INDEPENDENT MULTIDISCIPLINARY SCIENCE TEAM (IMST)

State of Oregon

March 7, 2001

The Honorable John A. Kitzhaber
Governor of Oregon
State Capitol
Salem OR 97310

The Honorable Gene Derfler
Oregon Senate President
State Capitol
Salem OR 97310

The Honorable Mark Simmons
Oregon House Speaker
State Capitol
Salem OR 97310

The IMST is pleased to provide the enclosed report on coho salmon harvest management as it relateds to the goals of the Oregon Plan. The scope of this report is Oregon coastal natural coho salmon (OCN coho salmon), but the principles and technical guidance it provides are equally applicable to other anadromous salmonid species that are included in the Oregon Plan.

Harvest management is only one of the several factors that influence the recovery of depressed stocks of OCN coho salmon, but it is the single most important factor influencing the escapement of adults from the ocean to spawning areas. For this reason harvest management decisions have the most immediate effect on the rate of salmonid recovery. In addition, in those north coast stocks where species abundance is very low, harvest management decisions are critically important in determining the likelihood of stock extinction.

Our recommendations are to the Oregon Department of Fish and Wildlife, but unfortunately Oregon is not able to act alone in determining harvest management strategies and practice. For that reason some of our recommendations are that ODFW should actively advocate that the technical elements of our recommendations be incorporated into the harvest management decision process by other entities, such as the Pacific Fisheries Management Council, State of Washington, Tribal Nations, Northwest Power Planning Council and other with whom Oregon co-manages these stocks.

In most of our reports we emphasize the importance of the landscape perspective in working to achieve the goals of the Oregon Plan. We do the same in this report on harvest management. The landscape perspective simply put is to

- Manage with a larger spatial perspective – for harvest management this means effective coordination with the other entities that are involved in establishing harvest policies, and it means managing individual stocks as part of a larger aggregation of the population of coho salmong.

- Manage with a longer time horizon – for harvest management this means having a multiple generational perspective, which will allow for the natural variability in population dynamics due to ocean condition and climate trends and the need to achieve an adequate level of seeding of high quality spawning and rearing habitat to accelerate recovery.
- Manage harvest in coordination with the management of artificial propagation (hatcheries) and the management of the land in urban, forest, agricultural and other areas.

In this report we also highlight the need to:

- Define in measurable terms what is meant by the term recovery (see recommendation 1)
- Formulate and operate a specific program that integrates fish population modeling (such as the coho life history model), monitoring and the development of harvest management decisions (see recommendation 2).
- Give strong consideration to the technically outstanding product from the OCN working group as it relates to the management of coho salmon harvest strategies, especially during periods of low abundance and poor ocean conditions.

Copies of the report are available from OWEB, and can also be downloaded from the IMST Website (http://www.fsl.orst.edu/imst). The IMST will brief the ODFW Commission on this report at their March 23 meeting in Coos Bay.

We hope this report will be helpful in accomplishing the mission of the Oregon Plan. We'd be pleased to clarify any of the material in this report if that would be helpful.

Sincerely Yours,

Logan A. Norris
Chair, Independent Multidisciplinary Science Team

Enclosure

cc with enclosure:

House Committee on Stream Restoration & Species Recovery
ODFW Commissioners
Roy Hemmingway, Manager, Oregon Plan
OWEB
Kay Brown, ODFW
IMST

Salmon Abundances and Effects of Harvest: Implications for Rebuilding Stocks of Wild Coho Salmon in Oregon

Technical Report 2000-3

A report of the Independent Multidisciplinary Science Team, Oregon Plan for Salmon and Watershed

December 15, 2000

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LIST OF ACRONYMS AND ABBREVIATIONS

CRI - Cumulative Risk Initiative
EMAP - Environmental Monitoring and Assessment Program
EPA - Environmental Protection Agency
ESA - Endangered Species Act
ESU - Evolutionarily Significant Units
FRAM - Fishery Regulation Assessment Model
GCG - Gene Conservation Group
GLOBEC - Global Ocean Ecosystems Dynamics Research Program
IMST - Independent Multidisciplinary Science Team
KRTAT - Klamath River Technical Advisory Team
MSE - Minimum Sustainable Escapement
NBS - National Biological Service
NMFS - National Marine Fisheries Service
NRC - National Research Council
OCN - Oregon coastal natural coho salmon
OCNL - Oregon coastal natural lakes (rearing in lakes)
OCNR - Oregon coastal natural rivers (rearing in streams and rivers)
ODFW - Oregon Department of Fish and Wildlife
OFWC - Oregon Fish and Wildlife Commission
OWEB - Oregon Watershed Enhancement Board
Oregon Plan - Oregon Plan for Salmon and Watersheds
OPI - Oregon Production Index
OPITT - Oregon Production Index Technical Team
PFMC - Pacific Fisheries Management Council
SAS - Salmon Advisory Subpanel
SRS - Stratified Random Sample
SSC - Scientific and Statistical Committee
STT - Salmon Technical Team
WDFW - Washington Department of Fish and Wildlife
WDF - Washington Department of Fisheries

PREFACE

The Independent Multidisciplinary Science Team (IMST) developed the following conceptual scientific framework for the recovery of depressed stocks of wild salmonids in Oregon. It was developed originally as we evaluated Oregon's forest practices. Since then, it has been expanded to cover all land uses and fish management. Although not testable in a practical sense, we believe this conceptual framework is consistent with generally accepted scientific theory.

