with spawning success, competition, and predation, and that harvest is only one source of mortality. It is one of the "4Hs" commonly used to describe the primary influences that affect recovery. Actions taken to increase freshwater productivity (increase freshwater productivity via enrichment, or decrease competition between hatchery and wild fish, etc.), and actions taken to reduce mortalities related to the other H's, affect the determination of what is an appropriate harvest level (i.e., sustainable or appropriate for restoring abundance). Consideration of the 4Hs reflects social policy determinations that involve notions of fairness, legal obligations, and choices that pit long-term conservation of stocks and habitat against short-term harvest, power generation, agriculture, and other economic use of natural resources.

A comprehensive and consistent decision framework that integrates all sources of mortality and sources of improved productivity and their associated uncertainties would be extremely useful when addressing the role of harvest management in conserving ESUs. Significant technical and institutional challenges would have to be addressed to establish such a framework. For example, technical challenges to be addressed would include: uncertainty in implementation of harvest management; scientific uncertainties in quantifying relationships between habitat conditions and productivity, and interactions between hatchery and wild fish; and the role of dam passage on survival and productivity. Institutionally, the diffusion of responsibilities for listing, science, sustainable fisheries, recovery planning within agencies, and eventually enforcement of recovery

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[16] Dygert, P. and S. Bishop. 2004. Report Prepared by Northwest Region, Sustainable Fisheries Division, NOAA Fisheries. November 16, 2004.

actions, coupled with exploitation by fisheries regulated by multiple jurisdictions, poses formidable difficulties for consistency and coordination.

The current focus on "adequacy" should be squarely placed on whether management measures are sufficient: to make predictable progress towards population recovery on the basis of those factors that are reasonably well-characterized; to maintain options and avoid irreversible damage to the capacity of ESA-listed populations to recover over time; and, to monitor the status of listed populations and identify key uncertainties. Because of the potential for rapid adjustment of harvest, and given the existence of systems that collect and analyze data in a timely manner to monitor impacts, harvest management measures can be adjusted both annually and in-season. The ability for managers to directly intervene, however, carries the liability that harvest management may be called upon to bear a greater share of the conservation burden in a crisis situation, particularly for protecting populations in listed ESUs. It is essential to note, though, that if the predominant limiting factor to recovery is not harvest, then those other factors must be addressed, or the value of reduced harvest will be temporary and not sufficient for recovery.

3. **What are the consequences of mark-selective fisheries on the accuracy and precision of forecasting and on consideration of harvest regime options (NOAA Fisheries, NWPCC, and CRITFC question)? Are there practical measures that could be implemented in the short- or long-term to address the challenges posed by mark-selective fisheries (NOAA Fisheries, NWPCC, and CRITFC question)?**

Generally, mark-selective fisheries can be expected to increase uncertainty in harvest management of natural (unmarked) salmons, in terms of both precision and bias. The consequences of mark-selective fisheries are situational. Depending on the location and intensity of harvest, mark-selective fisheries might or might not have a significant effect on a variety of harvest management tools, such as in-season run size estimation and forecasting. The reports of the Pacific Salmon Commissions Selective Fishery Evaluation Committee identify and discuss potential effects of mark-selective fisheries on harvest and management tools (ASFEC 1995). Additionally, a report in preparation by the Expert Coded Wire Tag Panel convened by the Pacific Salmon Commission in June 2004 is expected to address this issue in depth.

Potential practical measures that could be employed to compensate for increased uncertainty caused by mark-selective fisheries center on two areas: (1) increasing investment in sampling and monitoring programs to improve the capacity to gather the data necessary to assess the effectiveness of mark-selective fishing in accomplishing resource management objectives; and (2) revising management targets or constraints to adjust for increased uncertainty, e.g., jeopardy assessments could be conditional, depending upon whether or not mark selective fisheries are relied upon to constrain harvests of unmarked fish. Currently, the magnitude of mark-selective fisheries is determined by the impact limits allowable on natural stocks under non-selective fishing; those limits are not reduced to compensate for increased risk due to uncertainty.

Two other important factors should be recognized when dealing with mark-selective fisheries. First, the capacity to conduct mark-selective fisheries depends upon continued investment in hatchery production and mass-marking. There are significant ecological risks[17] associated with developing fishing strategies that depend on sustained hatchery production, and these should not be cavalierly dismissed (e.g., density-dependent competition and/or predator dynamics involving interactions of hatchery and naturally produced juveniles). Second, the costs of mass marking, double index tagging, and sampling/reporting programs for catch and escapement will likely strain agency budgets and result in reduction of services or other programs, such as data collection, research, or enforcement. If investments are not made to improve sampling and reporting programs, increased management uncertainties will result from reduced quality of data.

Although the potential benefits of mark-selective fishing are intuitively appealing, the effectiveness of this tool in addressing conservation needs for depressed natural populations needs to be evaluated. There are critical uncertainties that would benefit from additional research, particularly in the following areas:

- the ability of double index tagging to provide reliable estimates of mortalities of unmarked fish in practice;
- the variability and magnitude of release mortality rates in relation to the gear employed and fleet behavior;
- quantification of drop-off mortality losses (i.e., hooked but not handled); and
- biases that could be introduced by multiple encounters (fish being hooked again after release).

4. Are analytical tools sufficient to adequately track future harvest rates (NWPCC and CRITFC)? If not, what tools or performance standards will be most effective for managing fisheries (CRITFC, NWPCC)? Are there opportunities to use PIT tags to improve management capabilities and reduce uncertainty (NOAA)?

Harvest management of Columbia River salmon involves a number of data collection systems that monitor impacts and analytical tools to evaluate results. For example, spawning escapements and dam counts provide data on escapements past fisheries; differences in run-timing (e.g., spring vs. summer vs. fall Chinook), skin coloration (e.g., URBs vs. tules), and size (e.g., distinguishing between A & B Run steelhead) are used to differentiate populations; run reconstruction and CWT analysis are employed to provide insight into patterns of fishery exploitation, abundance forecasting employ statistical regressions based on sibling relationships; modeling is employed to facilitate planning of fisheries to constrain impacts; Passive Integrated Transponder (PIT) tags provide information on migration rates and dam passage mortalities; etc. Certainly, there are several areas where the scientific basis for some of the tools and methods is unclear/suspect and there is undoubtedly much room for improvement (some of these questions are noted in the last column of Appendix B of this report and in the discussion of the management of B run steelhead in Appendix C). The determination of "adequacy" of these tools is situational and beyond the capabilities of ISAB to evaluate in this report. An independent analysis would be helpful to provide an in-depth evaluation of current tools and methods and to develop recommendations for improvement. At a minimum, it would be beneficial for the users of these tools to themselves undertake a systematic effort to fully document and explain these methods, and to make this documentation readily accessible.

[17] For example, predator attraction, proliferation of disease, limits to carrying capacity, detrimental effects of inbreeding of hatchery brood stocks, and interbreeding between hatchery and wild populations.

To-date, much of the information employed for the management of Columbia River salmon was derived from analysis of CWT data. Analysis of CWT recovery data must frequently involve statistical inference because this technology is based on group marking and single recoveries (sacrificial sampling is required to recover data) of individual members of a group. These characteristics require assumptions and interpretation to address questions of interest to managers and researchers. For example, migration routes and patterns are inferred by the timing, location, and frequency of recoveries.

CWT technology is over thirty years old. Newer technologies are now available and capable of providing data and information that is unattainable from CWTs. One of these technologies is the PIT tag, a tiny identification chip (about the size of a grain of rice - 11 mm by 2mm) that can be injected into fish for permanent, unique identification. PIT tags can be read without killing the host. This provides opportunities for research projects to generate data that enable fishery managers to gain insight into questions that have long evaded researchers. Since each fish carries a unique code that can be read electronically in proximity to an antenna, PIT tags can potentially provide data for estimation of natural and release mortality rates, migration patterns and rates, and growth rates. Additionally, since PIT tag data can be recovered without mutilating the fish, market values of the fish can be preserved, and barriers to processor and fisherman cooperation can be eliminated. While PIT tag data is now becoming more readily available for harvest management, designs for PIT tag deployment and sampling for recoveries to address various questions are still under development. Because mortality rates are high, and tag recovery rates are low, effective designs generally require large numbers of tags and a concerted tag recovery effort. For this reason, effective programs require broad consensus about design.

Numerous research studies involving PIT tag technology are being undertaken. PIT tag readers are being deployed at passage facilities at several dams in the Columbia River system. In the field, PIT tag readers are being installed at hatcheries to recover data on returning adults and in small streams to evaluate their potential utility in monitoring movement of juveniles and adults. So far, the principal use of PIT tags in the Columbia has been to monitor the magnitude and sources of juvenile mortality and the migration patterns of juvenile fish.[18] Fish from some PIT tag experiments are now beginning to return as adults.[19] The Pacific States Marine Fisheries Commission maintains a PIT Tag Operations Center and hosts a PIT tag Information System database (PTAGIS, http://www.psmfc.org/pittag/). Considerable investments are being made to

[18] NOAA has provided internet access to an example of PIT tag application on Snake River fish http://www.nwr.noaa.gov/1salmon/salmesa/pubs/pittag.html. "The PIT-tag data from 1994 through 1995 show that juvenile spring/summer chinook survival through each project (dam and reservoir) is about 90 percent. At that rate, survival through the entire system of eight dams and reservoirs is roughly 50 percent. The picture is different for Snake River fall chinook. They suffer a per-project mortality of about 80 percent, which translates into a system survival of 17 percent as they complete their downstream journey." A sidebar on the same webpage describes results of studies regarding the effects of flows on survival of Chinook – "For spring/summer chinook, studies since 1994 show that juveniles migrating in years with higher flows survive at a higher rate than juveniles migrating in years with lower flows. There appears to be little relationship, however, between flows and survival within a given year. The picture is different for fall chinook, which migrate during the summer when flows are low and water temperatures high. Here there is a much stronger correlation between increased flows and increased survival both within and between years."

[19] The Fish Passage Center provides internet access to adult return PIT tag data at http://www.fpc.org/adultsalmon/adultPITtag.html.

employ this technology extensively in the Columbia River system. There is no guarantee that the spatial distribution of PIT tagged hatchery and wild anadromous fish for experiments will meet management needs in the future. The region should begin planning of long term monitoring of life history parameters, including harvest mortality, of hatchery and wild fish by use of PIT tags. The potential application of PIT tags in harvest management is being considered by the CWT Expert Panel of the Pacific Salmon Commission, which will be reporting in the summer 2005.

7. Background Sections

7a. Sustaining Diversity

Pacific salmonids do not exist as a single homogeneous population, but rather as mosaics of discrete spawning aggregations (Ryman and Utter 1987, Fraser and Bernatchez 2001). This mosaic of sub-groups (sub-populations) is often referred to as a metapopulation. The subpopulations within a salmon metapopulation are believed to be differentiated from one another to varying degrees through adaptation to their local environments, yet linked through occasional gene flow (Hallerman 2003). This genetic and life history diversity within and among subpopulations is the currency that allows the species to adapt to the changing environmental conditions of the future (Noss 1990). A key feature of the metapopulation concept is that if one of the local populations becomes extirpated, it could be recolonized naturally from one of the other subpopulations in the mosaic. Furthermore, within a metapopulation, it is likely that some subpopulations could serve as key or core source populations for such recolonization. The core source subpopulations could change over time in response to habitat alterations, overfishing, climate change, etc. Our current understanding of metapopulations represents a refinement of the concept of fish stocks (Berg 1981) that has been used in shaping harvest management decisions over the past half-century.

Historically, harvest management focused both on the biomass production from, and the protection of, major populations (stocks) of single species (Cushing 1968, Hyatt and Riddell 2000). Referred to by fishery biologists as the Stock concept, this subdivision of species into populations for management was a major advance in Pacific salmon harvest decision-making (Morishima and Henry 2000). Unfortunately, this approach assessed exploited populations in isolation from their genetic processes and demographic history (Riddell 1993, Hyatt and Riddell 2000). Often, populations that were either low in numbers and/or low in productivity commingled with larger or more productive stocks. As the biology of Pacific salmon has become better understood, management strategies now put more emphasis on protecting the diversity of these populations and not just the total production of salmon. One challenge for setting harvest policy today is devising regulations that permit harvest but at the same time protect dwindling and, in some cases, federally protected fishes.

In the Columbia River, salmon harvest in a number of fisheries is limited by regulations designed to protect weaker stocks. Fall fisheries for both Chinook and coho salmon can be constrained by regulatory protections for ESA listed Snake River fall-run Chinook. Overall, a 32% impact is permitted on fall Chinook, which includes the productive “upriver bright” salmon from the Hanford reach along with the ESA listed Snake River population. In the fall of 2004, two lower Columbia River mainstem gillnet fisheries were cancelled when the total September allocation of fall Chinook was nearly reached. Fishermen had to forego catching hatchery and unlisted mid-Columbia fall Chinook to preserve the opportunity to fish for coho salmon in October – because that fishery incidentally takes the remainder of the fall Chinook allocation (CBB 2004).

The importance of maintaining diversity between spawning populations is not just an issue of conserving genetic diversity. Diversity is related to sustaining production and the full utilization of freshwater habitats. Stocks that are weak (i.e., lower productivity) at one point in time may become productive during other times and visa versa, and evidence has accumulated that protecting currently weak stocks is a prudent management approach to protect future production. A good example is the Bristol Bay, Alaska stock of sockeye salmon, for which record catches have been sustained over the past 20 years (Hilborn et al. 2003). This fished stock, however, is believed actually to be composed of hundreds of discrete populations, each of which may be spawning and rearing in a specific, different habitat. Hilborn et al. (2003) argue that this aggregate of Bristol Bay sockeye has maintained a productive fishery over a period of appreciable change in environmental conditions due to this diversity of populations and that some were likely minor producers during one period but dominated during others. Maintaining the diversity of sockeye populations through time has allowed different populations to sustain the fishery at different times and conditions.

The biodiversity inherent in the salmon populations of the Columbia River Basin (CRB) is under active and continuing study (Brannon et al. 2002, Myers et al. 2003). Currently, salmonids within the CRB are categorized as belonging to one of several Evolutionarily Significant Units (ESUs), i.e., a population or assemblage of populations that are substantially *reproductively isolated* from other con-specific populations and that represent an important component of the *evolutionary legacy* of the species (Waples 1991, 1995). There is also an increasing understanding that these ESUs are further subdivided into numerous demographically independent populations. For example, the Willamette/Lower Columbia Technical Recovery Team (WLC-TRT) concluded that historically there were likely at least 30 demographically independent Chinook salmon populations in the Lower Columbia River ESU (21 fall/late fall run and nine spring run) and seven in the Upper Willamette ESU. For steelhead, the WLC-TRT concluded that there were likely 24 populations in the Lower Columbia River ESU (18 winter run and six summer run) and five populations in the Upper Willamette ESU (Myers et al. 2003).

To take the genetic subdivision of CRB salmonids (whether defined as stocks, ESUs, or metapopulations) into account in their harvest management, one must determine how the harvest of that species within a mixed stock fishery impacts not only the viability of the species as a whole, but also the viability of each of the component subpopulations individually. For example, if related groups of returning adults migrate together and not randomly, harvest may not be uniform across all subdivisions. As a result, one or two of those groups (i.e., the individual subpopulations within a metapopulation) might be overfished relative to desired harvest targets, perhaps to an extent that successful reproduction of that subpopulation would be jeopardized for that year. Unfortunately, salmon harvest today consists of such mixed-stock fisheries. Furthermore, at this time we do not fully know the delineation of the various component populations that make up the greater metapopulations within each ESU, much less how these populations are connected via gene flow. We also do not know which populations can or cannot serve as key source populations for recolonization. These information gaps will continue to be a major obstacle to establishing effective conservation programs for our dwindling salmonid populations. The use of newly developed technology may, however, allow us to fill at least some of those gaps.

Given the emerging understanding of the spatial organization of Pacific salmonids and the importance of diversity in production and adaptability, harvest policy needs to go beyond setting "stock"-wide escapement goals and also incorporate a goal to conserve the biodiversity inherent in each CRB salmonid species, i.e., *setting harvest goals for each of the individual subunits within the legally defined ESU*.

The ISAB notes that the metapopulation concept summarized above addresses only a single species. Each species, though, is but one component of the larger ecological community involving many species. In the future, a major challenge for harvest management will be to incorporate our growing understanding of multi-species interactions and ecosystem linkages into harvest and conservation actions (Hyatt and Riddell 2000).

7b. Freshwater Ecosystems

There has been increased interest in the importance of marine-derived nutrients from salmon eggs and carcasses in supporting the food web productivity of freshwater habitats where salmon spawn (Stockner 2003), and recent evidence suggests that establishing escapement goals should include a consideration of the need for salmon carcasses to maintain the productivity of freshwater environments. Chinook, chum, coho, pink and sockeye salmon die after spawning, and a high proportion of steelhead also expire. The carcasses and reproductive products left by these fish can represent a substantial source of nutrients and organic matter for Pacific Northwest watersheds (Larkin and Slaney 1997, Naiman et al. 2002). This material is readily incorporated into the stream or lake food web (Kline et al. 1990, 1993, Bilby et al. 1996, Johnston et al. 1997), provides a food source for wildlife (Cederholm et al. 1989), and may also provide nutrients for plants in the riparian area (Helfield and Naiman 2001, Bilby et al. 2003). The significance of this relationship to the establishment of appropriate escapement goals and the consequences for harvest levels have increasingly become topics of discussion in the region.

Much about the process of nutrient transfer from carcasses to aquatic and riparian plants and animals is still poorly understood. However, the potential significance has long been recognized by both the scientific community (Juday et al. 1932) and in more popular literature.

> *"The death of a salmon is a strange and wonderful thing, a great gesture of abundance. Yet the dying salmon are not wasted. A whole natural economy is built on their bodies. Bald eagles wait in the trees, bears hunt in the shallows and along the banks, mink and marten and coons come nightly to the feast. All through the winter mallards and mergansers feed in the eddies, and in freshet time, the herring gulls come in to plunge down on the swifter water and pick up the rotting drift. Caddis larvae and other carnivorous insects crawl over the carcasses that are caught in the bottoms of the pools or against the rocks in the eddies. The stream builds its fertility on this death and readies itself to support a new generation of salmon." (Haig-Brown 1946).*

Scientists have also long recognized the importance of nutrients from salmon carcasses to freshwater production in lakes used by sockeye salmon, and subsequent research has supported these earlier findings. Sockeye salmon returning to Lake Illiamna in southwestern Alaska deposit 7×10^7 kg of nitrogen (N) and 3.3×10^6 kg of phosphorus (P) annually (Naiman et al. 2002). In contrast, the N and P exported from the lake by smolts represent only about 8% of that contributed by the adult salmon. Spawning salmon appear to be a net importer of nutrients to nearly all sockeye rearing lakes.

Many sockeye rearing lakes are nutrient limited (Hyatt and Stockner 1985, Gross et al. 1998). Thus, the nutrient subsidy provided by spawning salmon can stimulate primary (vascular plants and algae) and secondary (animal) production. This nutrient subsidy can be substantial. Juday et al. (1932) estimated that sockeye salmon transported in excess of 2 million kg of organic matter and 5,000 kg of phosphorus (P) to the Karluk River system in Alaska in an average year. Reduction of the sockeye salmon returning to Karluk Lake, Alaska, led to substantial reductions in P availability and reduced primary and secondary production (Schmidt et al. 1998). Reduced productivity causes a depensatory effect on salmon populations: *fewer spawning adults result in lower primary and secondary production, which reduces the growth and survival of juvenile salmon, which can lead to fewer returning adults, causing a downward productivity spiral.*

Scientific interest in the role salmon play in the nutrient dynamics of freshwater ecosystems has been spurred by the application of stable isotope analysis. Salmon returning to spawn contain higher proportions of the heavier isotopic form of nitrogen (N_{15}) and carbon (C_{13}) than is found in N and C in freshwater ecosystems from other sources. As a result, the ratios of stable isotopes to normal atomic weight elements can be used to track the movement of marine-derived N and C through the food web of lakes or streams. Isotopic ratios also provide an indication of the proportion of the nutrients of aquatic ecosystems provided by spawning salmon.