Conceptual Scientific Framework

The recovery of wild salmonids in Oregon depends on many factors, including ocean conditions, the availability of quality freshwater and estuarine habitats, the management of fish harvest and the adequacy of natural and artificial propagation. Freshwater habitat extends across all the lands of the State, and includes lands in urban areas and lands devoted to agriculture, forestry, and other uses. Estuaries provide a transition between fresh water and the ocean, and are a critical part of the habitat of wild anadromous salmonids. The ocean on which salmonids depend extends well beyond Oregon and is subject to fluctuations in productivity that markedly affect adult recruitment. Fish propagation and fish harvest are critical activities in which humans are directly involved with anadromous fish. The IMST is evaluating the science behind the management practices and policies that affect all of these freshwater and estuarine habitats and the management of fish and fisheries.

We have subdivided the work to focus on major types of land use (forestry, agriculture, and urban land uses) and fish management (artificial propagation and harvest). The land use subdivisions correspond to the different policy frameworks within which these lands are managed. Although the policies differ, these land uses interface and intermingle, and the aquatic environments on which the fish depend traverse and link them all; therefore, the boundaries we make in our reports are artificial.

Concepts

IMST is conducting its analysis of land use practices and fish management within a framework made up of the following three fundamental concepts:

1. ***Wild salmonids are a natural part of the ecosystem of the Pacific Northwest, and they have co-evolved with it.*** The contemporary geological landscape of the Pacific Northwest was established with the formation of the major river/stream basins of the region, approximately two to five million years ago. The modern salmonids of the region largely developed from that time (Lichatowich 1999). The abundance of these species at the time of Euro-American migration to Oregon is a reflection of more than 10,000 years of adaptation to the post-glacial environment and 4,000 to 5,000 years of adaptation to contemporary climatic and forest patterns. There is some indirect evidence from anthropological studies that salmon in Oregon's coastal streams may not have reached the high levels of abundance that the first Euro-Americans saw until about 1,000 to 2,000 years ago (Matson and Coupland 1995). The point is that the salmonid stocks of today co-evolved with the environment over a relatively long period compared with the length of time since Euro-Americans entered this landscape.
2. **High quality habitat for wild salmonids was the result of naturally occurring processes that operated across the landscape and over time.** These same processes occur today, but humans have altered their extent, frequency, and to some degree, their nature. Humans will

continue to exert a dominant force on the terrestrial, freshwater, and estuarine landscape of the Pacific Northwest, but current ecosystems need to better reflect the range of historic conditions.

The environment and habitat of these species is dynamic, not static. At any given location, there were periods of time when habitat conditions were better and times when habitat conditions were worse. At any given time, there were locations where habitat was better and locations where it was worse. Over time, the location of better habitat shifted, both in fresh water and the ocean.

Fresh water and estuarine salmonid habitat in the Pacific Northwest has been a continuously shifting mosaic of disturbed and undisturbed habitats. One of the legacies of salmonid evolution in a highly fluctuating environment is the ability to colonize and adapt to new or recovered habitat.

The ocean habitat also fluctuates and is dynamic, changing over several time scales. There are inter-decadal variations in climate called regimes (as well as shorter term variations) that affect the ocean productivity for salmonids. One regime that resulted in a shift from favorable to unfavorable ocean conditions, especially for coho salmon, occurred in 1977. Some believe that we are entering a more favorable regime that began with the 1998 La Niña. However, it is important to realize that full recovery of salmonid populations is a long-term process. A major assumption is that improved conditions of freshwater and estuarine habitat are buffers to poor ocean conditions. Without improvement of the condition of these habitats, the return to poor ocean conditions in the future will be more devastating to salmonids than what was experienced in the early 1990s (Lawson 1993).

These concepts apply regardless of the land use or fish management strategy and are the basis for the evaluations in this report.

Operation of the Concepts in Salmonids

Wild salmonid stocks historically accommodated changes in their environment through a combination of three strategies**. *Long-term adaptation*** produced the highly varied life history forms of these species, providing the genetic diversity needed to accommodate a wide range of changing conditions. ***High fish abundance distributed in multiple locations (stocks)*** increased the likelihood that metapopulations and their gene pools would survive. ***Occupation of refugia*** (higher quality habitat) provided the base for recolonization of poor habitat as conditions improved over time.

History

Since the mid 1850s, the rate and extent to which habitat conditions changed has sometimes exceeded the ability of these species to adapt; therefore, stock abundance currently is greatly reduced. Although refugia exist (at a reduced level) today, population levels of wild salmonid stocks are seriously depressed because of other factors (ocean conditions, fisheries and hatchery management, land-use patterns and practices) that limit habitat productivity and the rate and extent to which recolonization can occur. In addition, some harvest and hatchery practices have diminished the genetic diversity of salmonids, limiting their ability to cope with climate fluctuations. It is the combination of these factors and their cumulative effects since 1850 that have produced the depressed stocks of today.

The historic range of ecological conditions and the diversity of salmonid stocks in the Pacific Northwest are important because they provide a framework for developing policy and management plans for the future. The persistence and performance of salmonids under historic ecological conditions is evidence that these habitats were compatible with salmon reproduction and survival.

Prior to European settlement of the western United States, artificial propagation was not practiced, yet the level of harvest by Native Americans may have reached the levels of peak harvests by Euro-Americans (Beiningen 1976; Schalk 1986).

Conclusions

Land uses and fish management strategies resulting in non-historical ecological conditions may support productive salmonid populations, but the evidence for recovery of wild salmonids under these circumstances is neither extensive nor compelling. Recovery of wild salmonids also requires fish management (artificial propagation and harvest) strategies that are consistent with the goals of recovery and are compatible with the condition of the terrestrial and ocean landscape within which they operate.

Therefore, we conclude that:

- the goal of land use management and policy should be to emulate (not duplicate) natural processes within their historic range.
- the goal of fish management and policy should be to produce and take fish in a manner that is consistent with the condition of the environment and how it changes with time.
- the recovery of wild salmonid stocks is an iterative and a long-term process. Just as policy and management have changed in the past, they will continue to change in the future, guided by what we learn from science and from experience.

EXECUTIVE SUMMARY

In 1991, a review of the status of Pacific Northwest salmon concluded that a substantial proportion of existing salmon stocks faced significant risk of extinction. Unfavorable ocean conditions, habitat degradation and over harvest were among the factors implicated in the decline of stocks.

Populations of Oregon coastal natural (OCN) coho salmon historically exceeded 1.5 million adult spawners. As recently as the early 1970s, populations of OCN coho ranged from 200,000 to 690,000, but their numbers declined to approximately 70,000 in 1996 and 25,000 in 1997. From 1997 to 1999, the number of OCN ocean recruits in a given year has been less than the number of spawners that produced them, indicating a failure to replace themselves for three successive generations.

These trends for OCN coho salmon stocks resulted in the Endangered Species Act (ESA) listing of the Oregon Coast and the Southern Oregon/Northern California Evolutionarily Significant Units (ESU's) by National Marine Fisheries Service (NMFS) as "threatened". Oregon Department of Fish and Wildlife (ODFW) has identified 128 coho salmon populations that make up the total OCN coho salmon stock.

Coho salmon harvest peaked in 1895 in the Columbia River and in 1911 along the Oregon coast. Between 1890 and 1990, 40% to 90% of the ocean recruits were being harvested annually. Commercial and sport fishing for unmarked coho in the ocean off the coast of Oregon was stopped in 1994 but increases in the abundances of neither OCN ocean recruits nor spawners resulted. A selective fishery for hatchery coho was permitted along the Oregon Coast in 1999 and 2000.

Harvest management issues are complex. In addition to mortality from direct harvest of coho salmon, mortality is also caused indirectly from hook and release of fish in selective fisheries and in the harvest of other species. This indirect mortality must be accurately included in estimates of harvest impacts.

The decision process that establishes harvest levels and strategies for any given year is also complex. The State of Oregon manages most near-shore and inland fisheries, but co-manages many of the fisheries in the Columbia River Basin together with the State of Washington and Treaty Indian Tribes. The Pacific Fishery Management Council (PFMC) manages harvest of salmon in coastal marine waters. PFMC uses Amendment 13 of the 1984 Coastal Salmon Management Plan as a recovery and rebuilding plan (as it relates to harvest) for OCN coho salmon. ODFW recommends harvest practices to the Oregon Fish and Wildlife Commission (OFWC), and the OFWC provides guidance on the negotiating framework used by the Oregon delegation to the PFMC. The harvest practices that result are the product of the application of the Oregon Plan for Salmon and Watersheds (Oregon Plan), the Endangered Species Act (ESA), negotiations with Treaty Tribes, and deliberations of the PFMC.

Harvest management is critical to the management and recovery of depressed stocks of wild salmonids in Oregon. It includes a host of policy, management, technical, and scientific issues. This Technical Report of the Independent Multidisciplinary Science Team (IMST) focuses on the technical and scientific issues involving (a) management of coho salmon harvest by the State of Oregon and PFMC and (b) the analysis of salmonid population dynamics under the Oregon Plan. Our science questions, conclusions and recommendations are presented as the technical basis for actions under the Oregon Plan.

IMST addresses five science questions in this report. Following is a brief summary of the findings for each question and the conclusions that are reached. These are followed by the specific recommendations of IMST.

Question 1: How have harvest management practices affected the status of OCN coho salmon stocks? Are current harvest management policies likely to contribute to rebuilding of OCN coho salmon stocks under the Oregon Plan for Salmon and Watersheds?

The IMST finds that harvest management has seriously affected stocks of wild coho salmon and contributed to the population declines that led to listing under the Endangered Species Act (ESA). The IMST also finds that a continuation of the Amendment 13 harvest policies contributed only marginally to the rebuilding of salmon stocks under the Oregon Plan. Recovery and rebuilding of stocks are key goals of the Oregon Plan, but the meaning of these terms is not described in terms that provide a basis for assessing progress towards them or for implementing the adaptive management that is part of the Oregon Plan.

We agree with the following assessment from the Oregon Plan (1997):

> "Historically, over harvest has been a significant factor in the decline of coho salmon. Excessive catch and/or harvest, times and areas open for harvest, mixed stock and targeted fisheries, and gear used have all been substantial contributing factors."

> "The problems of over exploiting less productive stocks and species in mixed-stock fisheries and of selectively fishing populations and species have been widely recognized but poorly resolved by society. Mortality associated directly and indirectly with fishing can eliminate populations, reduce numbers within populations, alter or eliminate life history patterns, reduce fitness, and mask population trends. All of these effects may adversely affect the sustainability of wild salmon populations and should be evaluated in an assessment of extinction risk."

A review by PFMC shows that in the 11 years from 1981 to 1991, the ODFW escapement target for OCN coho salmon (200,000) was met only three times. Amendment 13 regulates OCN coho salmon harvest based on harvest impact rates, not the numbers of spawners that return to spawning grounds. The number of spawners required to meet the 50% full seeding level of high quality habitat is 66,100 for all four stock components combined. This number of spawners has been attained only once during the past 10 years, again indicating the lack of rebuilding of OCN coho salmon.