The application of stable isotope technology has enabled the reconstruction of long-term sockeye salmon abundance for some lakes in Alaska (Finney 1998). Some of the isotopically enriched nitrogen deposited by spawning sockeye becomes incorporated into the lake sediments. The variation in the isotopic ratios of sediment strata in the lakebed surface has been used to estimate historic abundance of salmon. The fossilized remains of plankton also are deposited, enabling the association of historic escapement levels with the attributes of the lakes planktonic community. These analyses have demonstrated that the advent of commercial fishing in Alaska in the early 20th century corresponded with a marked reduction in the deposition of marine-derived nutrients in some Alaskan lakes (Finney et al. 2000). There was also an increase in the abundance of benthic diatoms, suggesting a decrease in the production of algae suspended in the water column (phytoplankton). Reduced phytoplankton production may have been caused by higher consumption by zooplankton populations, which increased due to reduced predation by the sockeye. Reduced phytoplankton density would increase water clarity, thereby increasing light for the benthic diatoms.

In addition to fishing, other factors can limit the number of salmon returning to spawn, and where the cumulative effects of harvest and these other factors reduces escapement to very low levels there are important implications for nutrient dynamics and salmon productivity in freshwater ecosystems. Scheuerell et al. (2005) used a mass balance approach for phosphorus to estimate that the historical recruitment of P by adult Chinook salmon to the Snake River basin was about 70 times the current level, and furthermore that in several recent years the export of P from the basin by smolts actually *exceeded* the amount brought in by spawners. These authors stated that the loss of marine-derived nutrient subsidies from adult salmon has resulted in a marked shift in freshwater productivity, exacerbating strong density-dependent survival rates of juveniles.

Relatively little quantitative information on the nutrient contribution by salmon to stream ecosystems existed until fairly recently. Application of stable isotope analysis has demonstrated that the nutrient subsidy provided by spawning salmon can account for a substantial proportion of the nutrients in the biota of stream systems, including juvenile salmonids. Nitrogen and carbon contained in resident rainbow trout in a southeast Alaska stream were derived almost entirely from the large numbers of pink salmon that spawned at the site (Kline et al. 1990). Juvenile coho salmon, cutthroat trout, and steelhead in a tributary of the Snoqualmie River, Washington, obtained as much as 40% of the carbon and nitrogen in their muscle tissue from the carcasses of coho salmon (Bilby et al. 1996). Johnston et al. (1997) found a relationship between the proportion of marine-derived nitrogen in aquatic insects and the density of spawning sockeye salmon in tributaries of the Stuart River in interior British Columbia. A similar relationship has been reported for juvenile coho salmon in western Washington (Bilby et al. 2001).

The nutrient subsidy provided by spawning salmon can have an impact on stream productivity. Elevated primary production has been attributed to nutrients from salmon carcasses in a number of oligotrophic systems. Kokanee salmon (landlocked *O. nerka*) carcasses stimulated algal production in a small tributary of Lake Tahoe, California-Nevada (Richey et al. 1975), and the addition of 25 Chinook salmon carcasses to a tributary of Lake Superior, Minnesota, resulted in increased algal growth on the streambed (Schuldt and Hershey 1995). The increase in primary production and the availability of carcasses and eggs as a food resource can stimulate invertebrate production (Piorkowski 1995, Minikawa 1997, Wipfli et al. 1998).

Juvenile salmonids readily ingest eggs deposited by spawning salmon and flesh from decomposing carcasses. During the period of sockeye salmon spawning in small streams of the Wood River drainage in Alaska over 90% of the stomach contents of char (*Salvelinus* sp.) and rainbow trout consisted of salmon eggs and flesh (Eastman 1997). Char and trout grew rapidly while carcasses were present, with one individual increasing 58% in body weight in 36 days. Artificially increasing the availability of salmon carcass flesh and eggs by adding carcasses of coho salmon to a small stream in southwestern Washington doubled the growth rate of juvenile coho salmon relative to a nearby stream reach with a low availability of carcasses (Bilby et al. 1998). Higher invertebrate abundance in streams with spawning salmon (Minikawa 1997) also can enhance food availability for juvenile salmon. The importance of nutrient availability during summer was demonstrated by nitrogen and phosphorus additions to the Keogh River on Vancouver Island (see Stockner 2003). A slight increase in the concentrations of these elements produced dramatic increases in the abundance and growth rate of juvenile coho salmon, steelhead and Dolly Varden char (Johnston et al. 1990).

There is increased interest in developing escapement goals and harvest management strategies that account for nutrient delivery by adult salmon to freshwater ecosystems (Larkin and Slaney 1997). However, there is little information from which to determine escapement levels appropriate to satisfy the trophic needs of aquatic and terrestrial biota. Ideally, estimates of the number of spawners needed for this function would be determined experimentally by controlling escapement levels and monitoring survival of progeny. Escapement levels for each stock would be varied through time and the impact on system productivity evaluated. However, conducting these long-term experiments on multiple species and populations would be a formidable task and would not provide usable results for many years.

Two alternative approaches for incorporating salmon nutrients into escapement goals have been suggested. Michael (1998) estimated the amount of salmon carcass tissue required to meet the dietary needs of juvenile salmon, insectivorous birds and bald eagles for the Skagit River, Washington. In this exercise, he assumed that all food consumed by the fish and birds was supported by salmon carcasses deposited in the system. He determined that current salmon escapement goals for the Skagit would need to be doubled to provide this level of trophic support. However, salmon are not the only source of nutrients and organic matter for these organisms. A thorough understanding of the nutrient dynamics and energetics of a system and the contribution salmon carcasses make to these processes would be required to use a this type of approach to establish escapement goals.

Another alternative that has been proposed is based on a relationship between spawner density and the proportion of marine-derived N in the tissues of juvenile fish (Bilby et al. 2001). Ideally, this type of relationship would enable a "saturation level" for marine nutrients in a watershed to be established and escapement goals set accordingly. A "saturation level" would correspond to a spawning escapement above which additional spawners would not contribute significantly to aquatic and riparian ecosystem productivity. This relationship was examined for coho salmon in approximately 20 watersheds in western Washington (Bilby et al. 2001). N stable isotope levels in pre-smolt coho salmon, captured in late winter, were related to the amount of carcass tissue deposited at the location where the young fish was captured the previous autumn. N stable isotope values in the juvenile coho increased with increasing carcass deposition up to a level of approximately 0.15 to 0.20 kg/m^2 of stream surface area (approximately 80 – 150 salmon/km). However, this approach does not consider the full range of ecological interactions potentially associated with carcass deposition. It does not address carcass use by wildlife or the use of nutrients from spawning salmon by riparian vegetation. The relationship between carcass deposition and proportion of salmon-derived nutrients in the aquatic system may differ for species other than coho salmon. The relationship can also be obscured by temporal variability in environmental conditions other than nutrient availability. Nonetheless, this approach does merit further investigation as it is relatively easy to apply and broadens the scope of ecosystem processes that are considered in setting harvest levels for salmon.

Despite the incomplete knowledge of the role salmon-derived nutrients play in the trophic support of freshwater ecosystems, sufficient study on this subject has been completed to suggest that the value of salmon to maintaining freshwater ecosystem productivity should not be ignored in the harvest planning process. Application of traditional methods of setting harvest levels and escapement goals without due regard for the ecological role salmon play in watershed processes may have contributed to historic declines in stock productivity and may be hindering efforts to restore the productivity of freshwater habitats.

An improved appreciation of the ecological role of spawning salmon can assist harvest planning in several ways. First, it is important to consider the entrainment of marine-derived nutrients from all species using a watershed. There is no evidence that food webs depend on only one species and ample evidence that strong inter-specific dependencies exist among salmon (e.g., juveniles of one species are affected by spawner abundance of another species). Factoring considerations of marine-derived nutrients into escapement targets should include all species returning to a watershed. Second, the ISAB is not aware of any evidence that "over-escapement" leads to reduced population productivity or watershed harm (Walters et al. 2004); in fact, there are a number of processes that can store marine-derived nutrients (e.g., in riparian plant tissues) for future ecosystem benefits. We suggest that the concept of over-escapement, if limited to the notion of spawning adults in excess of the apparent habitat capacity, overlooks a positive feedback between the abundance of returning adults and freshwater productivity that is of fundamental long-term importance. Finally, we caution that replacing natural production of salmon with hatcheries can create an ecological dead end that diverts marine-derived nutrients and organic matter from where they are needed most (the watershed) to where they are needed least (the hatchery). Further, this diversion of nutrients (assuming hatchery carcasses are not deliberately replaced in natural streams) may be exacerbated by competition between hatchery-produced salmon and wild fish for limited food resources.

7c. The Hatchery Paradigm and Ocean Carrying Capacity

Techniques to spawn Pacific salmon ova and hatch and release fry were refined in the late 1880s, about the same time salmon harvest peaked on the Columbia River, and coincident with degradation of freshwater habitats due to logging. This technological advance permitted juvenile salmon produced in hatcheries to be released to complete their life-cycle in the ocean, with the intention of providing fish to harvest. Hatchery production was initially used to avoid imposition of regulatory restrictions on land-use and fishing practices. This management strategy was based on the belief that early life-stage mortality of the large numbers of salmon eggs and fry produced annually in freshwater was the main factor that limited the numbers of adult salmon available for harvest. Later in the 20th century hatchery production was employed to attempt to mitigate for habitat lost following dam construction. Currently selective harvest of hatchery-origin fish is promoted in an attempt to permit harvest to continue despite protection of listed species.

As many as 6.1 billion salmon smolts are released each year from hatcheries into the Pacific Ocean (Beamish et al. 1997). In the Columbia River over 200 million hatchery-origin smolts are released each year. When combined with naturally produced juveniles, the total smolt migration into the ocean from the Columbia River may exceed the numbers migrating before European settlement and hydrosystem development (HSRG 2004, NWPPC 1986).

Ever-increasing production of young salmon has not proven to be a panacea, however, as shown by the coastal coho fishery. In the 1960s and early 1970s improvements in fish husbandry led to a corresponding improvement in coho salmon survival following their release from coastal hatcheries in Oregon (Lichatowich 1993, Bottom 1999). Between 1960 and 1966, coho salmon egg collections, smolt releases, and the commercial catch increased proportionately (Lichatowich 1999). Soon thereafter however, adult coho production fluctuated erratically and with little apparent relationship to the abundance of smolts released. In 1977 commercial landings of coho salmon abruptly collapsed from a high of 3.9 million fish to only a million fish. Salmon smolts were being produced by hatcheries, circumventing freshwater mortality, when this collapse occurred. Consequently, the collapse generated interest in the role of the marine environment in fluctuations in adult salmon numbers. Over the last quarter century evidence has accumulated that short term (year-to-year - El Nino and La Nina) and intermediate term (decade-to-decade -

Pacific Decadal Oscillation) cycles in marine environment productivity are important determinants of salmon abundance. There is general scientific agreement that the carrying capacity of the ocean is not limitless or fixed, but is dynamic and fluctuating.

Incorporating the concept of a limited and variable ocean capacity into a scientific framework guiding salmon management raises an important question. *Are the large numbers of hatchery smolts that are being released to augment harvest reducing the survival and abundance of naturally produced smolts entering the ocean?*

Formerly, salmon production had been assumed to be independent of density. Salmon were believed to use only a small fraction of the food and space available in marine ecosystems. Recent observations challenge this assumption and raise the specter of density dependence. Population sizes of animal species, including salmon, can have density-dependent and density-independent causation. Typically, density-dependent factors involve the size of a population and the biological interactions like diseases, competition, and predation. Density-independent mortality is not associated with population size and involves limiting environmental factors such as annual climate variability and pollutants. In actuality, animal populations are affected by both density-dependent and independent processes, but the relative importance and scale of each effect is of interest. In salmon management, the choices and success of management strategies will be affected by the nature of population regulation. If the sources of mortality for salmon in the ocean have a substantial density-dependence, then releases of hatchery-origin juvenile salmon could increase mortality of natural-origin juveniles.

Formal experiments quantifying density dependence in salmon are lacking. Graphical and correlation analyses showing negative relationships between catch records, ocean survival, and hatchery release numbers and recent declines in age of maturity and size at age of salmon species are cited to support the thesis that hatchery programs may impact survival and growth of natural-origin salmon under some circumstances. In the Columbia River, smolt-to-adult returns of natural Chinook populations were negatively affected by large releases of hatchery smolts during periods of poor ocean productivity (Levin et al. 2001). Ruggerone and Goetz (2004) compared survival, growth, and maturation of sub yearling Chinook salmon released from Puget Sound hatcheries in years with and without juvenile pink salmon production. During years of abundant pink salmon production Chinook salmon survival was reduced 62%. They report a similar pattern in lower British Columbia streams where pink salmon are abundant. The pattern was not detected in Chinook salmon originating from streams along the Washington coast and lower Vancouver Island, where pink salmon are largely absent. Inter-specific competition with Asian origin pink salmon (*O. gorbuscha*) reduces the survival, abundance, and size of Bristol Bay sockeye salmon (*O. nerka*) (Ruggerone et al. 2003).

Beamish et al. (1997) conclude that ocean carrying capacity limits coho and Chinook stocks in Canada, Washington, Oregon, and California, because catches of coho and Chinook have steadily declined despite the release of hatchery smolts (Figure 7c-1). They base their conclusion on the assertion that catch is a reasonable index of abundance (Beamish et al. 1995, Beamish et al. 1997). Caution is warranted in attributing this relationship to limits on ocean carrying capacity/density dependence. During the time period analyzed, there were major changes in mixed stock fisheries. Treaty fishing rights in the United States required stock-specific conservation actions that resulted in restructuring and reducing ocean Chinook harvests and the Pacific Salmon Treaty resulted in limitations on coho harvests. The reduction in harvest attributable to reduction in fishing is not identified. The graphs would need to depict total production, not just catch. More recently though and based on direct sampling, Sweeting et al. (2003) have demonstrated that the percentage of hatchery-reared coho salmon in the Strait of Georgia, BC, has increased from nearly 0% in the early 1970s to more than 70% by 2001, during the development of the Canadian Salmonid Enhancement Program.

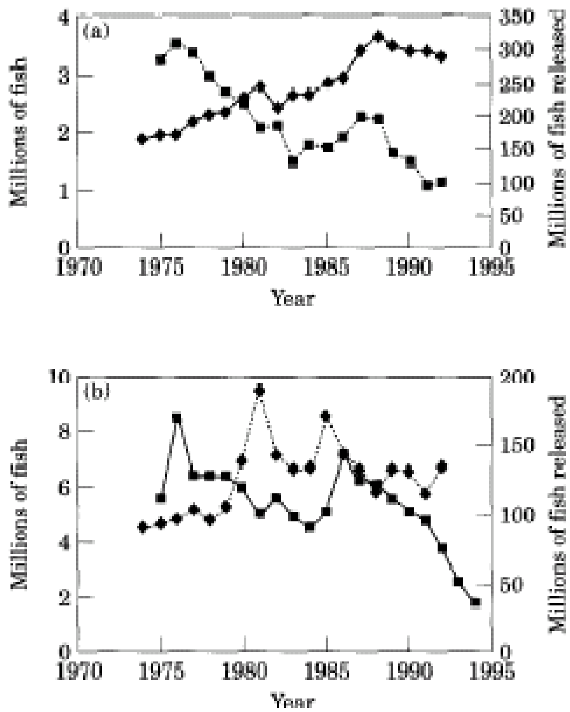

Figure 7c-1. (a). The decline in Chinook catch from southern British Columbia, Washington, and Oregon in relation to hatchery production. (b). The decline in coho catch from southern British Columbia, Washington, and Oregon in relation to hatchery production. Catch (■); Hatchery Releases (◆). From Beamish et al. 1997.

Further, Hilborn and Eggers (2000, 2001) concluded that in Prince William Sound, Alaska, release of nearly 500 million pink salmon fry from hatchery production has increased total production by at most only 2 million fish, and been associated with a decline in escapement of wild salmon. Instead of augmenting the fishery, they believe hatchery releases have largely replaced natural production. From the early 1950s through the late 1970s pink salmon catches were poor in Prince William Sound, averaging 3 million fish per year. In 1974 a hatchery program for pink salmon was begun and, since 1980 catches have averaged 20 million salmon; much of this production is hatchery produced. Hilborn and Eggers (2000) base their conclusion that these hatchery salmon have replaced rather than augmented natural production on the observation that catches of pink salmon in other Alaskan waters increased during this same time period without substantial hatchery programs.

There is not yet scientific consensus over density dependence of salmon production as it affects harvest. Wertheimer et al. (2001) question Hilborn and Eggers' conclusion. Wertheimer et al. (2001) believe, instead, that asynchrony of production across regions coupled with changes in zooplankton (salmon food) and predator populations can account for the observations. Several investigations explored the evidence for density dependent marine mortality of coho salmon (Lichatowich 1993). Three of the six concluded there was evidence of density dependence; three did not. Unfortunately, the power of statistical tests to detect density dependence is typically low. In the tests to detect density-dependence in OPI coho, there was an 81% chance of incorrectly accepting the null hypothesis of density-independence, and a smolt release of 88 million individuals would have been needed to conduct an experiment with convincing statistical power (Peterman and Routledge 1983, Peterman 1989, cf Lichatowich 1993).

Density may also affect size and age of maturation. Bigler et al. (1996) found that 45 of 47 North Pacific salmon populations, comprising five species from North America and Asia, are decreasing in average body size. They concluded that an inverse relationship between population abundance and average size during the period l975-l993 indicates that there is a limitation to the salmon carrying capacity of the ocean. They believed increases in hatchery programs in the l980s and early l990s have contributed to the ocean-wide reduced size of salmon. Size-selective harvest effects could also contribute to these trends (Hard 2004).

A decline in body size due to density-dependence could be as important to recovery as decreased survival rates. A positive correlation between spawner size and survival of their progeny has been demonstrated in chum salmon (Helle 1989). Fecundity and egg size increase with increased female body size. Larger egg size may improve survival of incubating embryos and produces larger fry. Decreased fecundity reduces the number of gametes available to produce subsequent generations of salmon.

While density dependence is not universally demonstrated statistically, there is increasing evidence of its effects on salmon abundance and growth. The last half-century of observations demonstrate that salmon harvests are not stabilized by the release of hatchery-origin salmon smolts. Research efforts are warranted to identify the magnitude of density dependence and the conditions under which it could impact the sustainability and recovery of Columbia River Basin salmon. Evidence of competition between salmon species originating from Asia and North America during marine residence suggests a need for international cooperation to determine the appropriate scale of the artificial production programs releasing juvenile salmon into the ocean.

7d. Climate Change and Potential Salmon Harvest

There is growing realization that global climate change and the climatic cycles of the ocean strongly affect salmon production, and that global climate change (i.e., a gradual warming of the earth's global atmospheric-oceanic system) is occurring (IPCC 2001). Inclusion of climate-related affects in salmon management could minimize over-fishing in times of predictably low salmon production thus reducing risk to stocks we wish to recover. Conversely, inclusion could also allow increased harvest when conditions are likely to be good for salmon production.

Whether climate change has been induced by human activities or is a reflection of natural cycles, long-term climate change is to be contended with in planning the use of natural resources in the future. During the 20th century, the Pacific Northwest region of the United States experienced a warming of 0.8°C. Using output from eight climate models, Mote et al. (2003) projected a further warming of 0.5-2.5°C (central estimate 1.5°C) by the 2020s, 1.5-3.2°C (2.3°C) by the 2040s, and an increase in precipitation except in summer. The foremost regional impact of this general warming will be a reduction in regional snow pack, which currently supplies much of the water for ecosystems and human uses in the dry summers (Service 2004).

Superimposed on this gradual change in the global system are shorter-term changes that are only now beginning to be understood and quantified. The year-to-year and decade-to-decade changes associated with the El Nino-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) cycles are generally felt throughout the Northwest despite significant annual differences in local climate (Mote et al. 2003). ENSO is an irregular oscillation of the tropical atmosphere and ocean with a period of 2-7 years (e.g., McPhadden et al. 1998). The more recently recognized PDO reflects monthly anomalies in Pacific sea surface temperature north of 20° latitude (Mantua et al. 1997) and has an irregular period of several decades; in the 20th century it stayed in a cool or warm phase for 20-30 years at a time. It is the cause of the "regime shifts" that have received recent attention; cool from 1900-1925, warm 1925-1945, cool to 1977, and then warm to about 1998 when the recent shift brought a cool phase again. Tree-ring data suggest that the PDO cycles have occurred at least since the 1600s (Gedalof and Smith 2001). Warmer, drier years often associated historically with El Nino (ENSO) and/or the warmer phases of the PDO tend to be associated with below average snow pack, low stream flow, and low flood risk in the Columbia River basin, and consequently below-average survival of most salmon stocks (Pulwarty and Redmond 1997). Alaska salmon tend to see the opposite trend, and British Columbia stocks are intermediate (Hare and Mantua 2000).