In spite of the fact that recovery of depressed stocks is the primary goal of the Oregon Plan and a legal mandate of the PFMC for some species of salmonids, the IMST has found no explicit statement of the definition of "recovery". Currently, the only criteria for determining whether specific stocks meet the goal of rebuilding stocks are the triggers for changing the levels of sport and commercial fishing harvest. Harvest management decisions have the most immediate impact on spawner abundance and are therefore critical to the recovery of depressed stocks of wild salmonids in Oregon. It is essential, therefore, that the meaning of recovery be defined in measurable terms to guide harvest management decision-making.

Based on these findings we conclude that:

- At recent low population numbers and lack of replacement of stocks and stock aggregates, fishery impacts on OCN coho salmon are very uncertain. Knowledge of population dynamics for coho salmon at extremely low populations is technically weak because of the lack of studies. Therefore, strongly conservative management criteria and explicit definition of "extremely low populations" are needed in such conditions (e.g., 10% of fully seeding high quality habitats). The proposed harvest matrix in the OCN Work Group report provides such an approach (see Appendix D). IMST strongly endorses the proposed changes to salmon management in this report.

- Measurable goals for recovery of depressed stocks of OCN coho salmon are needed to provide a technically strong basis for harvest management decisions. Measurable goals that are intuitively compelling to the public (e.g. number of spawners per mile, and proportion of streams with no spawners) are particularly valuable.
- Harvest impacts have been reduced dramatically (from 30%-90% prior to 1990 to 8-13% since 1994), an unprecedented advance in harvest management of Pacific salmon. Desired levels of escapement generally have not been achieved. Improved escapement is essential for the recovery of OCN coho salmon, and control of fishing mortality is the best available tool for achieving improved escapement.
- The likelihood of accomplishing recovery is low under Amendment 13 during periods of low ocean productivity because escapement of adult spawners is too low. At low marine survival rates, elimination or reduction of human-caused sources of mortality would reduce probability of extinction, and would possibly allow modest recovery. It would increase the rate of recovery under higher ocean survival rates.
- Widespread spawning distributions of coho salmon populations are needed to minimize risks of extinctions when the region shifts from climate regimes that are favorable for survival to conditions that result in low rates of ocean survival (IMST 1999).
- A harvest management criterion (from monitoring results) could be the proportion of all habitats of monitored stream reaches that are occupied by spawners. This measure of escapement could be a critical index for the recovery of OCN coho salmon stocks. Setting Minimum Sustainable Escapement (MSE) levels would improve probabilities of recovery.
- Current management includes the distribution of carcasses with no link to priorities or expected outcomes. Successful management of carcasses under the Oregon Plan will require explicit experimental measurement of the responses of salmon (at all life history stages) to additional food resources from carcasses.

Question 2: Are mortality estimates from non-retention fisheries accurate? Does this source of mortality affect the recovery of coho salmon?

The IMST finds that there is wide variability in the estimates of mortality from non-retention fisheries, reducing the reliability of any given estimate as an indicator of such mortality. A lack of data precludes a confident determination of the impact of this mortality on recovery of stocks of wild salmon, but for severely depressed populations even a low incidence of mortality from a non-retention fishery can significantly slow recovery.

Based on these findings we conclude that:

- Gear selection and deployment are important variables in the degree to which hook-and-release and drop off mortality occur at any given encounter rate. Impacts on OCN coho salmon potentially can be reduced by changing methods of fishing (gear selection and deployment), and by reducing the encounter rates at locations and times when OCN coho salmon are concentrated.
- The PFMC decision to increase the estimate of hook-and-release mortality from 13% to 19% for recreational selective coho fishery in 2000 is a prudent first step, but given the uncertainty of the estimate and the vulnerability of the most severely depressed stocks, continuing assessments of this mortality are required.
- An expanded program of “double-index” tagging will permit a better evaluation of the mortality rate of unmarked fish in selective coho fisheries.

Question 3: Are models used to represent population dynamics of Oregon coho salmon and impacts of harvest scientifically rigorous? Are these models effectively integrated into management, policy analysis and decision-making?

The IMST finds that the coho life-cycle model developed by Nickelson and Lawson (referred to as the coho life-cycle model) represents a scientifically rigorous approach and is a valuable analytical tool for evaluating the full life cycle of coho populations. However, it needs to be improved and it needs to be well integrated into policy and management decision-making.

Based on these findings we conclude that:

- The coho life-cycle model is rigorous and useful for examining the consequences of human actions on the population dynamics of coho salmon. Other models being developed should be viewed as independent checks of the coho life-cycle model. These models greatly strengthen the technical foundation of the Oregon Plan, and state and federal agencies should explicitly use them in the decision process.
- There are several components that (a) are not represented in the model, (b) use aggregated data or (c) lack empirical data. As model development continues these components should be addressed. Future model development and application should consider (a) scarcity of data, (b) aggregated functions that should be articulated separately, and (c) local and regional variability. The modeling effort could be linked to design of future monitoring. We note that even with these gaps and weaknesses, the life-cycle models are a powerful tool for policy and management.
- There is no centralized and focused attempt to develop the coho life-cycle model, provide extensive sensitivity analysis, and link the operation of the model to the monitoring program and development of harvest management policy. The Stratified Random Sample (SRS) survey monitoring system, basin habitat surveys, life cycle monitoring sites, and life-cycle models should be integrated to create a more scientifically sound decision-making context for salmon harvest management. Current research and monitoring are closely tied to model development and applications, but integration is based on the willingness and interests of researchers in ODFW and not part of an explicit analysis and assessment program. The IMST strongly endorses each of these measurement and analysis tools that ODFW and cooperating agencies have developed.
- The State of Oregon has no centralized or explicitly coordinated program that links the coho life-cycle model, ODFW monitoring, and State participation in PFMC decisions on annual harvest rates. The availability of these tools makes adaptive management possible. Oregon has a unique and powerful set of tools available for salmon assessment and management, but the fragmented administration, funding, reporting, and coordination significantly diminish its strength and effectiveness. The State of Oregon has captured a very small fraction of the potential application of models to the Oregon Plan. With adequate and centralized project administration, these integrated tools could serve as a national model for salmon management.