The ENSO and PDO cycles can pass into and out of phase to interact with gradual global change and strongly affect the success of the Northwest's natural resources (hydrology, forests, salmon; Mote et al. 2003). Historically, when ENSO and PDO have both been in their warm phase, the effects on snow pack, stream flow, floods, and salmon are all greatly reduced. Conversely, when both cycles are in phase for cool years, these features are all at extreme highs. When out of phase, the effects of either cycle are less extreme.

The strong potential for gradual increases in regional temperature and losses of snow pack (and runoff water in spring and through the dry summers) is unlikely to aid productivity of Columbia River basin salmon stocks and their availability for harvest. The detrimental effect is likely to be seen primarily in the 2-3 decade periods of a warm PDO and accentuated when the 2-7-year El Nino cycle hits its warm peaks. One study (Welch et al. 1998) suggested that the thermal suitability of most of the North Pacific for salmon could be eliminated in the worst years (most likely in the 21st century based on climate forecasts of the IPCC). Fortunately, we are currently in a cool PDO cycle with abundant salmon (Hare and Mantua 2000), although no one can tell with certainty when this cycle will revert to the warm period of the 1980s and 1990s when salmon stocks experienced sharp declines.

The greater understanding of both gradual climate change and of the ENSO and PDO cycles (and perhaps other cycles not yet understood) should, in principle, allow fisheries managers to forecast likely trends in salmon production some years in the future and make preparations for adjusting annual harvest quotas accordingly. The coincident warm ENSO and/or PDO years could be anticipated and stocks could be conserved at those times. Extreme caution in harvest of

Columbia River species and stocks is advisable when ENSO and PDO cycles are concurrently in the warm phase. Conversely, concurrent cool phases could allow a higher managed harvest from an abundance of most salmon. Practically, however, ENSO is irregular, but the warm peak is still reasonably predictable 1-2 years in advance. The PDO cycle is less well known, but caution in harvest could be exercised when regime shifts have occurred or seem imminent to a warmer portion of the cycle at the end of about 20 years. Perhaps the greatest risk to salmon could come when harvest managers become accustomed to high harvest levels during favorable periods and then fail to recognize climatic change when it occurs and harvest levels are not reduced appropriately. Although the desired predictive capabilities are not yet available, the ISAB believes harvest managers should be looking to the future to develop such capabilities.

The harvest-setting process will need to adapt to current understanding of climate changes and the rapid pace of new knowledge. The present annual development of pre-season abundance forecasts and in-season estimates of returning run sizes can, and probably should, shift to a longer temporal focus. Salmon harvest managers may need to become firmly attached to climatologists when they plan for both current-year and future harvest quotas. Although a stock assessment process is established for determining allowable harvest, these annual assessments will need to look farther ahead to incorporate expected ENSO and PDO cycles and to estimate whether the stock status in future harvest years will be affected by warm or cool periods, especially should they coincide.

Clearly, climate effects on salmon, whether cycles or long-term trends, have implications greater than for just harvest regulations. They affect how critical are the needs for maximizing survival of ESA-listed populations, protecting and enhancing important habitats, and managing other factors in the salmon life cycles. Overall protection needs to be more assiduous when the cycles are in a bad phase for salmon and might be relaxed somewhat when the cycles are in a good phase. One should not forget, however, that it is during the better climatic phases that stocks below sustainable levels in the poor phase should be allowed to recover their numbers and recolonize or expand areas of freshwater production. The reality of climate change cycles and trends belies many of the goals of the fishing industry, such as stable employment, consistent sources of fish, and firm markets. The nature of the beast, so to speak, will necessarily be one of much year-to-year and decade-to-decade variation. Economists and businessmen, as well as biologists, will have to learn to expect and contend with such variability.

What specifically might be done? The ISAB suggests two avenues for consideration: (1) alter the temporal focus of harvest management to multiple (future) years; and (2) inform strategies for long-term investment. Both ideas would require effort for their substantive development.

Temporal focus of harvest management. There are both near-term and long-term approaches. For the near term and for species that mature at multiple ages, harvest management practices could be modified to consider impacts on fish that are not anticipated to return to the Columbia in the coming/current year. Several years ago, Morishima (1999) developed a metric termed *Mature Run Equivalents* (MREs) to convert harvest (or environmental) impacts on fish to their equivalents on a return year basis (the idea was employed in the PATH analysis).[20] If the MRE concept were to be employed in harvest management, the focus of regulation would be changed because impacts would be considered on a cumulative basis. Harvest management plans in a single year would look at: (a) how factors (fisheries, environmental) that have already occurred in previous years have affected the fish that are anticipated to return in the current year; and (b) how factors in previous and the current year would be expected to affect prospects for returns in future years for the broods that already have begun their contribution to spawners. An MRE-type approach would necessitate a considerable change in the focus of harvest management from a single return year to multiple years; this would likely involve additional uncertainty that might be addressed through application of precautionary management techniques. Because of its near-term focus, such an approach would not address survival changes beyond the 2-7-year ENSO cycles.

The long-term approaches are less clear, but would involve anticipation of the ENSO and PDO cycles and long-term climate-change trends and their likely impacts on fisheries. As environmental predictability improves, the predictive capability for the output of freshwater production and the productivity of the ocean environment should improve. Times of lean and rich production should be forecasted with sufficient resolution that the likely results for the near-term would be evident. The near-term analysts would then be forewarned of impending change in their analytical ground rules.

<u>Long-Term Strategy.</u> Long-term climate changes would very likely alter the structure of salmon populations, as well as their abundance. The current focus of the ESA on preservation of the "status quo" ESUs is not well suited as a foundation for long-term strategic management. Costs of attempting to preserve something that cannot be sustained over the long run could be enormous, and extraordinary efforts could prove futile in the end. While not limited to harvest management issues, an initiative to examine the implications of long-term climate change should be valuable from a strategic perspective. It should be feasible to undertake a simulation study that would investigate how the 4-Hs might be expected to influence salmon population and community structures under various climate change scenarios, in order to inform decision makers on alternative futures. For instance, such an approach might integrate models on precipitation, flows, EDT, hatchery production, supplementation, habitat modification, etc. to determine the likely response of different population units. As information on the implications of climate change becomes available, such a model could prove helpful in establishing priorities and long-range plans for:

1. identification and preservation of important populations that could be pivotal to future survival of the species;
2. identification of populations that are unlikely to be preserved regardless of management intervention;
3. infrastructure such as hatchery facilities, gene banks, and supplementation programs; and
4. investments by the fishing industry.

The first two areas would obviously be most relevant for harvest management considerations.

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[20] The idea of MREs differs significantly from the concept of *Adult Equivalents* which converts impacts in the current year to fish that would be expected to return to terminal areas in the current or a future year in the absence of fishing.

In summary, the ISAB anticipates major increases in the understanding of climate change and climate cycles in relation to salmon and other natural resources in the next few years, and significant increases in the uncertainty of production forecasts in the short to medium term. Harvest managers and the harvest industry need to be in close touch with this increased understanding and to be prepared to change their procedures accordingly for conducting near-term and long-term assessments, setting annual quotas, and harvesting fish.

7e. A Primer for Salmon Harvest Management

The relationship between parent spawning abundance (Stock) and subsequent production of progeny (Recruitment) is referred to as Stock-Recruitment (S-R) and frequently forms the foundation for harvest management. S-R analysis employs mathematical models to estimate the production of mature adults from a given level of adult spawning escapement.[21] Thus, the fundamental data necessary are numbers of spawning adults (by sex and age) and the resulting progeny produced. For salmon, we can measure the spawning Stock, but not Recruitment. *Recruitment* refers to vulnerability of fish in a particular fishery and depends both on regulations (such as size limits and season structure), and the migration patterns, survival, and growth of the progeny. Data sets that are sufficient for S-R analysis are actually rare, but these models still form the foundation for harvest management. The relationships are determined for independent demographic groups of salmon that can be identified for fishery management (i.e., a stock).

Two Common Types of S-R Models

Two types of S-R relationships are most commonly applied in salmon management.

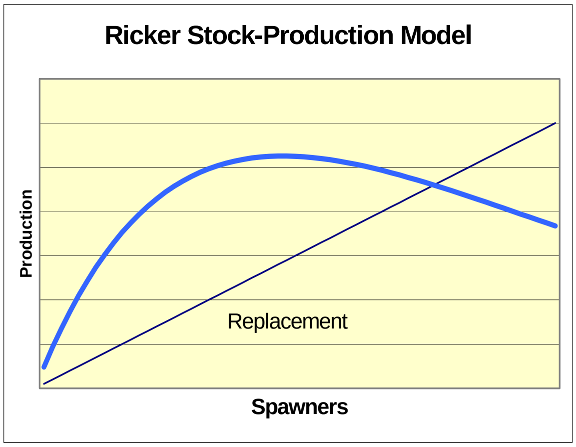

Fig 7e-1a. Ricker Model

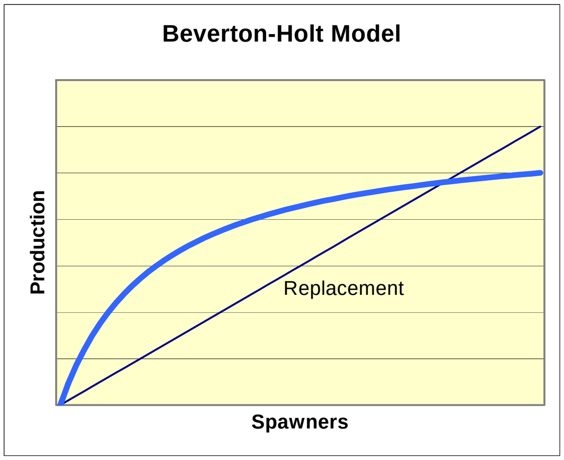

Fig 7e-1b. Beverton-Holt Model

Ricker Model. In the Ricker Model (1954), the relationship between spawning escapement and production is dome-shaped. This model indicates that the productivity of the stock is highest at low spawner densities and decreases monotonically as escapements increase. At high spawning escapement levels, strong density dependence becomes apparent and production actually decreases, as reflected by descending right hand limb.

Beverton-Holt Model. The Beverton-Holt model (1957) is hyperbolic in shape and asymptotic in form. Density dependence is incremental, suggesting that production is limited by some environmental carrying capacity. As with the Ricker Model, productivity is greatest at low spawner densities and decreases monotonically with increasing escapements.

Fundamental Concepts

[21] Habitat is also a critical factor in determining productivity of a salmon population but is not addressed in this primer. Habitat is the physical template for production (both its productivity and capacity). S/R models assume a fixed habitat background and random environmental variation. If temporal trends exist, current parameter estimates may be poorly predicted or biased relative to the full set of historical data.

Fundamental Concepts

Productivity and Capacity

Both the Ricker and Beverton-Holt models are characterized by parameters that relate to *productivity* and *capacity*.

The *productivity* of a stock is its efficiency to produce progeny at very low levels of spawning escapement. Each stock is believed to have its own inherent productivity. Graphically, the slope of the models at low spawning escapement levels reflects the productivity; the steeper the slope, the higher the productivity. It is important to understand that stock productivity is not constant; production from a given level of spawning escapement can vary by orders of magnitude depending upon freshwater and marine conditions. There is some evidence of cyclic variations in marine survival rates (decadal oscillation, see Section 7.d, Climate Change Effects on Potential Salmon Harvest); failure to adjust harvest to compensate to prolonged periods of abnormally low survival rates can lead to trends in declining spawning escapements and raise concerns for resource conservation. The simplistic forms of these S-R models consider each population as an independent unit; within complex ecosystems, potential interactions exist between populations, species, and harvest.

The *capacity* of a stock is the maximum number of fish that the population can be expected to produce under average conditions. For the Ricker Model, the capacity is depicted as the peak of the dome-shaped production curve. For the Beverton-Holt Model, production approaches an asymptotic limit (capacity) as spawning escapement increases.

Density dependence

Both the Ricker and Beverton-Holt models are based on the concept of density dependent productivity, that is, as spawning escapement increases, productivity (the number of adults produced per spawner) decreases. The stock becomes more productive, that is, more adults per spawner are produced as spawning escapement decreases. This raises the question, *"How low can you go?"* Although S-R theory suggests that the population can be sustained at very low levels of spawning escapements, harvest managers avoid risks of extinction or to the long-term viability of the population by establishing minimum acceptable escapement levels. At very low escapement levels, concerns that the population will not be capable of sustaining itself due to social dysfunction, failure to mate successfully, mechanical feedback (effects of salmon in processing spawning gravel), biogeochemical effects (marine derived nutrients), and genetic effects (inbreeding and loss of genetic diversity) – originally described as the "Allee effect" (Allee, 1931) but more generally described as "depensation"– outweigh short-term benefits of harvest.

Sustained Yield

The replacement line depicted on the figures for both the Ricker and Beverton-Holt models represents a 1:1 relationship between spawning escapement and production. An unfished population would generally be expected to stabilize at the equilibrium point where the replacement and production lines intersect. At spawning escapement levels beyond the intersection, production would not be expected to replace spawning escapements. To harvest managers, the area of greatest interest lies to the left of this intersection. Here, the difference between the replacement line and the production model line represents the level of "harvestable surplus", i.e., the number of fish that can be harvested at a given level of spawning escapement without depleting the parent stock.

Maximum Sustained Yield

One common management objective is to maintain spawning escapement at the level that maximizes the sustainable yield from the stock, i.e., to achieve the largest difference between production and spawning escapement. The size of the harvestable surplus at this point is commonly referred to as the Maximum Sustained Yield (*MSY*) and the associated spawning escapement is referred as S_{MSY}. Note that this point typically lies well below the levels of maximum production (*MSP*) and maximum sustainable spawning escapements (Figure 7e-2).

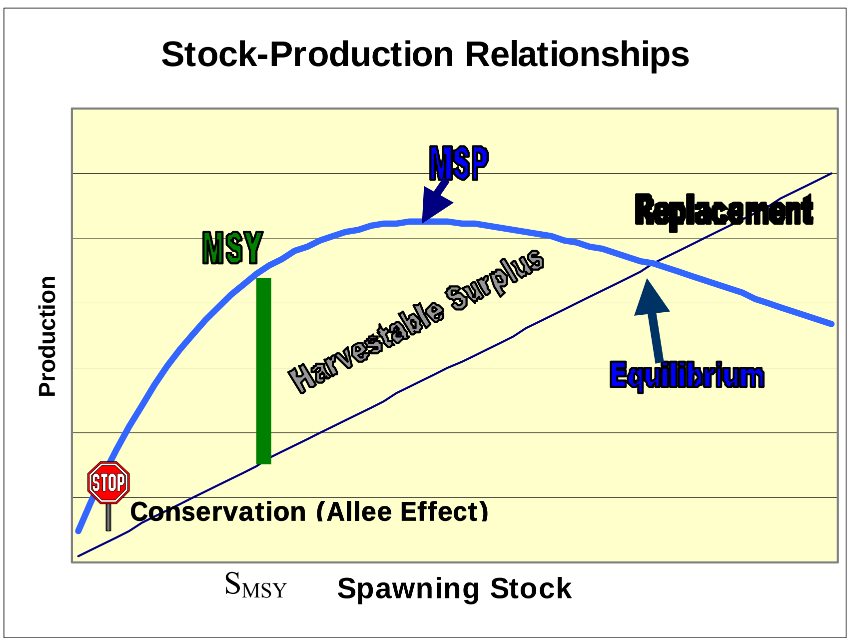

Fig. 7e-2. Key characteristics of S-R Models

In S-R models, each stock has a unique S_{MSY}, but it is important to understand that spawning escapements can deviate substantially from this level with minor reductions in sustainable yield. For example, suppose that a population characterized by a Beverton-Holt model has an S_{MSY} = 6,000 and an *MSY* = 6,000. Spawning escapements ranging from 4,200 to 7,700 would be expected to generate sustained yields within 5% of *MSY* (Figure 7e-3).

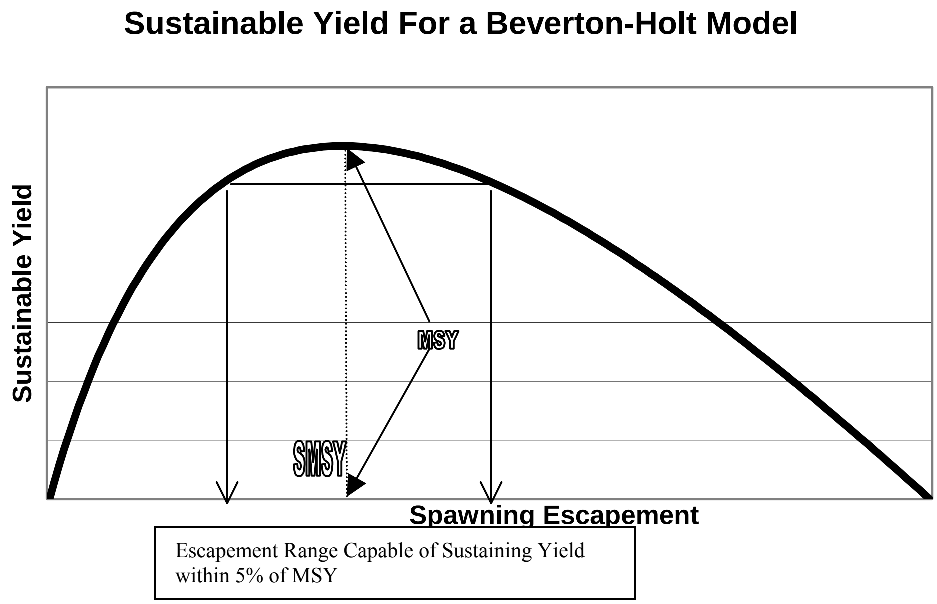

Fig. 7e-3. Sustainable yield for a Beverton-Holt Model

In a nutshell, the Ricker and Beverton-Holt S-R models illustrate that:

1. increasing salmon escapements will not always increase the potential number of fish available for harvest;
2. the largest sustainable harvest is not normally achieved when the total population size is largest;
3. the maximum sustainable exploitation rate for a population does not yield the maximum sustainable yield; and
4. salmon populations are capable of sustaining themselves and sustaining harvests over a broad range of spawning escapements.

Spawning Escapement Goals

Fisheries management objectives are commonly expressed in terms of spawning escapement goals. Implicit in a spawning escapement goal is the desire to perpetuate the resource and preserve it for future use. An escapement goal established solely for conservation purposes represents the minimum reproductive population that is necessary to assure that the resource can be perpetuated. Any escapement goal higher than that necessary for conservation is selected so as to utilize the reproductive capacity of the resource in a manner that society determines to be "optimal." The utilization aspect of a spawning escapement goal must be subservient to the constraints on exploitation, which are dictated by the conservation necessity. Thus, while there may be only a single spawning escapement level associated with conservation of a particular run of fish, there are an infinite number of possible spawning escapement levels that can be selected to meet various utilization objectives in some "optimal" way.

The selection of a particular level of harvest and spawning escapement is a social policy decision that essentially involves a choice of time preference, i.e., present utilization versus future production potential. A spawning escapement goal may be chosen to meet an endless number of legitimate management purposes, such as to:

- maximize the sustainable harvest;
- maximize the number of adults produced by the population;
- enhance scientific knowledge concerning the resource;
- increase genetic diversity in the population;
- maximize the value of the total production of all species of fish produced by a watershed;
- satisfy some aesthetic preference or political desire to see more fish in a river;
- promote the economic efficiency of a fishery;
- provide for a level of harvest that can sustain fishing communities;
- increase the number of spawner carcasses to improve nutrients available to support; ecological functions and provide food supplies for progeny;
- reduce social and economic dislocations;
- increase or decrease potentials for sustainable harvest.

A spawning escapement goal established for each of these purposes is “optimal” in its own way.

Harvest Management

Harvest management involves the simple concept of constraining the fishery to the level necessary to attain a specified management objective, i.e., the primary objective of harvest management is to ensure that the cumulative effect of all fisheries does not exceed the impact allowable for a given stock.

As straightforward as this task may sound, the capacity to regulate harvests to attain a given management objective can be an extraordinarily difficult and challenging task for many Columbia River salmon stocks. The reasons for this difficulty stem from several sources, including the biological characteristics of the stock and complex patterns of harvest under the jurisdictions of multiple management agencies.

Biological characteristics of the stock affect the complexity of harvest management. Management of coho salmon is relatively simple compared to Chinook. Columbia River coho are exploited and spawn predominantly as three-year old fish and ocean distribution patterns are limited to the extreme southern portion of British Columbia to northern California. In contrast, Columbia River Chinook are exploited at various ages over an extensive migratory range (e.g., Snake River fall Chinook are harvested by commercial and recreational ocean fisheries from central California to Southeast Alaska as well as fisheries in the Columbia River). Further, spawning escapements of this species are comprised of fish of different ages. Consequently, harvests of Chinook must be constrained over multiple years by multiple jurisdictions (see section on Institutional Structure).

Many different strategies can be employed in salmon harvest management. Two of the most basic are described here, harvest management based on: (a) escapement goals, and (b) exploitation rates.

Escapement Goal Management

A fixed escapement goal harvest management strategy attempts to attain a level of spawning escapement regardless of abundance. If abundance falls below the number required to achieve the goal, fisheries impacting the stock are closed. Otherwise, harvest is constrained to take the difference between total abundance and the escapement goal.

To attain an escapement goal, all fisheries impacting a given stock must be appropriately regulated so as to ensure that the appropriate harvest is not exceeded. This can be an extraordinarily difficult and challenging task for many Columbia River salmon stocks because of the complex life histories and number of jurisdictions involved. Escapement goal management thus requires a high degree of cooperation and coordination between jurisdictions affecting individual stocks, as well as information-intensive management systems.

While escapement goal policies place a premium on future production, they can have undesirable social consequences. Since salmon survivals often exhibit very high interannual variability, fixed escapement goal policies can lead to “boom or bust” instability and economic dislocation of fisheries. Fixed escapement policies are not always feasible or even desirable, given a stock’s pattern of exploitation. For instance, a stock may be harvested only by highly mixed stock fisheries outside the jurisdiction of the harvest manager; or there may be little capability to estimate abundance and adjust harvest to achieve an established escapement goal; or a stock may be taken incidentally during fisheries targeted at other abundant, valuable species with harvestable fish.

In practical terms, harvest management is an imprecise process. Fortunately, salmon populations are proven to be quite robust, capable of enduring wide variability in freshwater and marine survivals as well as harvest management error over an extended period of time. As indicated in Figure 4, the failure to exactly achieve a given spawning escapement goal in a single year should not raise alarms about a conservation crisis.

Exploitation Rate Management

Within the range of sustainable harvests, the sustainable exploitation rate is determined by the productivity of the stock, but must of course assume a value above zero (in the absence of an Allee effect) and less than one. An important characteristic of S-R models is that there is a unique sustainable exploitation rate associated with each given level of spawning escapement. Two reference points of particular interest to harvest managers are depicted in Figure 7e-4.

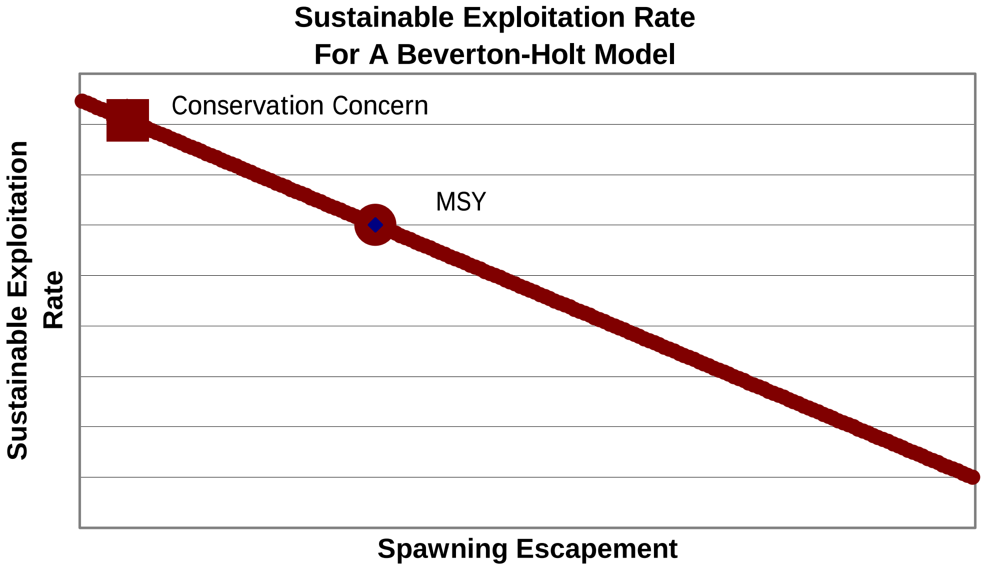

Fig 7e-4. Sustainable exploitation rate for MSY (circle) and conservation concern spawning escapement level (square) for a Beverton-Holt Model.

The circle represents the sustainable exploitation rate at MSY, while the square represents the sustainable exploitation rate at the level of spawning escapement associated with potential conservation concerns because of the potential for an *Allee effect*.

Under an exploitation rate strategy, the objective is to constrain exploitation rates so that a desired level of spawning escapement (e.g., S_{MSY}) can be attained over time. Because of data limitations, it is often easier to generate an estimate of the exploitation rate associated with S_{MSY} than it is to estimate S_{MSY} itself.

The theory behind the exploitation rate strategy is that, if fishery exploitation rates are constrained to the level appropriate for S_{MSY}, escapements should eventually stabilize at S_{MSY} over time, if the environment is constant.

When spawning escapement is below S_{MSY}, the population can sustain a higher exploitation rate. Consequently, when fisheries are managed to achieve the lower sustainable exploitation rate associated with S_{MSY}, fewer fish would be harvested and spawning escapements would be expected to increase. For example, suppose that a population that produces fish according to a Beverton-Holt model can sustain a 50% exploitation rate at an $S_{MSY} = 6{,}000$. Suppose further that a spawning escapement for that population produces 9,000 fish at an escapement of 3,600 fish. The sustainable harvest at that level is 9,000-3,600 = 5,400, so an exploitation rate of 60% (= 5,400/9,000) can be sustained. If fishery exploitation rates are constrained to 50%, 4,500 fish would be harvested and 4,500 fish would escape; the spawning escapement for the next generation would consequently increase from 3,600 to 4,500.

Conversely, when spawning escapement is above S_{MSY}, the population can sustain a lower exploitation rate. When fisheries are managed to achieve the higher sustainable exploitation rate associated with S_{MSY}, the harvest would exceed the sustainable level so spawning escapements would be expected to decrease. For example, if a spawning escapement level of 8,400 fish produces 14,000 fish, the sustainable yield would be 5,600 fish and the associated sustainable exploitation rate would be 40% (= 5,600/14,000). By allowing a 50% exploitation rate associated with S_{MSY}, the catch would be 7,000 fish and the spawning escapement for the next generation would be reduced from 8,400 to 7,000 fish.

Exploitation rate strategies are less dependent upon estimates of abundance than are escapement goal strategies, and the approach can be implemented at lower cost and with reduced potential for fishery disruptions. However, as with fixed spawning escapement goal harvest management strategies, a fixed exploitation rate strategy, blindly followed, can also have undesirable consequences. If spawning escapement levels fall below critical levels or sustained periods of abnormally low productivity are experienced, a fixed exploitation rate strategy can lead to stock collapse.

Neither fixed spawning escapement goal nor fixed exploitation rate management performs well in a dynamic environment with high inter-annual variability in survival rates, growth, habitat conditions, and patterns of fishery exploitation. Today, dogmatic adherence to such inflexible strategies has fallen into disfavor. Harvest managers are increasingly turning to a combination of the two, a ceiling on allowable exploitation rates adjusted for current expectations for short-term marine survivals, coupled with a spawning escapement floor to protect against stock collapse.

Management of Mixed Stock Fisheries

To this point, the discussion of harvest management strategies has been limited to circumstances where fisheries exploit a single population. However, nearly all fisheries on Columbia River stocks impact multiple stocks. Figure 7e-5 illustrates how stocks with different productivities are impacted in mixed stock fisheries. Sustainable exploitation rates for three populations with different productivities (Beverton-Holt Model) are depicted, each with points associated with MSY (circles) and conservation concerns (squares). The lowest line represents the least productive population while the uppermost line represents the most productive population. Note that different productivities alter both the sustainable exploitation rate and the range of spawning escapements that are capable of sustaining harvests (the least productive stock has the shortest range of sustainable escapement levels).

If a stock mixture is exploited at the MSY rate appropriate for the most productive stock (about 65% in this example), then the least productive stock would be extirpated over time because it cannot sustain exploitation rates in excess of about 40%. Spawning escapement for the third (middle) population would be expected to stabilize at a level well below its S_{MSY}, but the long-term viability of this stock would not be threatened.

To conserve the least productive stock, the exploitation rate in mixed-stock fisheries must be decreased to about 40%. Additional fisheries, though, could be conducted once the more productive stocks become separated from the less productive ones.

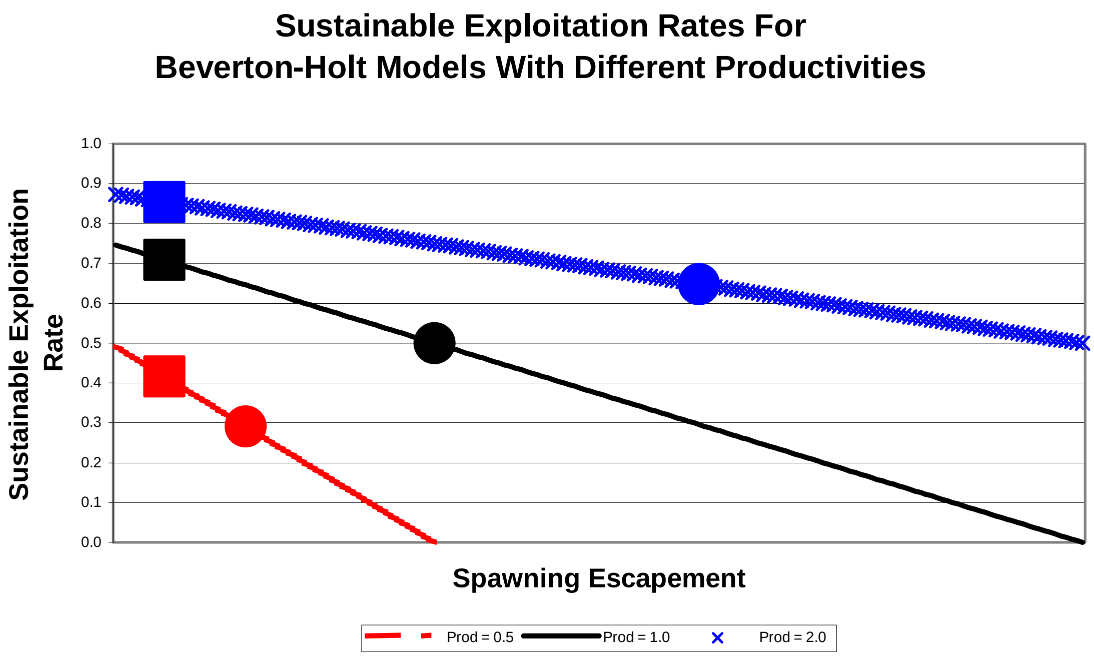

Fig 7e-5. Sustainable exploitation rate for MSY (circle) and conservation concern spawning escapement level (square) for Beverton-Holt Models with different productivities.

How do harvest managers attempt to contend with complex mixtures of stocks of different sizes and with different productivities and patterns of exploitation? The short answer is that, until recently, they haven't. Historically, harvest management failed to pay adequate attention to smaller stocks and differing capacities of individual populations to sustain harvest. The most notorious example is with hatchery-wild stock mixtures. In the Columbia River system, numerous hatcheries were constructed to produce fish to mitigate for habitat loss and degradation due to the construction of dams. These hatcheries released prodigious numbers of fish which were exploited at the highest rates possible while meeting egg take needs. Commingled naturally spawning stocks with lower productivities were unable to sustain the exploitation rates being exerted on the hatchery fish. Over time, naturally spawning coho populations were virtually extirpated from the Columbia River (save for very small remnant populations that are now candidate species being considered for listing under the Endangered Species Act) and became so depressed on Oregon coastal streams that they were listed as threatened under the Endangered Species Act.

How do harvest managers of mixed stock fisheries today attempt to simultaneously achieve specific objectives for each population in order to meet concerns for biodiversity and long-term viability? Managers of highly mixed stock fisheries have found it infeasible to try to attain fixed spawning escapement goals for every stock all the time. The approach now being embraced is to rely upon exploitation rate management. With mixtures of stocks with different productivities, the exploitation rates must be constrained so as not to exceed the level associated with critical conservation points on the stock (component) with the lowest productivity over extended periods of time. Production from each of the populations will not be sustained at SMSY levels, but viability should not be compromised.

Current management of Columbia River coho in mixed stock ocean fisheries, for example, is driven by exploitation rates that are determined by the annual status of Oregon coastal natural coho under the Pacific Fishery Management Council's Salmon Framework Plan (OCN 2000). The allowable exploitation rate under that Plan ranges from zero to a high of 45%, substantially below annual exploitation rates on hatchery fish that had approached 80% prior to the 1990s. In addition to reductions in mixed stock exploitation rates, the stock assessment program was improved to provide data to monitor stock response and trigger adjustments to management strategies if stocks responses fail to meet expectations.

Information Requirements

Harvest management strategies require extensive information for implementation.

For S-R analysis, data are required to characterize the relationship between spawning escapement and productivity and to estimate model parameters. The first step is to identify the reproducing population. This involves information on the dynamics of the metapopulations (populations that regularly interbreed) that may be involved. Once the reproducing population is identified, data on spawning escapements and production are required.

<u>Spawning escapement data.</u> For salmon, the number of adult spawners is commonly used in S-R analysis because adults are presumed to contribute most to future production. While S-R analysis can be performed using estimates of total spawning escapements, results can be clouded because the reproductive potential of that escapement is influenced by its age-sex composition. For example, the reproductive potential of a spawning stock of Chinook, which is comprised primarily of three-year old males, is vastly different from an escapement dominated by larger, older females. Ideally, data on the characteristics of the spawning population, such as age, sex, size, and fecundity would be available along with estimates of error.

For S-R analysis based on fish-to-fish relationships, spawning escapement data are often available over a very limited range. Observations at low escapements are necessary to estimate the inherent productivity of the stock. Observations at relatively high escapement levels are needed to provide the information required to define the response to changes in spawning stock size. Data limitations commonly prove problematic when attempting to employ S-R analysis. Usually, S-R analyses only involve a small number of observations and little quantitative information about uncertainty (principally measurement error) surrounding these estimates is available. Further, the data are often inconsistent over time, reflecting changes in methods, personnel, and variations in environmental conditions. [22]

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[22] A variety of methods can be employed to apply S-R theory to harvest management in the face of uncertainty. For example, an adaptive management approach can be instituted to obtain information on production response by monitoring juvenile production when spawning escapements are intentionally varied. Another approach could involve the estimation of habitat carrying capacity, coupled with estimates of productivity at low spawner densities. Production can also be estimated by dividing the sum of spawning escapements and terminal harvests for a given brood year by the adult-equivalent-brood year exploitation rates estimated from cohort analysis of representative

Estimating Production. For estimation of spawning escapements, measurement error is of principal concern. When it comes to production, both measurement error and process error (variable production from a given level of spawning escapement) must be taken into account.

For either the Ricker or Beverton-Holt models, production from a given spawning escapement is usually expressed in terms of adult equivalents[23] because fish can be exploited at different stages of maturity. For Chinook, data on escapements, catch, and tagging experiments form the most common foundation for estimating production.

Ideally, production estimates would begin by estimating egg-deposition resulting from a given spawning escapement. Then spawning escapement surveys from subsequent years provide estimates of the number of fish produced by this escapement, which survive to spawn by age. Since Chinook mature at different ages, data may be collected over 3-6 years to estimate the production from a single spawning escapement. Since escapement in any given year is comprised of fish produced by several different broods, the number of spawners must be partitioned into fish of different age classes in order to estimate production from individual broods. A variety of methods are used (e.g., age structure of catch in terminal fisheries) that can introduce bias if sampling techniques (e.g., size or sex selectivity of gear) are not random. Partitioning should involve all age classes.

Estimates of production would finally be generated by expanding spawning escapements for pre-spawning mortality, fishing mortality, and natural mortality based on tagging data. For most natural stocks, estimates of pre-terminal fishery exploitation are derived from CWT experiments involving a closely related hatchery stock. Cohort analysis of CWT data is commonly employed to provide estimates of impacts of pre-terminal fisheries, natural mortality, maturation schedules, and adult equivalence factors. The basic procedure for estimating production in adult equivalents involves the following steps:

For each age class:

1. Estimate Spawning Escapement.

2. Estimate escapement past fisheries by dividing (1) by an estimate of pre-spawning, post-fishery survival.

3. Estimate the terminal run size by adding terminal fishery impacts to (2).

CWT data. Care must be taken, however, to account for potential differential estimation of spawning escapement by age and sex. For some early-maturing stocks, the failure to account for precocious males could bias estimates of production. This is because accurate spawning escapement estimates for jacks are rarely available, but jacks are included within estimates of adult equivalent brood year exploitation rates. When it is not possible to generate useful estimates of age-specific spawning escapements, other procedures can be employed. For instance, assumptions may be made regarding the predominant age class in escapement so that spawning escapement and production can be lagged by a fixed interval.

[23] Adult equivalents are the number of potential adults that would be expected to return to their rivers of origin in the absence of fishing. Morishima (1999) provides detailed information regarding the derivation and use of various metrics employed in fishery management.

4. Estimate the number of fish remaining in the ocean after fishing by dividing the terminal run (3) by the maturation rate derived from cohort analysis.

5. Estimate the cohort size prior to fishing by dividing (4) by (1- ocean fishery exploitation rate) derived from cohort analysis.

6. Estimate the ocean fishing mortality by multiplying (5) by the ocean fishery exploitation rate derived from cohort analysis.

7. Estimate ocean fishing mortality in adult equivalents by multiplying (6) by the adult equivalence factor derived from cohort analysis.

8. Normalize adult equivalent ocean fishing mortality to compensate for variability in early marine survivals. When performing stock-production analysis, the environment in which these fish reproduce is assumed to be stable. This assumption is of questionable validity, given the time required to obtain each observation (e.g., 5-6 years for Chinook) and high variability in marine survival rates. Normalization also provides a means to try to distinguish between variations due to process error and trends or survival patterns associated with periodic environmental conditions.

To estimate production from the brood year escapement, ocean fishing mortality in adult equivalents and terminal run sizes by age are summed. In summary, the capacity to employ S-R analysis to guide harvest management requires well-designed monitoring programs for estimating spawning escapement and impacts of pre-terminal fishing. The estimates for S-R analysis for many of the ESA listed stocks are subject to very large error because the counts may be contaminated by inclusion of supplementation releases or hatchery strays, and because the estimate of central importance is the effective number of recruits per spawner of natural spawning origin. This latter requires distinguishing between the naturally spawned progeny of supplementation releases (or strays) and the naturally spawned progeny of fish that themselves were naturally spawned. Empirical measurements of these respective rates are generally lacking, and "expert opinion" spans a wide range.

Abundance Estimates. Annual implementation of harvest management strategies involves information about abundance, both preseason and in-season. The same types of data required for S-R analysis have proven to be useful for preseason abundance forecasting. For many stocks, estimates of age-specific spawning escapements, terminal run sizes, and ocean exploitation rates provide the basis for annual abundance forecasts that drive harvest management planning processes. These forecasts commonly rely upon sibling relationships; the abundance of a younger age class from a given brood year has proven to be a useful indicator of the abundance of older age classes.