Question 4: Are uncertainties in rebuilding OCN coho salmon stocks and the risks of extinction adequately addressed in coho salmon management? Are scientifically based strategies for extinction risk assessment effectively incorporated into salmon management to facilitate accomplishment of the mission of the Oregon Plan for Salmon and Watersheds?

The IMST finds that assessing the risk of extinction is fundamental to the Endangered Species Act (ESA). The risks of extinction models developed by ODFW and NMFS (1998) are rigorous, but can be improved. Further, we find that the models have not been used to their full potential in the Oregon Plan.

Based on these findings we conclude that:

- Many populations of OCN coho salmon are at critically low levels of abundance, with the highest risks of extinction in the North Coast Gene Conservation Group (GCG). Metapopulation structure and basin-scale abundance need to be considered in modeling and assessment of extinction risk and recovery rates, and in the design of harvest management. Small populations are more likely to become extinct from random fluctuations in environmental conditions than are large populations.
- Existing models may be inadequate to fully characterize risks of extinction for individual populations within aggregates of populations (Allendorf et al. 1997; Wainwright and Waples 1998). Therefore, other approaches for population evaluation and risk assessment are also needed.

Question 5: Does the monitoring program provide information that is necessary to accomplish the mission of the Oregon Plan for Salmon and Watersheds? What measurements or analyses need to be included in the monitoring program to make it more scientifically credible and relevant to management and policy?

The IMST finds that Oregon has one of the most scientifically rigorous monitoring programs for anadromous spawner estimation, providing much relevant information for the Oregon Plan. However, the monitoring is not adequate to reliably detect trends within individual basins. This is important for monitoring escapement, evaluating recovery, and estimating extinction risk over time and among Gene Conservation Groups (GCG's).

Based on these findings we conclude that:

- The monitoring program is rigorous but it needs to be more comprehensive and systematic. Future development of the monitoring program should incorporate key measures of abundance, productivity, spatial and temporal structure, genetic diversity, and ecological functions. The life cycle monitoring sites are particularly important.
- Estimates of ocean mortality (natural and fishing-induced) of wild salmonids are necessary to partition ocean and freshwater survival rates. The State needs better estimates of the ocean distribution of stocks and ocean survival of wild fish, which could be done by marking wild coho (coded wire tags or use of genetic markers) in concert with the life cycle monitoring sites.

Overall Conclusions:

Based on these findings and the individual conclusions based on the science questions the IMST reaches the following overall conclusions.

- Numerous assessments, including the Oregon Plan (1997), have concluded that historical harvest rates have been too high and have contributed to the decline of OCN coho salmon. Harvest management decisions can have immediate and direct influence on spawner abundance. This makes all harvest management decisions critical for both the survival and the recovery of remaining wild stocks.

- In recent years, poor ocean conditions have prevented recovery. Sound harvest management in combination with effective habitat restoration and hatchery management can strongly influence the rate at which populations of wild salmonids recover (when climate-related conditions for ocean survival improve).
- Major advances have been made in management of salmon harvest and monitoring of adult escapement in Oregon since the mid-1980s. The current direction and innovations in management should be continued and strengthened by the State. In particular, the coho life-cycle model and spawner monitoring surveys are scientifically rigorous and represent some of the most advanced salmon management tools in North America.
- The State of Oregon needs to explicitly define recovery of depressed salmon stocks and criteria for evaluating recovery.
- The recovery of wild salmonids under the Oregon Plan may require 1) development of a coordinated program of modeling and monitoring of salmon populations, habitat, and harvest and 2) revision of the current policy framework and fishery management programs to meet the criteria for recovery.

Recommendations

The findings and the conclusions of the IMST are the basis for the following specific recommendations of the IMST. The first two recommendations are to the State of Oregon, and Recommendation 2 includes a specific recommendation to ODFW. All other recommendations are to ODFW. In some cases recommendations involve decisions in which the State collaborates with others (such as PFMC). In these instances, the IMST recommends that ODFW advocate that its collaborators adopt the essence of the recommendation in the interest of accomplishing the mission of the Oregon Plan.

1. **The IMST recommends that the State of Oregon define in measurable terms what is meant by the "recovery" of depressed stocks of salmonids.**

   Without a measurable definition, there is no technical basis on which progress towards accomplishing the mission of the Oregon Plan can be assessed. This severely limits the application of the principles of adaptive management, and the prioritization of recovery and research initiatives. Criteria for recovery need to incorporate demographic and genetic factors. A scientific workshop may be helpful in developing these criteria.

2. **The IMST recommends that the State of Oregon provide the legislative and executive support to enable ODFW to adopt the use of an explicit analytical process as part of the decision process for harvest levels. Further, we recommend that ODFW use the results from the analytical process in representing the State of Oregon to the PFMC.**

   We consider the adoption and use of an explicit analytical process as part of the decision process for harvest levels to be technically and scientifically critical to accomplishing the goals of the Oregon Plan. We believe implementation of this recommendation by ODFW requires that the executive and legislative leadership of the State explicitly endorse the concept and provides the financial resources needed.