Reliable in-season estimates of abundance for individual populations of interest to harvest management are rarely available for highly mixed-stock fisheries. In-season estimates of abundance are extensively employed in the management of terminal area fisheries in order to constrain fishing mortality to achieve specific management objectives for escapements. Methods used to estimate abundance as fish approach terminal areas involve consideration of a variety of data, including dam or weir counts, run timing patterns, catch rates, and tag detections.

Fishery monitoring. Harvest management requires estimates of fishing mortalities to constrain impacts to allowable levels. For highly mixed-stock fisheries, the composition of fishery mortalities is projected through the use of planning models that integrate annual, stock-specific forecasts of abundance, historical CWT data to characterize observed patterns of fishery exploitation on individual stocks, and expectations for fishing patterns. Data collected to monitor ocean fisheries are largely limited to aggregate catches of all stocks and ages, fishing effort and catch rates, and fish size. Catches are monitored in-season to ensure that allowable harvest levels (e.g., quotas) are not exceeded. Effort and catch rates are employed to determine opening and closing dates for fisheries and to identify substantial deviations from preseason expectations of abundance and fishing patterns. Data on fish size are commonly relied upon to detect abnormal ocean conditions that affect growth and survival. In terminal areas, fishing effort patterns and stock-specific estimates of fishery impacts are considered when decisions are made to open or close fisheries in-season. Monitoring fishing mortality rates for ESA listed stocks presents special and severe practical difficulties. These stocks for the most part are not tagged or marked, and estimates of their fishing mortality depends on extrapolation from estimates of fishing mortality rates on other marked stocks which are predominantly hatchery stocks. The uncertainty introduced by this extrapolation needs some attention for it to be quantified realistically. Further, listed stocks are rare in abundance and difficult to sample in large mixtures of stocks in most fisheries.

Variable needs for accuracy and precision. Figure 7e-5 depicts the need to consider different productivities in the management of mixed stock fisheries. This figure also illustrates the effect of prolonged periods of abnormal survival. The middle line representing an average stock could just as well represent the exploitation rate that can be sustained by a single population under normal environmental conditions. The upper and lower lines could then represent the exploitation rates that can be sustained when survivals are abnormally high and low, respectively. These lines indicate that different exploitation rates for the same population would be appropriate if prolonged periods of abnormal survivals are experienced; for example, the lower line indicates that a failure to reduce exploitation rates during a period of prolonged depression in survivals could lead to stock depression or even extirpation over time.

Figure 7e-5 provides insight into how changes in stock status or differences in productivities among populations might be taken into account in monitoring programs. When survival is above average (or for more productive populations) and exploitation rates are low relative to sustainable levels, a greater degree of imprecision can be tolerated in estimates of exploitation rates and spawning escapements. In contrast, the steep slope of the lower line indicates that sustainable exploitation rates for less productive populations are much more sensitive to spawning escapement levels and that harvests can be sustained over a much narrower range of spawning escapements. When survival is low (or for stocks with low productivity), tolerance for error decreases. Monitoring programs should be capable of providing more precise and accurate estimates of fishery exploitation and spawning escapements for less productive stocks or during periods of depressed survivals, especially when exploitation rates are allowed to approach conservation limits.

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Appendix A. Harvest Management Functions for Three Columbia River Basin Stocks

Harvest management functions differ between salmon species or sub-groups within a species. The table below describes and compares some of these differences using three examples of Columbia basin salmon runs of varying characteristics: 1) a healthy natural stock (Upriver Bright fall Chinook); 2) an ESA-listed stock impacted by ocean fisheries (Snake River fall Chinook); and 3) an ESA-listed stock that is not harvested significantly in ocean fisheries (spring Chinook). For each example, the range of management functions is identified vertically in the table. For each management function, the responsible institutional entities, legal authorities, decision time frames, and relevant scientific issues and questions are presented horizontally.

1. Upriver Bright Fall Chinook

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Define harvest management unit	State of Washington	RCW…			Are management unit definitions appropriate for the structure of the reproductive population (e.g., combining SRF into a URB management unit for purposes of harvest management)?
	Columbia River treaty tribes	Co-management under U.S. v Oregon (OR)			
Establish conservation objectives and constraints for naturally spawning stocks	Columbia River treaty tribes, WA, OR, ID	Co-management under U.S. v. Oregon (OR)	Comply with conservation and allocation obligations	Reflected in long-term management plans when such exist, otherwise memorialized in annual fishing plan agreements.	Are conservation objectives and legal obligations adequately described and relevant technical basis documented? (Note the escapement goal for Upriver Bright Chinook has been reviewed by the PSC Chinook Technical Committee, but components, such as Snake River fall Chinook have not been separated – this is an aggregate spawning escapement goal for all naturally spawning fish, regardless of origin) How are contributions of hatchery fish to natural spawning escapements estimated? Are hatchery strays accounted for when determining whether or not escapement objectives have been achieved? Is the scientific and policy basis for jeopardy standards adequately described?
	USFWS & NOAA fisheries	ESA	Establish jeopardy standards for ESA listed stocks (Snake River fall Chinook and B run Steelhead) which may affect or be affected by management of URB, i.e., Snake River fall Chinook, upriver summer Chinook, and steelhead		
Establish conservation objectives and production goals for hatchery complexes	States of WA, OR, ID, USFWS, and tribes operating hatchery facilities	Agencies establish escapement needs and production goals. Production objectives subject to negotiation under U.S. v. OR	May operate under an overall mitigation plan or U.S. v. OR management plan.		Is hatchery production properly balanced with wild production objectives?

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Ocean Fisheries Management (Upriver Bright Fall Chinook)					
Preseason abundance forecasts	Prepared by agencies and processed thru Columbia River Technical Advisory Committee (TAC)	US. V. OR		Preliminary expectations of the number of fish expected to return to Bonneville Dam, converted to river mouth returns. First forecasts available in December, age-specific forecasts in February	What are the methods employed to generate the forecasts? What is the reliability of the forecasts?
Establish management objectives and constraints	PFMC	MFCMA	Specified in framework management plan	Periodic	
	Treaty Troll Tribes	U.S. v. WA	Intertribal agreements	Periodic	
	PSC	Pacific Salmon Treaty Act	Fishery regimes adopted by PSC establishes international obligations	Periodic	Estimation of abundance index
	CDFO		Domestic management objectives within constraints of PSC regimes	Annual, allowable impacts determined through calibration of CTC Chinook model	Estimation of abundance index
	NPFMC & State of Alaska		Management objectives within constraints of PSC regimes	Ditto	
	NOAAF-NMFS	ESA	Establish annual guidance for ESA listed stocks, which may affect management of URB.	Mar-Apr	Scientific basis for guidance?
Develop annual management plans	PFMC	MFCMA	Framework Plan, PSC Chinook model, Chinook FRAM	March-April	Are the models and methods of analysis scientifically sound?
	Treaty Troll Tribes	Inherent management authority	Negotiated harvest levels	March-April	
	CDFO		Domestic planning processes	May-June	
	Alaska Board of Fisheries		Sector (troll, sport, net) allocation schedule for Southeast Alaskan fisheries	Routine	

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Ocean Fisheries Management (Upriver Bright Fall Chinook) continued…					
Approve management plans	US Secretary of Commerce	Administrative delegation	Compliance with National Standards and applicable law	May	
In season management to implement regulations	States of WA, OR, AK, treaty troll tribes, CDFO, NOAAF thru PFMC		Compliance with management plans	Continuous in season	Are the in-season monitoring measures adequate to constrain impacts to allowable levels?
Reporting	States of WA, OR, AK, CDFO, treaty troll tribes		Provide periodic updates of fishery progress	Continuous in season, postseason report	Is the reporting timely and accurate? Are post-season analyses of ocean fishery impacts completed in a timely manner so as to be taken into account in harvest management planning?
			Post season report	January following season end	

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
In-River Fisheries Management (Upriver Bright Fall Chinook)					
Regulate Commercial Fisheries	Columbia River Compact. For Non-Indian fisheries, OR/WA staff typically review proposals for fisheries and make recs. TAC reviews "fact sheets" and past fishery harvest data, but does not typically review fishery proposals in advance of the conduct of fisheries.	USC…	Meet conservation and treaty allocation requirements. Treaty Indian fisheries authorized by enacting regulations that allow non-Indians to purchase Indian fish.	Aug-Oct	In season run size updates made when ~50% of run expected to return (~Sept 10) and periodically afterwards. Upriver Run components broken out by URB, MCB, and BPH. BPH distinguished from Brights by skin coloration. URB & MCB separates jacks and adults by size with stock separation via CWTs. Recent 5-year average dam conversion rates are assumed.
	For tribal commercial fisheries, tribes set actual regulations	Compact adopts regulations authorizing the purchase of fish caught in Indian fisheries by non-Indian residents of WA & OR			
	NOAA-NMFS	ESA	Jeopardy standards for SRF based on % of river mouth run size. Assuming that SRF is a fixed proportion of URB run. B-run steelhead constraint differs for treaty and nontreaty fisheries. For nontreaty fisheries, B-run impacts are based on preseason estimates of abundance and estimates made through run-reconstruction since fish are released. Treaty impacts are based at % limits of impacts at Bonneville, based on monitoring at Bonneville, based on length (fish>78cm are assumed to be B-Run fish), ad-clips and scale sampling.		What is the scientific basis for the jeopardy standards? How valid is the assumption of a fixed proportion of the URB run being comprised of SRF wild fish? What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates? Is the separation of A&B run steelhead based on size well supported by data?

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
In-River Fisheries Management (Upriver Bright Fall Chinook) continued…					
Regulate Sport Fisheries	WA/OR work cooperatively, but act separately from the Columbia River Compact in setting season, bag limits, etc. States take action in "Joint State Sport Hearings" that function much like the Compact does for commercial fisheries. Joint Columbia River staff reviews sport fishery proposals. Harvest data reviewed by TAC	RCW… RCO…		Aug-Oct	
	NOAA-NMFS	ESA	Jeopardy standards for SRF based on % of river mouth run size. Assuming that SRF is a fixed proportion of URB run. B-run steelhead constraint based on preseason estimates of abundance since fish are released.		How valid is the assumption of a fixed proportion of the URB run being comprised of SRF wild fish? What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates?
Post Season Review (Upriver Bright Fall Chinook)					
Escapement Estimation & reporting	WDFW, ODFW, Tribes, IFG, NOAA fisheries, USFWS			Sep-Jan	Escapement of URBs by McNary Dam counts. Age composition via CWTs and scales taken during sampling of spawning grounds and hatchery rack returns. Accuracy of age composition estimates for fun components?
Read & report CWT recoveries	ODFW	Agreement		Aug-Jan	
In-river run reconstruction	WDFW. Review by TAC	Agreement		Jan-Feb	Accuracy of dam passage conversion rates (Dam counts minus estimated catch minus known turn offs to tributaries)?

2. Snake River Fall Chinook (Sub-Group) of Upriver Brights

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Basis
Define harvest management unit	States of WA, OR, ID	RCW…			Are management unit definitions appropriate for the structure of the reproductive population (e.g., combining SRF into a URB management unit for purposes of harvest management)?
	Columbia River treaty tribes	Co-management under U.S. v Oregon			
Establish conservation objectives and constraints for naturally spawning stocks	Columbia River treaty tribes	Co-management under U.S. v. Oregon	Comply with conservation and allocation obligations	Reflected in long-term management plans when such exist, otherwise memorialized in annual fishing plan agreements.	Are conservation objectives and legal obligations adequately described and relevant technical basis documented? How are contributions of hatchery fish to natural spawning escapements estimated? Are hatchery strays accounted for when determining whether or not escapement objectives have been achieved? Is the scientific and policy basis for jeopardy standards adequately described?
	NOAA fisheries	ESA	Establish jeopardy standards		
Establish conservation objectives and production goals for hatchery complexes	States of WA, OR, ID and tribes operating hatchery facilities	Agencies establish escapement needs and production goals	May operate under an overall mitigation plan or U.S. v. OR management plan.		Is hatchery production properly balanced with wild production objectives?
Ocean Fisheries Management (Snake River Fall Chinook)					
Preseason abundance forecasts (None – fixed small cohort sizes to estimate exploitation rates)		MSFCMA			
Establish management objectives and constraints	PFMC	MFCMA	Specified in framework management plan	Periodic	
	PSC	Pacific Salmon Treaty Act	Fishery regimes adopted by PSC establishes international obligations	Periodic	Estimation of abundance index
	CDFO		Domestic management objectives within constraints of PSC regimes	Annual, allowable impacts determined through calibration of CTC Chinook model	Estimation of abundance index
	NPFMC & State of		Management objectives	Ditto	
	Alaska		With in constraints of PSC regimes		
	NOAAF-NMFS	ESA	Establish annual guidance	Mar-Apr	Scientific basis for guidance?
Function	**Responsible Entity**	**Authority**	**Legal constraints and**	**Time frame**	**Scientific Basis**

			obligations		
Ocean Fisheries Management (Snake River Fall Chinook) continued…					
Develop annual management plans	PFMC	MFCMA	Framework Plan, PSC Chinook model, Chinook FRAM, KOHM	March-April	Are the models and methods of analysis scientifically sound?
	Treaty Troll Tribes	Inherent management authority	Negotiated harvest levels	March-April	
	CDFO		Domestic planning processes	May-June	
	Alaska Board of Fisheries		Sector (troll, sport, net) allocation schedule for Southeast Alaskan fisheries	Routine	
Approve management plans	US Secretary of Commerce	Administrative delegation	Compliance with National Standards and applicable law	May	
In-season management to implement regulations	States of WA, OR, AK, treaty troll tribes, CDFO, NOAAF thru PFMC		Compliance with management plans	Continuous in-season	Are the in-season monitoring measures adequate to constrain impacts to allowable levels?
Reporting	States of WA, OR, AK, CDFO, treaty troll tribes		Provide periodic updates of fishery progress	Continuous in-season, postseason report	Is the reporting timely and accurate? Are post-season analyses of ocean fishery impacts completed in a timely manner so as to be taken into account in harvest management planning?
			Post season report	January following season end	

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Basis
In-River Fisheries Management (Snake River Fall Chinook)					
Regulate Commercial Fisheries	Columbia River Compact. Proposed fishing schedules reviewed by TAC	USC…	Meet conservation and treaty allocation requirements. Treaty Indian fisheries authorized by enacting regulations that allow non-Indians to purchase Indian fish. In-season run size updates based made when 50% of run expected to return (~Sept 10). Run components broken out by URB, MCB, BPH. BPH distinguished from Brights by skin coloration. URB & MCB separates jacks and adults by size with stock separation via CWTs. Recent 5-year average dam conversion rates are assumed.	Aug-Oct	
	NOAA-NMFS	ESA	Jeopardy standards for SRF based on % of river mouth run size. Assuming that SRF is a fixed proportion of URB run. B-run steelhead constraint differs for treaty and nontreaty fisheries. For nontreaty fisheries, B-run impacts are based on preseason estimates of abundance since fish are released. Treaty impacts are based at % limits of impacts at Bonneville, based on monitoring at Bonneville, based on length (fish>78cm are assumed to be B-Run fish), ad-clips and scale sampling		What is the scientific basis for the jeopardy standards? How valid is the assumption of a fixed proportion of the URB run being comprised of SRF wild fish? What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates? Is the separation of A&B run steelhead based on size well supported by data?
Regulate Sport Fisheries	WA/OR work cooperatively, but act independently in setting season, bag limits, etc. Technical review by TAC	RCW… RCO…		Aug-Oct	
	NOAA-NMFS	ESA	Jeopardy standards for SRF based on % of river mouth run size. Assuming that SRF is a fixed proportion of URB run. B-run steelhead constraint based on preseason estimates of abundance since fish are released.		How valid is the assumption of a fixed proportion of the URB run being comprised of SRF wild fish? What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates?

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Post Season Review (Snake River Fall Chinook)					
Escapement Estimation & reporting	WDFW, ODFW, Tribes, IFG			Sep-Jan	Escapements of SRF via counts @ Lower Granite Dam, trap data, & Lyons Ferry returns to account of hatchery fish, supplementation fish, and natural origin fish. SRF wild age composition assumed identical to CWT'd sub-yearling releases as determined from CWTs. Some age data collected at Bonneville, but not at Lower Granite. Accuracy of age composition estimates? Accuracy of age composition estimates? Accuracy of age composition estimates?
Read & report CWT recoveries	ODFW	Agreement		Aug-Jan	
In-river run reconstruction	WDFW. Review by TAC	Agreement		Jan-Feb	Accuracy of dam passage conversion rates (Dam counts minus estimated catch minus known turn offs to tributaries)?

3. B-Run Steelhead

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Basis
Define harvest management unit	States of WA, OR, ID	RCW…			Are management unit definitions appropriate for the structure of the reproductive population (A&B run components)?
	Columbia River treaty tribes	Co-management under U.S. v Oregon			
Establish conservation objectives and constraints for naturally spawning stocks	Columbia River treaty tribes	Co-management under U.S. v. Oregon	Comply with conservation and allocation obligations	Reflected in long-term management plans when such exist, otherwise memorialized in annual fishing plan agreements.	Are conservation objectives and legal obligations adequately described and relevant technical basis documented? How are contributions of hatchery fish to natural spawning escapements estimated? Are hatchery strays accounted for when determining whether or not escapement objectives have been achieved?
	NOAA fisheries	ESA	Establish jeopardy standards		Is the scientific and policy basis for jeopardy standards adequately described?
Establish conservation objectives and production goals for hatchery complexes	States of ID, USFWS, and tribes operating hatchery facilities	Agencies establish escapement needs and production goals	May operate under an overall mitigation plan or U.S. v. OR management plan.		Is hatchery production properly balanced with wild production objectives?

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Ocean Fisheries Management (B-Run Steelhead) (Harvest Presumed Negligible)					
In-River Fisheries Management (B-Run Steelhead)					
Regulate Commercial Fisheries	For Non-Indian fisheries, OR/WA staff typically review proposals for fisheries and make recs. TAC reviews “fact sheets” and past fishery harvest data, but does not typically review fishery proposals in advance of the conduct of fisheries. For tribal commercial fisheries, tribes set actual regulations; the Columbia River Compact adopts regulations authorizing the purchase of fish caught in Indian fisheries by non-Indian residents of WA & OR Tribal terminal fisheries are negotiated with ID. Impacts are included in overall in-river impacts negotiated in U.S. v. OR.	USC…	Meet conservation and treaty allocation requirements. Treaty Indian fisheries authorized by enacting regulations that allow non-Indians to purchase Indian fish.	Aug-Oct	Separation of steelhead into A&B run components is based on size (fish >78 cm assumed to be B Run). Recent PIT tag data suggest that this may not be a valid assumption. Is the separation of A&B run steelhead based on size well supported by data? Steelhead run sizes are only estimated at Bonneville Dam. Fall season, non-Indian commercial fisheries are not monitored for total steelhead handled or mortality. B-Run impacts estimated using old creel census data and a stock composition model. How accurate are the impacts estimated and accounted for in lower river fisheries? In-season run size updates based made when 50% of run expected to return. Recent 5-year average dam conversion rates are assumed. Impacts of tribal commercial fisheries during the fall season are estimated through fishery monitoring programs and adjusted by sampling data collected at Bonneville Dam
	NOAA-NMFS	ESA	Jeopardy standards for B-run steelhead differ for treaty and nontreaty fisheries. For nontreaty fisheries, B-run impacts are based on preseason estimates of abundance since fish are released. Treaty impacts are based at % limits of impacts at Bonneville Dam, based on monitoring at BD, based on length (fish>78cm are assumed to be B-Run fish), ad-clips and scale sampling. Jeopardy stds for B-run steelhead only apply during fall fisheries. Impacts during the summer season are not estimated separately for A and B run fish.	Aug-Oct	What is the scientific basis for the jeopardy standards? How valid is the assumption of a fixed proportion of the URB run being comprised of SRF wild fish? What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates? Are estimates of ceremonial and subsistence and take home fish available and of sufficient magnitude to warrant consideration in management constraints

Function	Responsible Entity	Authority	Legal constraints and obligations	Time frame	Scientific Issues and Questions
Regulate Sport Fisheries	WA/OR work cooperatively, but act independently in setting season, bag limits, etc. Technical review by TAC ID regulates its fisheries independently	RCW… RCO…		Aug-Oct	Sport fisheries for steelhead are all selective, requiring the release of all fish with adipose fins intact. Impacts on B-run fish in mainstem Columbia River fisheries are limited to a specific percentage of the run, but actual impacts are not estimated because requisite data are not collected in sport fisheries. Is the coordination among the managers sufficient to insure that allowable impacts are adequately constrained?
	NOAA-NMFS	ESA	Jeopardy standards for B-run steelhead constraint based on preseason estimates of abundance since fish are released.		What is the accuracy of preseason abundance forecasts of B-run steelhead and sensitivity to assumptions regarding release mortality rates?
Post Season Review (B-Run Steelhead)					
Escapement Estimation & reporting	WDFW, ODFW, Tribes, IFG			Sep-Jan	Escapement by Lower Granite Dam counts. Age composition via scales taken during sampling at dams. Very little sampling data exists for B-run steelhead on spawning grounds. Accuracy of age composition estimates?
Read & report CWT recoveries	ODFW	Agreement		Aug-Jan	CWTs are not used for harvest management, but may be used for purposes of hatchery management.
In-river run reconstruction	WDFW. Review by TAC	Agreement		Jan-Feb	A & B run returns are estimated separately for Bonneville and Lower Granite Dams. Are TAC's estimates for A&B run fish comparable and accurate ((a) separation is by size & some large fish go to places other than the Snake and some B run fish are <78 cm and would not be considered B run fish at Bonneville Dam or in tribal fisheries; (b) some steelhead pass dams during the winter when no counts are made)? Complete information is not available so conversion loss is not estimated. Since no total run reconstruction is available, how are impacts evaluated and run status determined?