   The process should incorporate:

   - Monitoring results (includes harvest records)
   - The coho life-cycle model results

It should take into consideration:

- The dynamic and changing landscape conditions that reflect potential habitat restoration
- Human-related degradation and restoration
- Natural disturbances in terrestrial and fresh water environments
- Ocean condition and climatic regime changes

The analysis process should link spawner surveys, habitat surveys, marine survival or impacts and model projections. It should also be spatially explicit to the greatest degree allowed by the data and model structure.

The IMST believes these are important because the use of dynamic conditions for both ocean and freshwater environments will provide more realistic projections of future population trends and risks of extinction. As an example, we feel it is important to compare data from ODFW on the numbers of OCN adult spawners in each of the stock component units to see how they compare with the 50% full seeding at low marine survival. Earlier data show that we are below these levels given in Amendment 13, especially for the northern component. This emphasizes the importance of this analytical process as a basis for harvest management decisions and the extinction risk assessment modeling.

Such integration also recognizes regional goals to protect and restore watershed conditions along the Pacific Coast. This process would require effective focus on the process that coordinates these separate activities and integrates their findings into a recurring report on the status of salmon and the impacts of various sources of mortality. This will require more extensive application of sensitivity analysis and risk analysis.

We feel it is essential to the Oregon Plan that this analytical process also be used by PFMC.

The IMST Recommends that the Oregon Department of Fish and Wildlife:

3. **Evaluate the ability of the current monitoring and research programs to provide data required for life-cycle modeling and to measure the following:**

   - **Recolonization of habitats as stocks recover**
   - **Straying rates**
   - **Distribution and abundance of spawners across their range**
   - **Degree of unoccupied habitats, and**
   - **Ocean survival (both within and among Gene Conservation Groups (GCG's)).**

   These measures are needed over a range of survival conditions.

   The Stratified Random Sample (SRS) surveys should be expanded to accomplish the desired measurement objectives and improve estimates of spawners within the Gene Conservation Groups (GCG's). It is important to develop and analyze data on variation in spawner numbers by basin. The trends/variation of spawner numbers in small tributaries are important because of the increased risk of extinction in smaller populations. Because many populations of OCN coho salmon are at critically low levels of abundance, Stratified Random Sample (SRS) surveys should be conducted in basins with life cycle monitoring sites, and in other reference basins to better assess population sizes and extinction risks. Distributions within a basin and estimates of spawners per mile within spawning habitats of various qualities should be measured in addition to total basin abundance.

The current Stratified Random Sample (SRS) survey is a labor-intensive effort across a large geographic area. Coordination, management, data analysis, and reporting will be challenging and will require resources and management assistance.

These data will be helpful in evaluating the recolonization, straying rates, distribution and abundance of spawners and occupation of habitat called for in this recommendation.

The life cycle monitoring effort should be expanded to cover a greater extent of Oregon coastal and lower Columbia River coho salmon stocks. Stratified Random Sample (SRS) surveys should be increased in the basins with life cycle monitoring sites (and where smolt trapping occurs) to provide estimates of marine and freshwater mortality. Within these sites and additional associated monitoring sites, surveys of habitat conditions should be related to trends of spawner abundance by basin.

4. **Strengthen life-cycle modeling.**

Current life-cycle models are rigorous analytical tools for evaluating coho salmon populations. However, additional components could add to the rigor of models. These include:

- Incorporation of time delays and lag effects into models.
- Improvement in measurement of smolt-to-jack survival to estimate the marine survival of OCN coho salmon.
- Incorporation of fluctuations in egg-to-parr survival into models.
- Incorporation of error in spawner estimation into models.
- Measuring straying rates more accurately and incorporating them into models.
- Incorporating error in the estimation of habitat quality into models.
- Incorporating the use of marginal habitat into the model.
- Increased sensitivity analyses.

Models have their limitations. Evaluations of model performance should incorporate real-world checks that compare empirical observations of stream habitat condition to salmon abundance and distribution. Criteria for healthy salmon stocks and healthy streams need to be developed to serve as these “real world” checks on the predictions of simulation models.

Decision-making needs to incorporate information from the models, taking into consideration the evaluation of model performance (see above). The State should use compelling intuitive measures (such as the percent of streams with no spawners, or the number of spawners per mile) in describing the outcomes of the analytical process to the public.

5. **Strengthen extinction-risk modeling.**

Modeling of extinction risk addresses several, but not all, criteria for recovery. There are high levels of uncertainty in life-cycle model projections. If models are used to estimate extinction risk, the relationship among models and assumption of the models must be specified. Empirical analysis of stock performance related to extinction risk projections is needed but is currently non-existent or preliminary. In addition, extinction risk modeling should incorporate the observed range of estimated encounter rates and hooking mortalities rather than average values or current best estimates. Sensitivity analysis will strengthen the understanding of and application of the results of risk-extinction models (see strengthen life-cycle modeling - Recommendation 4).

6. **Adopt harvest management strategies that reduce fishery impacts on OCN coho salmon to as close to zero as possible when survival and spawner abundances are at critically low**

levels (OCN Work Group Report 2000) until established signs of recovery are observed. ODFW should advocate this same position to PFMC.

This recommendation applies to those policy and management decisions that affect the fisheries that are the sole responsibility of ODFW, those they co-manage with other entities, and those they participate in with the PFMC. The importance of this recommendation is reinforced because spawner abundances and marine survival have been extremely low and recruitment for all three recent brood years (1995, 1996, 1997) has been below replacement and at critical levels.