Appendix B. Table of Columbia River Salmonids organized by Ocean, In-River, and ESA Management Units

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
Chinook								
Snake River spring/summer-run Chinook salmon	Not applicable for ocean fisheries - negligible impact	Not applicable for ocean fisheries - negligible impact	Management period January 1 through June 15. Sliding scale harvest rates, depending on status of upriver spring Chinook and Snake River summer Chinook. Ceremonial and subsistence harvest treated separately from commercial and recreational fisheries.	Dam counts, in-season catch monitoring. Upriver spring Chinook includes all natural and hatchery spring Chinook stocks originating from the Columbia River and its tributaries upstream of Bonneville Dam. Snake River summer Chinook includes all natural and hatchery summer Chinook stocks originating from the Snake River watershed.	Snake River spring/summer-run Chinook salmon	Threatened	All natural populations of spring/summer-run Chinook salmon using tributaries to the mainstem Snake River. Major subbasins are the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River. Spring/summer Chinook introduced into the Clearwater River subbasin were excluded from the ESU.	Lower Snake River Tributaries: Tucannon River; Asotin Creek Wenaha; Wallowa-Lostine; Minam; Catherine Creek; Upper Grande Ronde; Imnaha Main Stem; Big Sheep; Lookingglass Creek (extirpated) Little Salmon River South Fork Salmon: South Fork Mainstem; Secesh; East South Fork Chamberlain Creek: Chamberlain Creek Middle Fork Salmon: Big Creek; Lower Middle Fork Mainstem; Camas Creek; Loon Creek; Pistol Creek; Sulphur Creek; Bear Valley Creek; Marsh Creek; Upper Middle Fork Mainstem Upper Salmon: North Fork Salmon River; Lemhi River; Pashimeroi River; Upper Salmon Lower Mainstem; East Fork Salmon River; Yankee Fork; Valley Creek; Upper Salmon River Mainstem; Panther Creek (extirpated)
Upriver Springs	Ensure that ocean fishery impacts remain rare and recognize Columbia River Management Plan Objective	Not applicable for ocean fisheries - negligible impact	Same as for Snake River spring/summer Chinook	Same as for Snake River spring/summer Chinook	Upper Columbia River spring-run Chinook salmon	Endangered	All naturally spawned populations of spring-run Chinook salmon in all Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington State. Major tributary subbasins with existing runs are the Wenatchee, Entiat, and Methow Rivers.	Wenatchee River and all its tributaries except Icicle Creek Entiat River Methow River: Methow and Twisp Rivers

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
Middle Columbia River spring-run Chinook salmon	Hold ocean fishery impacts <1% and recognize Columbia River Management Plan objective	Not applicable for ocean fisheries - negligible impact	Same as for Snake River spring/summer Chinook	Same as for Snake River spring/summer Chinook	Middle Columbia River spring-run Chinook salmon	Not warranted	Naturally spawned populations of spring-run Chinook salmon in the Columbia River basin upstream of the Wind River, Washington, and the Hood River, Oregon, to and including the Yakima River, except for Chinook from the Snake River subbasins. Major tributaries in the ESU are the Yakima, Klickitat, Deschutes, John Day, Umatilla, and Walla Walla Rivers.	
Upriver summer Chinook	Hold ocean exploitation rates <2% and recognize in-river management objectives	Wells Hatchery; CTC Chinook Model, PFMC Chinook FRAM	Management period June 16 through July 31. Hatchery production and natural spawning escapement goal. Sliding scale of in-river harvest rates depending on in-river run size.	Dam counts	Upper Columbia River summer/fall-run Chinook salmon	Not warranted	Naturally spawned populations of summer and fall-run Chinook in streams in the Columbia River basin upstream of and including the Yakima River to the U.S.–Canada border. Major tributary subbasins in this ESU are the Yakima, Wenatchee, Entiat, Methow, and Okanogan Rivers.	
Snake River fall-run Chinook salmon	NMFS jeopardy or recovery standard. Since 1995, total age-4/4 adult equivalent exploitation rate no greater than 70% of 1988-1993 average for all ocean fisheries combined.	Lyons Ferry Hatchery Stock; CTC Chinook Model and PFMC Chinook FRAM	Inriver mainstem non-Indian and treaty Indian fisheries managed under harvest rate limits with a combined impact comparable to a 30% reduction in the age 3/4 adult equivalent exploitation rate for ocean fisheries.	Dam counts, assumed percentage of total upriver bright run, in-season catch monitoring	Snake River fall-run Chinook salmon	Threatened	All natural populations of fall-run Chinook salmon in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins.	Snake River Mainstem and Lower Tributaries

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
Upriver Bright fall Chinook	40,000 natural bright adults above McNary Dam (increased to 43,000 by Columbia River state and tribal managers) and recognize in-river management objective	Brights: Priest Rapids Hatchery Stock and Hanford Reach natural stock;	40,000 escapement goal at McNary Dam plus production goals for Spring Creek National Fishery, Klickitat Hatchery, Little White Salmon Hatchery, and Mid-Columbia Bright Fall Chinook which are not treated as management constraints.	Dam counts, assumed percentage of total upriver bright run, skin coloration, run timing, in-season catch monitoring	Upper Columbia River summer/fall-run Chinook salmon	Not warranted	Naturally spawned populations of summer and fall-run Chinook in streams in the Columbia River basin upstream of and including the Yakima River to the U.S.–Canada border. Major tributary subbasins in this ESU are the Yakima, Wenatchee, Entiat, Methow, and Okanogan Rivers.	
Deschutes River summer/fall-run Chinook salmon	None	None	Managed as part of upriver bright complex with special consideration for escapement of Deschutes River component.	Dam counts, assumed percentage of total upriver bright run, skin coloration, run timing, in-season catch monitoring	Deschutes River summer/fall-run Chinook salmon	Not warranted	Naturally spawned populations of summer and fall-run Chinook in the Deschutes River basin.	

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
Steelhead								
	None - negligible ocean fishery impacts	None - negligible ocean fishery impacts	Managed in accordance with annual in-river modeling results.	A-Run Steelhead (fish smaller than 78 cm, primarily returning to Snake, Salmon, Grande Ronde, Imnaha Rivers	Snake River basin steelhead	Threatened	All naturally spawned populations of steelhead in the Snake River basin. Major tributary subbasins in this ESU are the Tucannon, Clearwater, Grande Ronde, Imnaha, and Salmon Rivers.	Lower Snake River: Tucannon River; Asotin Creek Clearwater River: Lower Clearwater River; South Fork Clearwater River; Lolo Creek; Selway River; Lochsa River; North Fork Clearwater River (extirpated) Grande Ronde River: Lower Grande Ronde; Joseph Creek; Wallowa River; Upper Grande Ronde
			Managed in accordance with annual in-river modeling results. Separate harvest rate constraints on wild B-run steelhead for non-Indian fisheries outside the Snake River and Treaty Indian Zone 6 fisheries.	B-Run Steelhead (fish returning after August 25th and larger than 78 cm fork length and passing Bonneville Dam between July 1 and October 31), primarily returning to Clearwater and Salmon Rivers				Salmon River: (Resident & Migrant) Little Salmon & Lower Salmon Tributaries; South Fork Salmon River; Secesh River; Chamberlain Creek; Lower Middle Fork Salmon River; Upper Middle Fork Salmon River; Panther Creek; North Fork Salmon River; Lemhi River; Pashimeroi River; East Fork Salmon River; Upper Mainstem Salmon River Imnaha River: (Resident & Migrant) Imnaha River Hells Canyon: (Resident & Migrant) Hells Canyon Tributaries
None	None - negligible ocean fishery impacts	None	Expected in-river mainstem harvest rates up to 3.4%		Upper Columbia River steelhead	Endangered	Naturally spawned populations of steelhead in streams in the Columbia River basin upstream of the Yakima River to the U.S.–Canada border. Major tributary subbasins in this ESU are the Wenatchee, Entiat, Methow, and Okanogan Rivers.	Wenatchee River: (Resident & Migrant) Wenatchee River & Tributaries Entiat River: (Resident & Migrant) Entiat River; Methow River; Twisp River Okanogan River: (Resident & Migrant) Okanogan River

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
None	None - negligible ocean fishery impacts	None	Non-Indian in-river mainstem fisheries subject to a harvest rate constraint; treaty Indian fishery impacts on winter-run steelhead considered negligible.	Dam counts, in-season catch monitoring	Middle Columbia River steelhead	Threatened	Naturally spawned populations of steelhead in the Columbia River basin upstream of the Wind River, Washington, and the Hood River, Oregon, to and including the Yakima River, except for steelhead from the Snake River subbasins Major tributaries in the ESU are the Yakima, Klickitat, Deschutes, John Day, Umatilla, and Walla Walla Rivers.	Cascades Eastern Slope Tributaries: (Resident & Migrant) Klickitat River; Fifteen Mile Creek; Deschutes River Eastside Tributaries; Deschutes River Westside Tributaries; White Salmon River (extirpated); Deschutes River above Pelton Dam (extirpated)
								John Day River: (Resident & Migrant) Lower Mainstem John Day; North Fork John Day; Middle Fork John Day; South Fork John Day; Upper Mainstem John Day
								Rock Creek: (Resident & Migrant) Rock Creek (cont.)
								Walla Walla & Umatilla Rivers: (Resident & Migrant) Umatilla River; Walla Walla River; Touchet River
								Yakima River: (Resident & Migrant) Satus and Toppenish Creeks; Naches River; Upper Yakima
Sockeye								
None	None - negligible ocean fishery impacts	None	Escapement goal for adult sockeye at Priest Rapids Dam. Non-Indian in-river harvest rate fixed constraint. Treaty Indian fishery harvest rates regulated on sliding scale depending on upriver sockeye run size.	Dam Counts, separation of Snake River and Columbia River stocks	Snake River sockeye salmon	Endangered	The only extant population of the anadromous form is the Redfish Lake population. Historically, sockeye runs were found in the Stanley River basin, Payette Lake, Warm Lake and Wallowa Lake.	Redfish Lake: Redfish Lake (anadromous and residual/resident beach spawners)
None	None - negligible ocean fishery impacts	None	Same as above	Dam Counts, separation of Snake River and Columbia River stocks	Okanogan River sockeye salmon	Not warranted	Naturally spawned populations of sockeye salmon in Osoyoos Lake and its U.S. tributaries, and the U.S. portion of the Similkameen River.	
None	None - negligible ocean fishery impacts	None	Same as above	Dam Counts, separation of Snake River and Columbia River stocks	Lake Wenatchee sockeye salmon	Not warranted	Naturally spawned populations of sockeye salmon in Lake Wenatchee and its tributaries, including the White and Little Wenatchee Rivers.	

OCEAN FISHERY MANAGEMENT			IN-RIVER MANAGEMENT		ESU INFORMATION			
(1)	(2)	(2)		(3)	(4)	(4)	(4)	(4)
Harvest Management Unit	**Ocean Harvest Management Objective**	**Indicator & method**	**In River Harvest Management Objective**	**Indicator & method**	**ESU**	**Listing Status**	**Description**	**Major Groupings: Component Populations**
Coho	50% of the harvestable upriver adult coho (south of the US-Canada border) available to fisheries above Bonneville Dam (PFMC requirement).	Prorated proportion of forecast abundance of Columbia River Early and Late Stocks derived from Coho FRAM model	Meet requirements for brood stock escapement necessary to meet Columbia River hatchery production goals. Natural spawning escapement goal to be developed and incorporated into a new Columbia River Fish Management Plan.	Dam counts	None	NA	NA	NA
White Sturgeon	None	NA	Annual review of sturgeon management issues results in reservoir-specific annual harvest constraints.	None	None	NA	NA	NA

(1) Commonly used name for harvest management unit

(2) Except for coho (PFMC requirement) and sturgeon, Appendix A of NMFS FPEIS for Ocean Fisheries.

(3) PSC Chinook Technical Committee

(4) Independent Populations of Chinook, Steelhead, and Sockeye for Listed Evolutionarily Significant Units Within the Interior Columbia River Basin Domain. Interior Columbia Basin Technical Recovery Team. July 2003.

Appendix C. Supplement to Questions, Section 6; Reductions in Fishery Impact Rates for Three Columbia River Salmon Populations

The distinction between the terms *harvest rate* and *exploitation rate* is important to understand when reviewing these examples.

> *Harvest rate* refers to the proportion of a population available to a fishery that is killed by that fishery. Harvest rates are most frequently used to quantify impacts of terminal area fisheries, such as those conducted on fish returning to the Columbia River on their spawning migration. Qualifiers are used to describe the type of proportion involved. For example, for a net fishery in the Columbia River, the *age 4, reported catch harvest rate* on URBs would represent the ratio between the numbers of age 4 URBs reported as being caught by that fishery divided by the terminal run size of age 4 URBs.
>
> In contrast, the term *Exploitation rate* refers to the proportion of an entire population that is killed by a fishery. Exploitation rates are most frequently used to quantify fishery impacts in ocean fisheries because the proportion of fish available to those fisheries is unknown. Both the proportion and the population involved are commonly described by the use of qualifiers. For example, an *adult equivalent, brood year, total mortality exploitation rate* represents the ratio between a numerator which consists of total fishing mortality (landed catch plus non-landed mortality) expressed in terms of adult equivalents[24] (the number of fish killed by fishing converted to potential numbers of adults) divided by the total number of adults that could be produced from the spawning escapement of a given stock and brood year. Similarly, an *age 3, reported catch exploitation rate for fishery X* represents the ratio between the number of age 3 fish from a given stock reported as being caught in fishery X divided by the total number of age 3 fish in that stock before fishery X occurs.

<u>Columbia River Up-River Bright Fall Chinook</u>

Adult equivalent (AEQ) brood year exploitation rates on the CWT indicator stock (Priest Rapids Hatchery fingerling releases) for Columbia River Up-River Bright Fall Chinook (URB) are depicted in Figure C-1. Three sources of fishing mortality are depicted: (a) the dark bar represents the AEQ exploitation rate for reported catch in all ocean fisheries; (b) the cross-hatched middle bar represents the AEQ exploitation rate for all in-river fisheries; and (c) the top portion of the bars represents the AEQ exploitation rate for incidental (non-catch) fishing mortality. AEQ Brood year exploitation rates are rarely employed as the basis for harvest management, but are commonly used to monitor impacts of fisheries in relation to stock productivity (see discussion in Background section 7e, and Morishima 1999).

[24] Since Chinook salmon are harvested at various ages and stages of maturity, exploitation rates are commonly expressed in terms of *adult equivalents* for this species to provide a consistent basis for monitoring fishery impacts over time. Adult equivalents are derived by multiplying the number of fish from a given stock and age harvested by a particular fishery by the appropriate adult equivalence factor, the probability that a fish that is alive at a given age would survive to return to its river of origin to spawn in the current or any future year, in the absence of fishing.

The data employed to generate Figure C-1 is derived from coded-wire-tag (CWT) releases of the *exploitation rate indicator stock* for URBs, fingerling releases from the Priest Rapids Hatchery. An *indicator stock* is consistently tagged to provide a means of monitoring changes in fishery impacts over time; this is particularly important for management of Chinook salmon because stock-age-fishery specific estimates of fishing mortality are otherwise extremely difficult and costly to obtain for the highly mixed stock fisheries in which this species is intensively exploited. The time series of data from CWT indicator stocks provides the only available source of historical data available to estimate changes in fishing mortality over an extended period of time.

Prior to enactment of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) in 1976, there was no capacity to constrain exploitation by ocean fisheries outside state territorial waters. Consequently, ocean fishery exploitation rates were simply the result of the fishing effort that was exerted, and fisheries inside state territorial waters bore the brunt of the responsibility for resource conservation. When the MSFCMA was enacted, regional fishery management councils were established within the United States to develop measures to regulate ocean fisheries within the fishery conservation zone (3-200 miles offshore). But there was still no capacity to constrain total impacts on far-north migrating stocks because Canadian fisheries were also impacting the same stocks.

In the early 1980's, the United States and Canada were engaged in bilateral negotiations to develop an international treaty that would constrain interceptions (the harvest of salmon originating in one country by fisheries conducted by the other) of salmon. During those deliberations, analysis of available coded-wire-tag (CWT) data revealed that the lack of adequate constraints on harvests throughout the migratory range of individual stocks had created an imminent conservation problem for Chinook salmon. Fishery impacts were increasing while spawning escapement levels plummeted. CWT data for URBs were employed in bilateral technical analyses that determined that substantial reductions in fishery exploitation rates were necessary to stop declining trends in spawning escapements and rebuild depressed stocks. Ultimately, the need to establish a coastwide approach for rebuilding depressed stocks of naturally spawning Chinook salmon proved to be pivotal in the capability of the United States and Canada to reach agreement on the Pacific Salmon Treaty (PST) in 1985.

During the final stages of the negotiations, CWT data indicate that the exploitation rates on URBs approached 80% in the mid-1980s. Now, total mortality AEQ brood year exploitation rates have been reduced to about 45%. Both ocean and in-river exploitation rates have been reduced due to a combination of the Pacific Salmon Treaty and the effects of listing Snake River Fall Chinook (a component of the URBs) under the Endangered Species Act (ESA) in May 1992. The ESA jeopardy standard for Snake River Fall Chinook, depends upon the level of coordination between fisheries, but is generally expressed as a 30% reduction on age 3/4 total adult equivalent fishing mortality exploitation rates from the level observed in 1988-1993. Exploitation rates by ocean fisheries have been reduced by from 25-30% for brood years of the mid-1980s to about 15%-20% for more recent broods.

As useful as AEQ brood year exploitation rates may be for comparing fishery exploitation rates in relation to stock productivity, these metrics are not commonly employed for harvest management. Harvest for fisheries impacting Columbia River Chinook salmon occurs annually and involves fish from many brood years simultaneously.

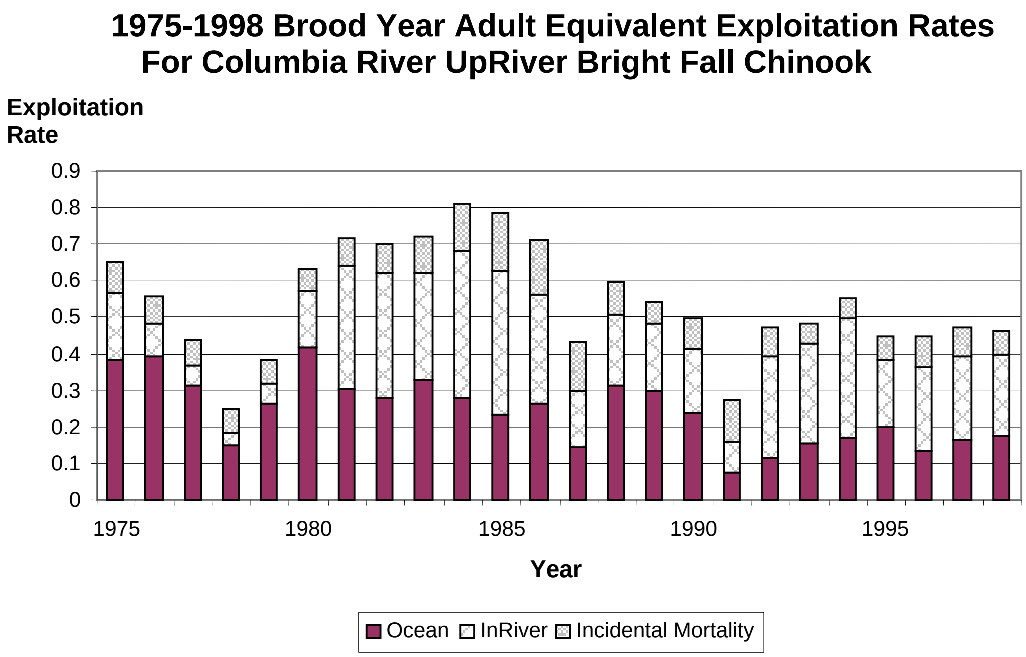

Figure C-1. 1975-1998 Brood Year Adult Equivalent Exploitation Rates for URBs, data from PSC document, TCCHINOOK (04)-4, Dec. 31, 2004. (www.psc.org/pubs/)

Ocean fisheries operate on a mixture of immature and maturing fish and are managed to try to constrain exploitation rates so that the appropriate escapement of mature fish results. For URBs, these mature fish are of various ages, which were produced by spawning escapements from several brood years.

Once fish escape highly mixed stock ocean fisheries, they return to their rivers on their spawning migrations. At this point, fewer stocks are involved and it is often possible to separate out individual complexes for harvest management.

Figure C-2 illustrates that in-river fishery harvest rates on URBs have fluctuated, but remained relatively stable. One of the objectives for the Pacific Salmon Treaty's (PST) coastwide Chinook rebuilding program was to provide stability for fisheries in terminal areas. For many stocks, terminal fisheries had been severely curtailed for several years in response to escalating impacts of ocean fisheries; further, impacts on naturally spawning fish had been reduced to by-catch during fisheries directed at other stocks and species. Figure C-2 depicts impacts of in-river fisheries on an annual basis for URBs. Five types of information are presented: (a) the cross-hatched bars reflect the URB terminal run size (number of adult fish entering the Columbia River); (b) the solid bars reflect URB spawning escapements; (c) the dotted line represents the URB spawning escapement goal; (d) the solid line represents the in-river harvest rate; and (e) the dashed line represents Bonneville-McNary Dam passage mortality rate (expressed as a proportion of fish escaping fisheries). Dam passage mortalities can be significant (occasionally exceeding 30%) and are additional factors that are taken into account in harvest management.

Prior to the mid 1980s when agreement on the PST was reached, spawning escapement levels were well below the established goal. Since that time, spawning escapements have rarely failed to achieve the goal even though in-river harvest rates have fluctuated in response to adjustments of fisheries in response to in-season data on abundance and harvest.

The in-river harvest rate depicted in Figure C-2 represents the proportion of the terminal run that is killed by in-river commercial and recreational fisheries. In contrast to the AEQ brood year exploitation rates depicted in Figure C-1, the data depicted in C-2 present annual data. Over much of the time series, the figure illustrates application of a harvest strategy based on escapement goal management (see Background section 7e). From 1990-1995, the in-river harvest rates were decreased in order to meet the escapement goal. Since then, terminal run sizes have increased, but in-river harvest rate decreased in response to declining run sizes. In recent years, in-river harvest rates have not increased to the extent supportable by the URB stock because of jeopardy standards established in response to concerns for fishery impacts on the ESA listed Snake River Fall Chinook stock. As a result, spawning escapements for this stock have exceeded the escapement goal established for this stock, preventing the harvest of otherwise harvestable URBs and commingled stocks.

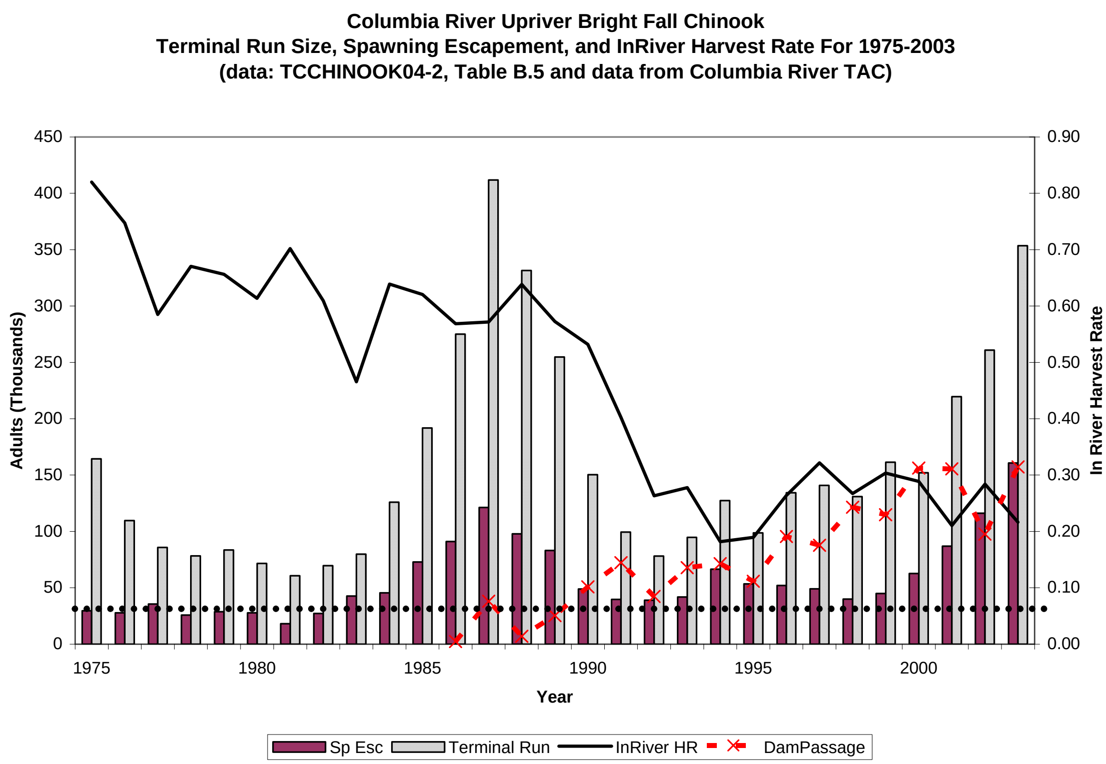

Figure C-2. 1975-2003 Annual Terminal Run Sizes, Spawning Escapement, Escapement Past Fisheries, and In-River Fishery Harvest Rates on URBs.

The fishery impacts depicted in Figure C-2 are due to a combination of management directed at reducing ocean and in-river fishery harvest rates and annual variations in abundance. Survival rates for URBs have exhibited substantial variability over the time series of available data. Figure C-3 depicts survival rate indices derived from releases of the indicator stock for URBs, CWT fingerling fall Chinook from Priest Rapids hatchery. The index (average = 1) shows a distinct downward trend, periods of depression and high interannual variability. Trends and extended periods of depressed survival suggest a potential need to adjust harvest management strategies to protect productivity (see Background section 7e) and respond to annual variability in stock conditions.

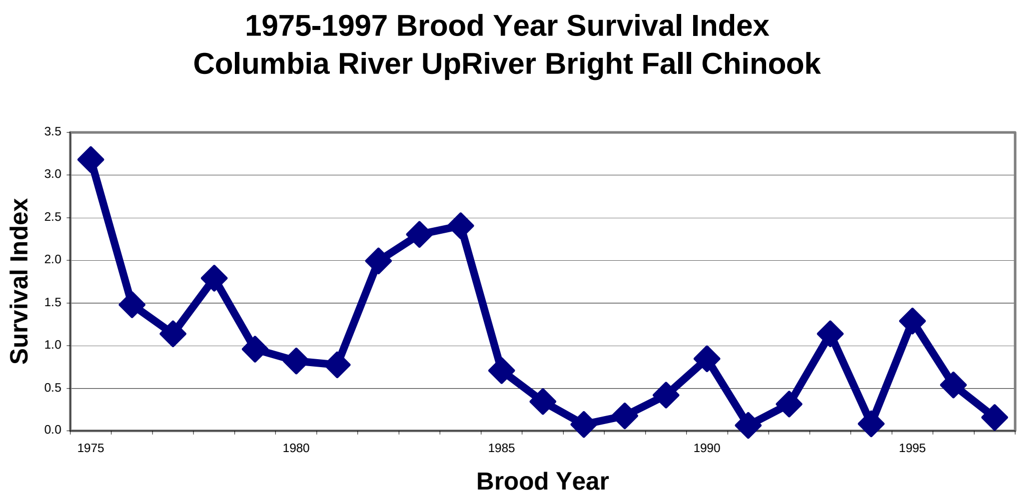

Figure C-3. Survival Index for CWT Indicator Stock for URBs.

Impacts of harvest management on the ESA listed Snake River Fall Chinook stock are depicted in Figures C-4 and C-5 which present data comparable to those for URBs. The Snake River stock is one component of the total URB complex. Fishery impacts on Snake River Fall Chinook are monitored through the use of fingerling releases from the Lyons Ferry Hatchery.

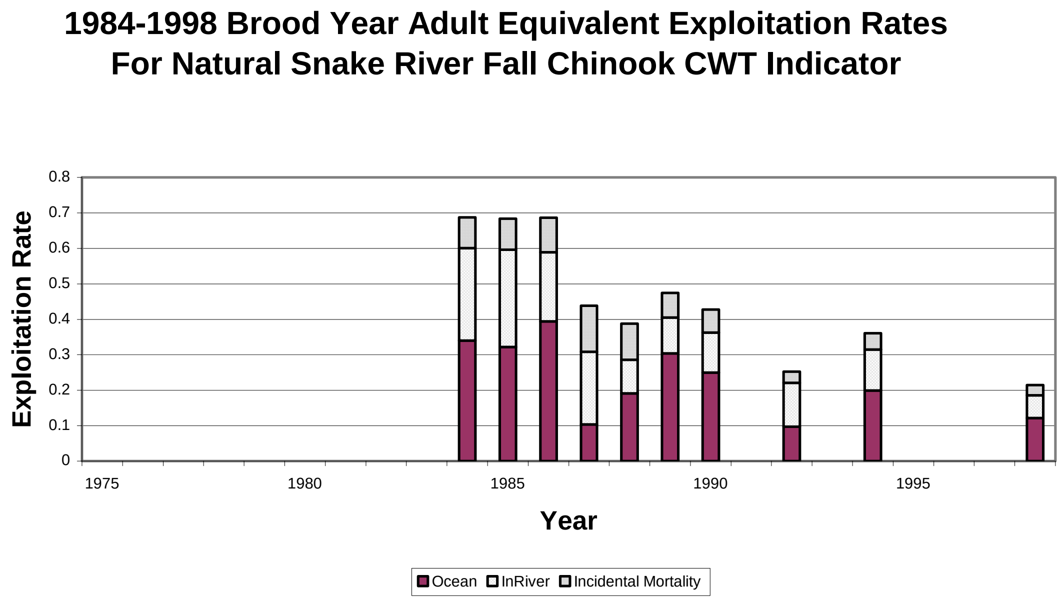

Figure C-4. 1984-1998 Brood Year Adult Equivalent Exploitation Rates for Snake River Fall Chinook (CWT indicator stock – Lyons Ferry fingerling releases). TCCHINOOK(04)-4

Lyons Ferry fingerling releases were not tagged consistently, so a complete time series is unavailable. Further, recoveries of these releases are sparse compared to those from Priest Rapids releases used for URBs because survivals are relatively poor. Figure C-4 indicates that AEQ brood year exploitation rates have declined substantially from a level approaching 70% in the mid 1980s to about 20% for the most recently available brood year.

Figure C-5 shows that in-river fishery harvest rates have been reduced markedly from about 60% in the mid 1980s to about 20% in more recent years. The ESA jeopardy standard calls for a 31.29% limit on in-river harvest rates (comparable to the 30% reduction in harvest rates from the 1988-1993 average established for ocean fisheries)[25]. Terminal run sizes and spawning escapements for Snake River Fall Chinook have steadily increased since the late 1990s. Bonneville-Lower Granite Dam passage mortality rates (expressed as a proportion of escapement past fisheries) for Snake River Fall Chinook are much higher than for URBs, frequently exceeding 50% since 1986.

[25] Biological Opinion on Impacts of Treaty Indian and Non-Indian Fall Season Fisheries in the Columbia River Basin in Year 2004, on Salmon and Steelhead Listed Under the Endangered Species Act. NMFS Consultation F/NWR/2004/00825. August 6, 2004. Biological Opinion on Impacts of Treaty Indian and Non-Indian Fisheries in the Columbia River Basin in Years 2005-2007, on Salmon and Steelhead Listed Under the Endangered Species Act, Conference on Lower Columbia Coho, and Magnuson-Stevens Act Essential Fish Habitat Consultation. Consultation Number: F/NWR/2005/00388. May 9, 2005.

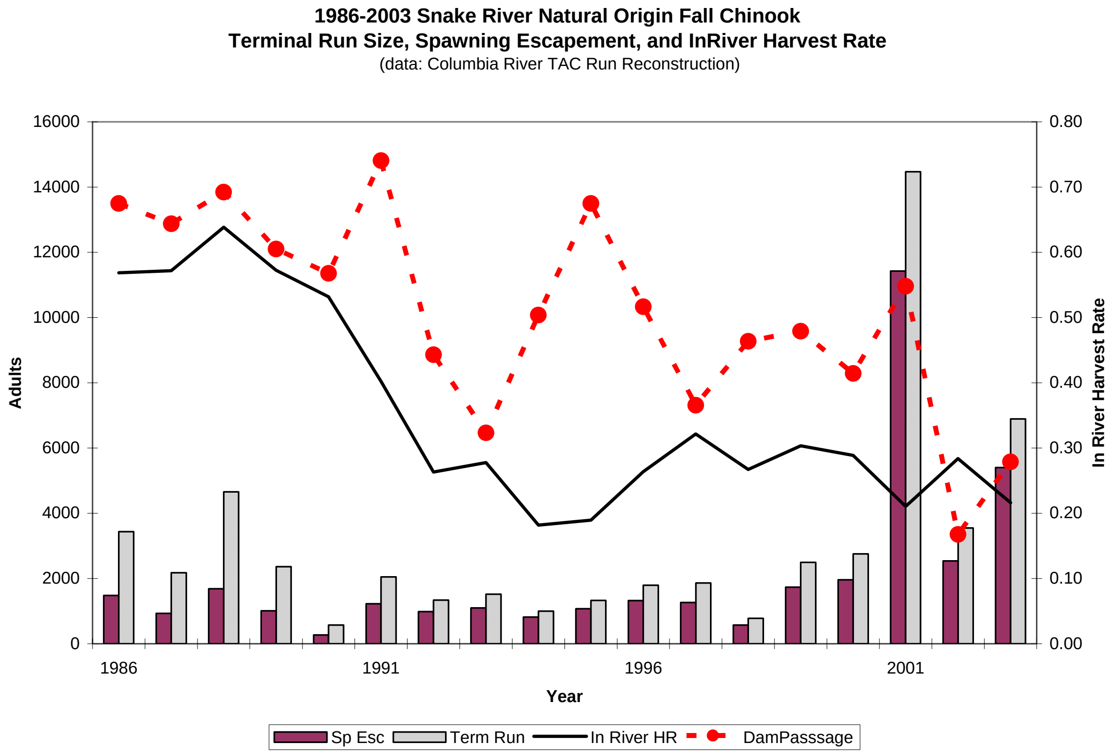

Figure C-5. 1986-2003 Terminal Run Size, Spawning Escapements, and In-River Harvest Rates for Snake River Fall Chinook.

Although the Snake River stock is considered a component of the URBs, available data indicate that fishery impacts differ significantly in both ocean and in-river fisheries. CWT recovery data indicate that the Priest Rapids stock is a far-north migrating stock with ocean harvests predominantly occurring in northern British Columbia and Southeast Alaska. In contrast, recoveries for Lyons Ferry fingerling releases indicate that the Snake River fall Chinook stock is harvested by fisheries ranging from central California to Southeast Alaska. Available information also indicate that in-river fisheries affect Snake River fall Chinook differently from URBs, with the Snake River component exhibiting much greater reductions in in-river harvest rates. Further investigation would be required to identify the reasons for these differences. An important point to keep in mind is that the components of large stock complexes can exhibit significant differences that need to be identified and taken into account in harvest management.

Columbia River Coho

In contrast to Chinook salmon, Columbia River coho mature and are harvested predominantly as three-year-old fish. Consequently, interpretation of exploitation rates for this species can avoid complications like AEQs and brood year/calendar year differences.

Estimates of fishery impacts for Columbia River coho are available for a thirty-five year period beginning in 1970. Figure C-6 depicts three time series: (a) total mortality (catch plus non-catch) exploitation rates for ocean and in-river fisheries combined are represented by the topmost heavy line; (b) total mortality exploitation rates for ocean fisheries represented by the line with round markers; and (c) in-river fishery harvest rates (the proportion of fish returning to the Columbia River that is killed by fisheries in the Columbia River) are represented by the dashed line.

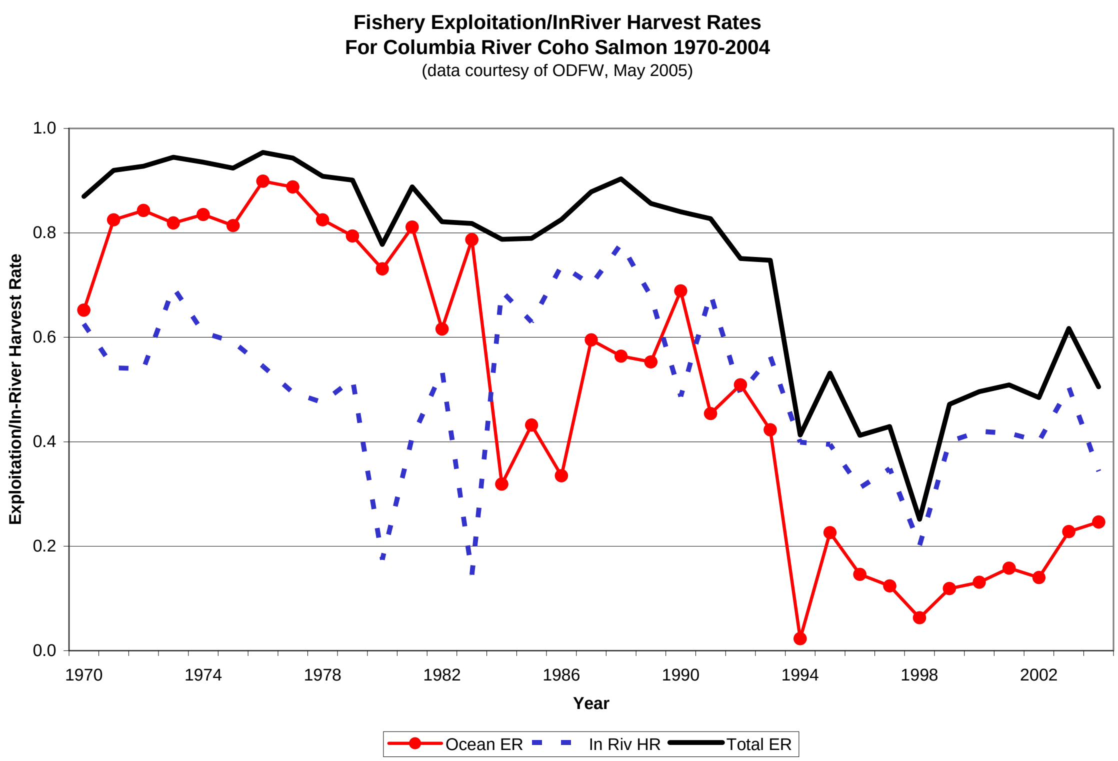

Figure C-6. 1970-2004 Exploitation and Harvest Rates for Columbia River coho.