7. **Advocate to PFMC that new criteria be incorporated into the matrix of Amendment 13 to include "very low" OCN coho salmon parent spawner abundance and "very low" marine survival.**

   Under these conditions, no coho fisheries should be allowed and fishery related impacts should be 0-8%, but as close to zero as possible.

8. **Develop harvest management criteria that include consideration of the distribution of spawners and the percentage of streams or basins with viable populations of spawners within sub-aggregate units. ODFW should advocate this same position to PFMC.**

   The objective of this recommendation is to accomplish a more rapid recolonization of the available habitat during improved conditions of ocean survival.

9. **Use the Minimum Sustainable Escapement (MSE) concept to augment the use of harvest impacts in estimating harvest related OCN coho mortality. ODFW should advocate this same position to PFMC.**

   This could provide a safeguard against loss of stocks during periods of low freshwater or ocean survival. The National Research Council (1996) recommends this methodology to minimize extinction risks of a population or metapopulation and to enhance recovery. The "critical" and "very low" parental spawner categories proposed by the OCN Work Group are consistent with this concept.

10. **Adopt a decision process that enhances recovery over longer periods of time and includes consideration of the spatial distribution of stocks. ODFW should advocate this same position to PFMC.**

    The timeframe, abundance and spatial distribution of OCN coho salmon stocks are critical elements of measures of recovery. Harvest policies should be revised to require responses over sufficient time to indicate real population trends. We offer the following criteria as possible examples to be incorporated into the decision process whereby harvest levels are changed.

    Criterion 1. *Stock Abundance*. Stock abundance has achieved a defined Minimum Sustainable Escapement (MSE) before harvest impacts can exceed 10-13%.

    Criterion 2. *Duration of Recovery.* Stocks have achieved greater than 1:1 spawner-to-spawner replacement for each brood year over at least three brood cycles.

    Criterion 3. *Spatial Distribution.* Stocks have achieved two consecutive generations of recovery (spawning recruits/parental adult of >1.5) with seeding above level 2 (75% seeding of available habitat).

11. **Link decisions on ocean harvest to the status of the weakest stock component. Advocate that PFMC use this same approach.**

Amendment 13 is clear on this point —" opportunities for increased ocean harvest may be constrained by the weakest component. In the foreseeable future, the northern stock component may dictate low harvest levels in marine fisheries for all components" and "In the event that a spawner criteria is achieved, but a basin within the stock component is identified to have a severe conservation problem, the next tier of additional harvest would not be allowed in mixed-stock fisheries for that component, nor additional impacts within the basin".

Oregon currently adheres to this requirement, but pressures to allow fishing by sport or commercial fishermen create challenges for following this policy.

12. Determine the relationship between the response of salmon juveniles and their food webs to carcass abundance and distribution, and determine the processes by which these relationships operate.

Scientific experiments are needed to establish this relationship and to determine the processes that are involved. Determining the processes is critical to understanding what is occurring and to be able to extrapolate relationships to other settings and situations. Knowledge from the processes and relationships will provide the scientific basis for adjusting harvest management to accomplish desired goals of carcass abundance and distribution.

Strategies for stock recovery need to recognize the various roles of salmon carcasses in the production of smolts in freshwater habitats. As an example, management criteria could identify minimum numbers of spawners per mile of stream to provide the food base necessary to support young salmon, and this can then be incorporated into the harvest management decision process.

13. Advocate that PFMC obtain more accurate estimates of hook-and-release mortality of OCN coho salmon to better assess the impacts of the fishery.

Encounter rates for OCN coho salmon vary with the different fisheries, regions of the ocean and at different times of the year. Hooking mortality varies with the type of fishing gear and how it is deployed. Sensitivity analysis can help evaluate the potential impacts of non-retention fisheries that are greater than those currently used in harvest management for OCN coho salmon stocks in general, and on North Coast components and Lower Columbia River wild stocks in particular. Analysis of hook-and-release mortality should continue after 2000 because uncertainty is high and ocean conditions are highly variable.

There are three subparts to this recommendation.

13a. Support PFMC's review of hook-and-release mortality.

It is essential that PFMC continue to evaluate the impact of hook-and-release mortality, taking into account encounter rates as well as the rate of mortality that ensues.

13b. Continue and expand double-index tagging of hatchery fish during years when selective coho fisheries are implemented.

Double-index tagging is a technique that can provide estimates of non-retention mortality. These experiments should be carefully designed to provide statistical tests of the differences in recovery rates. In order to account for differences in recovery rates of marked and unmarked fish, accurate data are needed on exploitation rates in both commercial and recreational fisheries.

13c. Continue monitoring of the encounter and retention of marked and unmarked fish in any selective fisheries (e.g., Buoy 10, the Ocean Recreational, terminal fisheries for fish released from net pens in the Columbia River estuary).

14. **Continue to determine compliance rates with respect to release of unmarked coho salmon.**

    Compliance rates for release of all coho salmon with adipose fins (wild coho) and methods for their analysis are an important element in the public's trust and confidence in selective fisheries. Additional review of estimates and methods of determining compliance rates in selective fisheries in the ocean, bays, and rivers is needed. Both troll and recreational fishery seasons and fishing methods should be formulated to minimize impacts on OCN coho salmon.

15. **Manage all wild coho salmon in Oregon---lower Columbia River, north coast, central coast, and south coast stocks---under the same principles and with the same goals. ODFW should advocate this same position to all entities with whom they collaborate in the management of coho salmon stocks.**

    There is no scientific basis for treating lower Columbia River coho salmon separately from coastal coho salmon.