Although suitable CWT data are available for much of the time period covered in Figure C-6, the ocean fishery exploitation rates depicted are estimated from a surrogate represented by the Oregon Production Index (OPI). The OPI is an index that consists of the sum of the ocean catches of all coho salmon harvested south of Leadbetter Point, Washington plus the numbers of fish returning to the Columbia River and Oregon coastal rivers. The OPI is considered an index because: (1) some of the coho caught south of Leadbetter Point originate from rivers north of Leadbetter Point or in California; and (2) Columbia River and Oregon coastal coho are also harvested north of Leadbetter Point. The exploitation rate is simply the ocean catch in a given year divided by the OPI.

The use of a single exploitation rate to characterize the harvest of Columbia River coho is inaccurate and can be misleading. There are two distinct types of coho produced by the Columbia River, termed early and late due to their relative timing of river entry[26] on their

[26] Due to its timing, the late run can be harvested by in-river fisheries with fewer concerns for impacts on Chinook. Hatcheries in the lower Columbia River produce Chinook that are predominantly north-migrating, hence Washington's fisheries receive greater benefits than Oregon's. Consequently, Washington has a greater self-interest in separating harvest management of coho and Chinook. Not surprisingly, to meet constituency needs, Oregon

spawning migrations, and it is extremely likely that these types are experiencing different exploitation rates in both ocean and in-river fisheries. The ocean distribution of the early run is more southerly than the late run. The PFMC manages ocean fisheries north and south of Cape Falcon, Oregon to meet objectives for different stocks. South of Cape Falcon, the primary objective for coho management is directed at naturally spawning fish from Oregon coastal rivers. North of Cape Falcon, coho are managed to meet spawning escapement objectives and treaty Indian harvest allocation requirements for individual populations of coho originating from Washington Coastal and Puget Sound rivers; in addition, coho management in this area is also constrained by conservation concerns for coho stocks originating in Southern British Columbia under the provisions of agreements reached by the Pacific Salmon Treaty.

The history of exploitation of Columbia River coho illustrates a well-known problem arising when complex mixtures of stocks with different productivities are harvested intensively by mixed-stock fisheries (Background section 7e). Pursuant to the construction of several dams on the Columbia River system, numerous hatcheries were constructed to mitigate for habitat loss. These hatcheries released large numbers of coho, which were harvested along with naturally spawning coho by both ocean and in-river fisheries. Fishery exploitation rates were constrained only by the need to allow sufficient numbers of fish to return to hatchery facilities to meet egg take needs. Ocean fisheries exerted exploitation rates that frequently exceeded 80% until the early 1980s, and total exploitation rates of over 90% were sometimes observed.

Naturally spawning stocks were harvested along with hatchery fish by mixed-stock ocean and in-river fisheries. Because these natural stocks had lower productivities, they were unable to sustain the exploitation rates being exerted on the hatchery fish. Over time, naturally spawning coho populations were virtually extirpated from the Columbia River (save for very small remnant populations that are now candidate species being considered for listing as a threatened species under the ESA).

In the early 1980s, alarms for the conservation of Oregon Coastal natural (OCN) coho stocks were sounded as spawning escapements plummeted. Ocean fisheries were exploiting these stocks at rates in excess of 80%. Concurrently, litigation brought by the Hoh, Quinault, and Quileute Tribes (located along the Washington coast) clarified the obligation of the Secretary of Commerce to regulate mixed stock ocean fisheries on a river-by-river, run-by-run basis in order to satisfy legal obligations under Indian treaties with the United States.[27] In response to conservation concerns and legal obligations, the Pacific Fishery Management Council substantially reduced exploitation rates of ocean commercial and recreational fisheries. The effect of these actions is evidenced by the dramatic reduction in ocean fishery exploitation rates in Figure C-6. By reducing ocean fishery exploitation rates, more fish became available to fisheries in the Columbia River so in-river harvest rates increased (dashed line, Fig. C-6).

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hatcheries produce predominantly early run fish while Washington hatcheries produce more late run than early run fish.

[27] Hoh v. Baldrige, 605 F. Supp 833 (W.D. Wash. 1985).

The history of harvest management of Columbia River coho provides a useful illustration of how conservation requirements to protect natural stocks can affect the exploitation of commingled hatchery fish. In 1990, Oregon Trout filed a petition for listing coho salmon under the ESA, claiming excessive exploitation by commercial and recreational fisheries as a contributing factor.[28] Following a status review, in 1991 the National Marine Fisheries Service (NMFS) was unable to identify any indigenous population of naturally spawning coho in the Columbia River that warranted protection, i.e., these populations had been extirpated by a combination of hatchery stock transfers, habitat degradation, and overfishing.[29] Oregon Trout filed another series of petitions in 1993 asking that 40 coho salmon populations be listed under the ESA, including coho from the Clackamas River. A formal status review was completed in 1995 (see footnote 25) which concluded that no naturally spawning coho populations from the Columbia River warranted listing, but left the issue open for reconsideration if new information became available.[30] Naturally spawning coho from the lower Columbia River are now proposed for listing as a threatened species under the federal ESA.[31] The Oregon Fish and Wildlife Commission (OFWC) listed lower Columbia River wild coho salmon as an endangered species under Oregon's threatened and endangered species statute in July 1999.

Since 1984, the harvest of Columbia River coho in mixed stock ocean fisheries has been driven by exploitation rates that are determined by the annual status of OCN coho under the Pacific Fishery Management Council's Salmon Framework Plan (FMP). In 1984, the FMP was amended to establish a fixed MSY escapement goal of 200,000 spawners for OCN coho. Because of concerns for economic dislocations of the commercial and recreational fisheries at low abundance, Amendment 7 to the FMP allowed deviations from the fixed escapement goal policy in 1987 when OCN abundance dropped below 400,000 fish. In 1993, Amendment 11 to the FMP revised the MSY escapement goal to 42 fish per mile and established an exploitation rate limit of 20% at OCN abundances below 250,000 fish. These measures proved insufficient to halt the decline in OCN stocks. In the early 1990s, various petitions were filed to list OCN coho under the ESA. Oregon developed a Coastal Salmon Restoration Initiative and PFMC-FMP amended its FMP in 1997 (Amendment 13) by establishing a sliding scale of exploitation rates ranging

[28] NMFS 1995. Status Review of Coho Salmon from Washington, Oregon, and California. NOAA Tech Memorandum NMFS-NWFSC-24. September 1995.

[29] NMFS. Endangered and threatened species: Lower Columbia River coho salmon. Fed. Reg. 56(124):29553-29554.

[30] *"The Clackamas River produces moderate numbers of natural coho salmon. The Clackamas River late-run coho salmon population is relatively stable under present conditions, but depressed and vulnerable to overharvest. Its small geographic range and low abundance make it particularly vulnerable to environmental fluctuations and catastrophes, so this population may be at risk of extinction despite relatively stable spawning escapements in the recent past. As noted above, the BRT (Biological Review Team) could not reach a definitive conclusion regarding the relationship of Clackamas River late-run coho to the historic Columbia River ESU (Evolutionarily Significant Unit). However, the BRT did conclude that if the Clackamas River late-run coho salmon is a native run that represents a remnant of a lower Columbia River ESU, the ESU is not presently in danger of extinction, but is likely to become so in the foreseeable future if present conditions continue."* NMFS 1995, fn 3.

[31] Even though lower Columbia River natural coho are not presently listed under the ESA, a May 2005 biological opinion established a 6.5% in-river harvest rate limit for non-Indian fisheries in the lower Columbia River (no limit was established for treaty Indian fisheries because they do no operate in the lower Columbia). Biological Opinion on Impacts of Treaty Indian and Non-Indian Fisheries in the Columbia River Basin in Years 2005-2007, on Salmon and Steelhead Listed Under the Endangered Species Act, Conference on Lower Columbia Coho, and Magnuson-Stevens Act Essential Fish Habitat Consultation. Consultation Number: F/NWR/2005/00388. May 9, 2005.

from zero to a high of 45%. Exploitation rates are triggered by forecasts of abundance and historical escapement patterns. OCN coho were ultimately listed under the ESA in 1998.

In addition to reductions in mixed stock exploitation rates, Amendment 13 provided for: improved stock assessment program (to provide data to monitor stock response and trigger adjustments to management strategies if stocks responses fail to meet expectations); and, a multi-year review of performance. The review was completed in 2000[32] by representatives of the PFMC's Scientific and Statistical Committee and Salmon Technical Team, representatives from the Washington and Oregon Departments of Fish & Wildlife, and a Multidisciplinary Science Team appointed by the Governor of Oregon.

Managers subsequently turned to mark-selective fishing because constraints imposed to protect OCN coho severely curtailed the ability of ocean fisheries to catch more abundant Columbia River hatchery coho. Under this concept, the adipose fins of fish produced by hatcheries are removed to provide a visible mark to distinguish hatchery from wild fish. Mark-selective fisheries are then employed under regulations that allow the retention of marked hatchery fish, but require the release of unmarked fish. Because some of the released fish survive, the harvest of hatchery fish can be increased while maintaining the same impact on wild fish of conservation concern. To illustrate, suppose that a fishery operates on a population comprised of 1000 wild fish and 10,000 marked hatchery fish, that the wild fish can only be harvested at a 10% rate, and that 20% of the fish released die. Without mark selective fisheries, 100 wild and 1000 hatchery fish could be taken. With mark-selective fishing, however, the allowable mortality rate can be maintained by releasing 500 wild fish (100 = 500 x 0.20 = number of wild mortalities); with a 50% contact rate permitted, 5,000 hatchery fish could be retained. In this example, the exploitation rates on wild and hatchery fish under mark-selective fishing would be 10% and 50%, respectively. In practice, harvest management involving mark-selective fisheries is more complex than implied by this simple example, but the basic concept is still the same.

The PFMC and state managers have employed mark selective fisheries on coho salmon since the late 1990's. Before such fisheries, the magnitude and trends of ocean fishery exploitation rates on OCN coho could be directly inferred from exploitation rates on Columbia River hatchery coho. In recent years, ocean fishery exploitation rates on OCN coho have been lower than the rates depicted in Figure C-6 for Columbia River coho because of mark selective fishing.

B-Run Steelhead

Unlike Chinook URBs and coho, Columbia River steelhead originating in the Snake River are not significantly impacted by ocean fisheries. Nonetheless, they are still harvested by mixed stock fisheries in-river (Appendix B, provides information on the stock structure of management units), including some listed under the ESA.[33] Snake River steelhead are considered summer run fish based on their June-October timing of entry into the Columbia River. Snake River steelhead

[32] 2000 Review of Amendment 13 To the Pacific Council's Salmon Plan. OCN Workgroup. (http://www.pcouncil.org/salmon/salother/ocn1102.pdf)

[33] Five Columbia River steelhead ESUs are currently listed: Upper Columbia River, Lower Columbia River, Upper Willamette River, Middle Columbia River, and Snake River.

were listed as threatened under the ESA on August 18, 1997 (Federal Registry 62:43937-43954) following a petition filed by the Oregon Natural Resources Council in 1994.

Management of Snake River steelhead is heavily dependent on assumptions. Snake River steelhead are classified as being A-Run or B-Run, based on a bi-modal pattern of passage over Bonneville Dam. A-run fish pass Bonneville from June to August and are small, believed to be comprised principally of fish that spend only a single year in the ocean. B-Run fish pass Bonneville from August through October and are larger fish that spend at least two years in the ocean. Two criteria are usually employed to distinguish between A and B-Run fish. Steelhead passing Bonneville Dam after August 25 are considered to be from the B-Run, while those passing before that date are considered to be from the A-Run. Steelhead are also classified as being A or B Run fish, depending on size, with fish larger than 78 cm considered B-Run. Data to evaluate the ability of these criteria to accurately identify A and B-Run fish are sparse. Above Bonneville Dam, the bimodal migration pattern is not evident; further, the relationship between spawning populations and migratory behavior or size differences has not been demonstrated.[34] Because of uncertainties regarding the management basis, the recently completed “2005-2007 Interim Management Agreement for Upriver Chinook, Sockeye, Steelhead, Coho, and White Sturgeon” between Columbia River treaty tribes, the States of Washington, Oregon, and Idaho, and Federal agencies directs the Columbia River Technical Advisory Committee to develop recommendations for research relating to steelhead management issues.

Currently, data available to estimate historical harvest rates are quite limited and of uncertain quality, particularly for lower river fisheries. No catches for lower river commercial fisheries are reported in available databases because the sale of steelhead by non-Indians has not been permitted since 1975, but mortalities from drop-off and release mortalities are known to occur. Total catches of steelhead by sport fisheries are estimated largely through punch card data, but harvest estimates for A-Run or B-Run fish[35] are not readily available. Mortalities are estimated through modeling of in-river fisheries. A limited data set is available from the July 2002 Status Report. Columbia River Fish Runs and Fisheries, 1938-2000 prepared by the Washington and Oregon Departments of Fish & Wildlife (Figure C-7). These data clearly indicate that in-river harvest rates for both lower and upper river fisheries have decreased substantially.

[34] Status Review of West Coast Steelhead. NOAA/NWFSC/NWFSC-TM27.

[35] Regulations that prohibit retention of fish with intact adipose fins make it infeasible to directly estimate sport fishery impacts on wild steelhead.

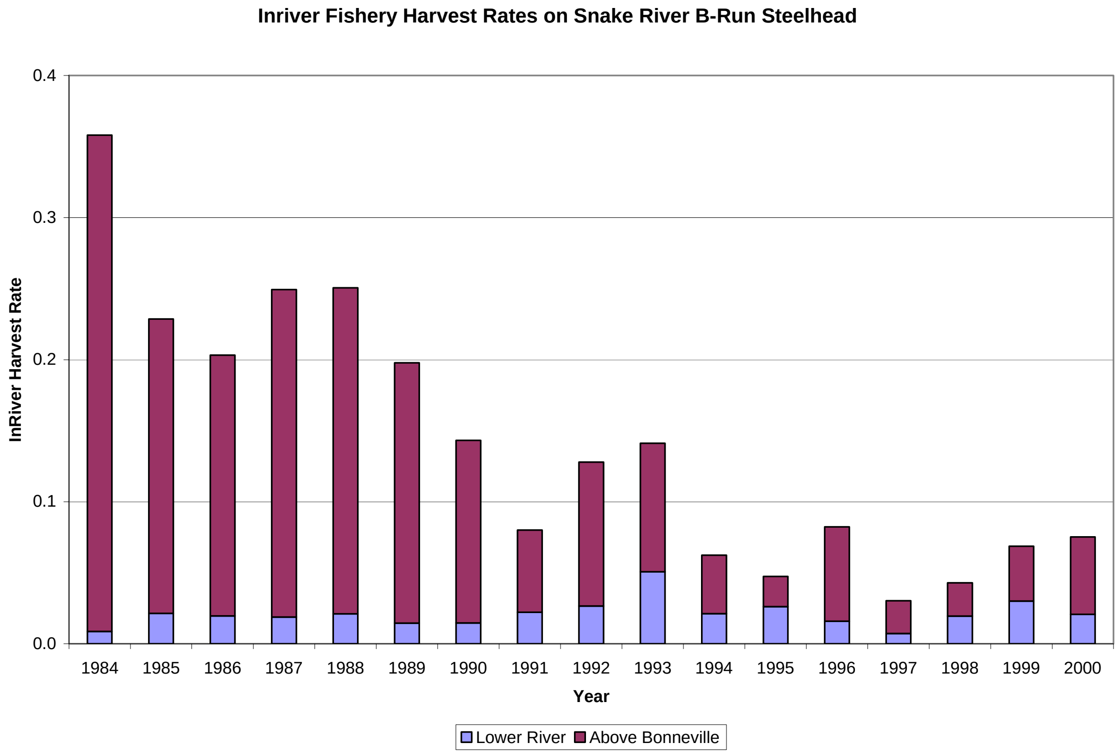

Figure C-7. 1984-2000 Harvest Rates for B-Run Steelhead.

The harvest rates depicted in Figure C-7, however, represent fishery impacts on the entire B-Run, which is comprised of both hatchery and wild fish. Constraints on harvest impacts are expressed in terms of maximum 15% harvest rate on the wild component of the B-Run. Under the management plan[36] for Columbia River fisheries, steelhead larger than 78 cm in length with adipose fins intact and which pass Bonneville Dam from July 1 through October 31 are considered wild B-Run fish. Data are not readily available to evaluate the effectiveness of these criteria in distinguishing wild B-Run steelhead from other commingled stocks of hatchery[37] and wild steelhead. Estimated harvest rates on the estimated number of wild B-Run steelhead passing Bonneville Dam by the treaty "zone 6" fishery are depicted in Figure C-8.

The quality of the available data set for wild B-Run steelhead is uncertain. At least one inconsistency is apparent - the number of fish passing Lower Granite Dam in 2003 was larger than the number passing Bonneville Dam. The reason for this discrepancy is not evident, but may be related to sampling.

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[36] 2005-2007 Interim Management Agreement For Upriver Chinook, Sockeye, Steelhead, Coho, and White Sturgeon.

[37] Available CWT data are not sufficient to provide information to test the effectiveness of criteria employed for stock-separation. Because these criteria depend only on run timing and size, separation of hatchery and wild fish can be problematic. The Dworshak National Fish Hatchery releases approximately 1.2 million yearling B-Run smolts on-station and another 1.1 million yearling B-run smolts for outplanting. Biological Opinion on Artificial Propagation in the Columbia River, March 29, 1999.

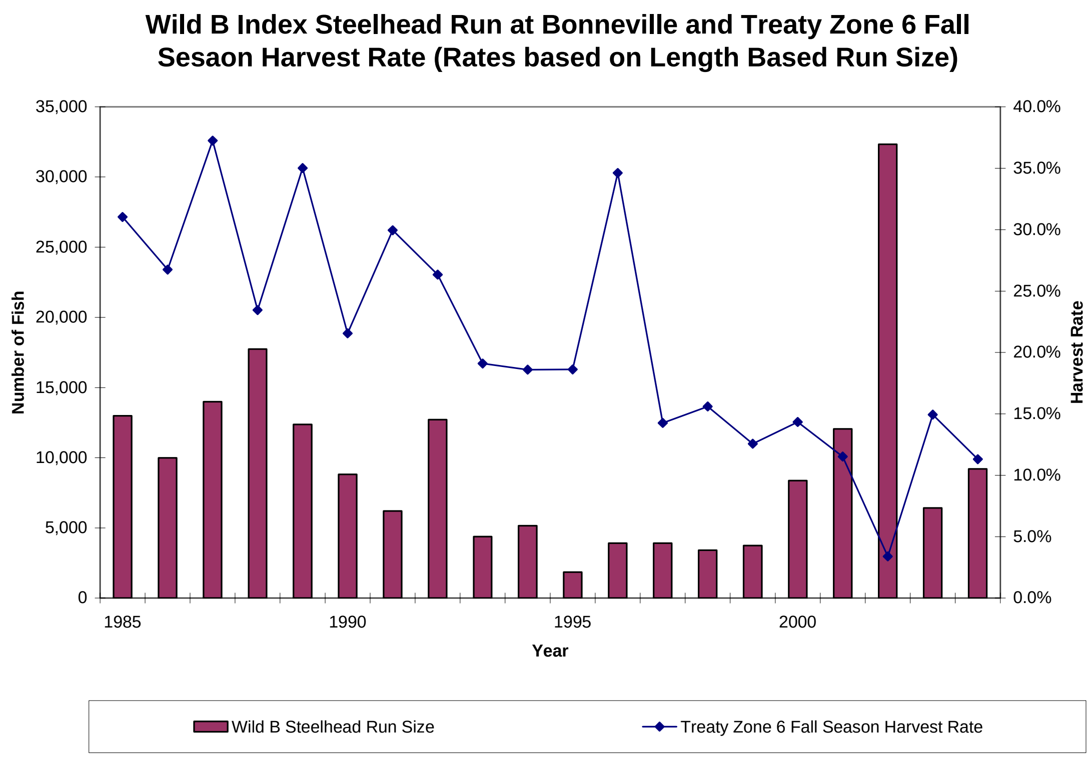

Figure C-8. 1985-2004 Zone 6 Harvest Rates for Wild B-Run Steelhead.

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