16. **Tag all hatchery coho in the Columbia River. ODFW should advocate this same position to all co-managers in the Columbia River basin (e.g. State of Washington, Tribes and federal agencies), and also determine from Pacific States Marine Fisheries Commission (PSMFC) the number of untagged fish that have adipose fins.**

    This should be done by all agencies responsible for management of lower Columbia River coho salmon. Currently estimates of harvest impacts are biased if all hatchery fish are not fin clipped. This result adds an additional source of uncertainty to the estimates of harvest impacts. Currently the number of unmarked hatchery fish in the “catch” is impossible to ascertain and this number varies from year to year.

INTRODUCTION

In 1991, a review of the status of Pacific Northwest salmon concluded that a substantial proportion of existing salmon stocks faced significant risk of extinction (Nehlsen et al. 1991). Habitat degradation and overharvest were implicated in a majority of the declining or extinct stocks. This assessment is consistent with a series of regional and national reviews (Walters and Cahoon 1985; Chapman 1986; Konkel and McIntyre 1987; Nickelson et al. 1992; Frissell 1993; Washington Department of Fisheries et al. 1993; Botkin et al. 1995; National Research Council 1996), leading to the development of the Oregon Plan for Salmon and Watersheds (Oregon Plan) and the listing of some stocks of salmon as threatened or endangered under the Endangered Species Act (ESA). This crisis led to this science report on harvesting as it affects the recovery of coho salmon in Oregon.

Background

Populations of Oregon coastal natural (OCN) coho salmon historically exceeded 1.5 million adult spawners. Harvest peaked in 1895 in the Columbia River and in 1911 along the Oregon coast (Cobb 1930). As recently as the early 1970s, populations of OCN coho salmon from both rivers and lakes ranged from 200,000 to 690,000, but their numbers have declined to a high of approximately 70,000 in 1996 and a low of 25,000 in 1997 (Figs. 1, 2). Similar declines in coho salmon stocks have also been documented for British Columbia, Washington, and California (Beamish et al. 1999).

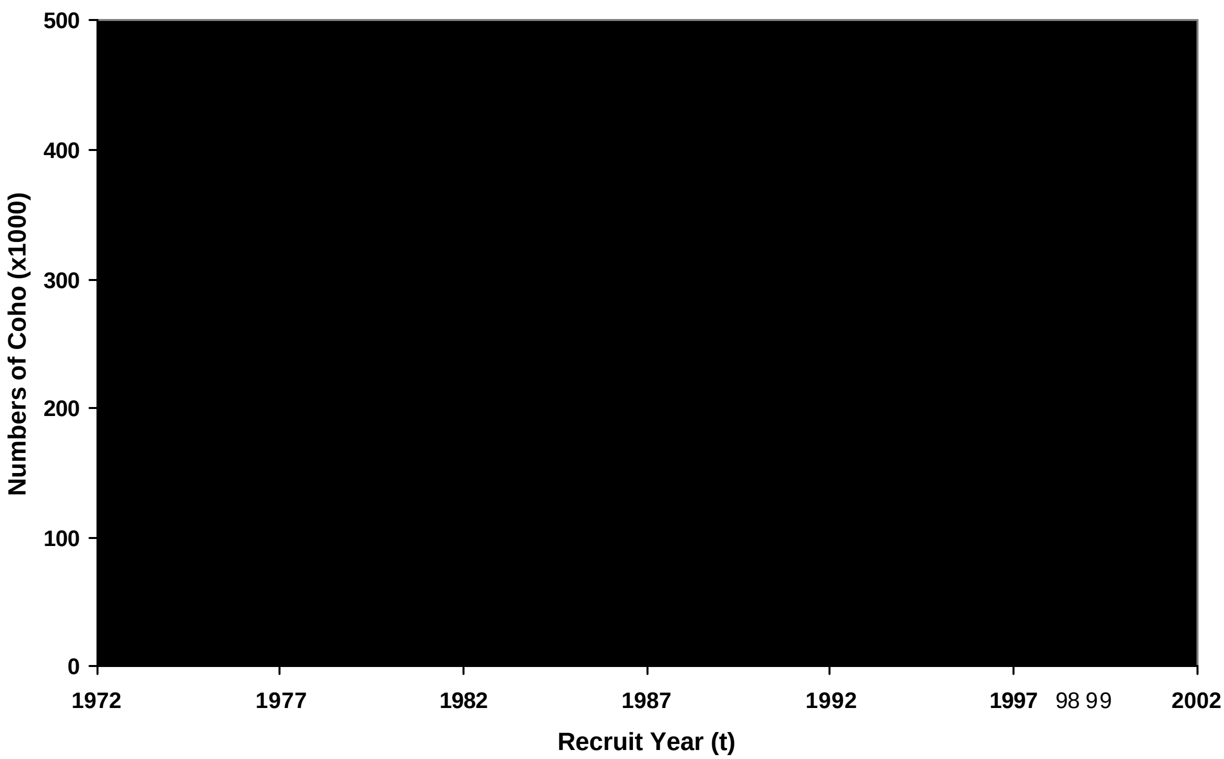

Figure 1. Trends in spawning escapement and ocean recruits of Oregon coastal coho salmon as indexed by counts in standard spawning surveys, 1972-99 (Jacobs 1998, Jacobs personal communication). Numbers of spawners are shifted forward in time to match up with the recruits they produced three years later. Recruits are adult salmon in the ocean prior to harvest and return to freshwater; spawners are numbers of salmon on the spawning grounds.

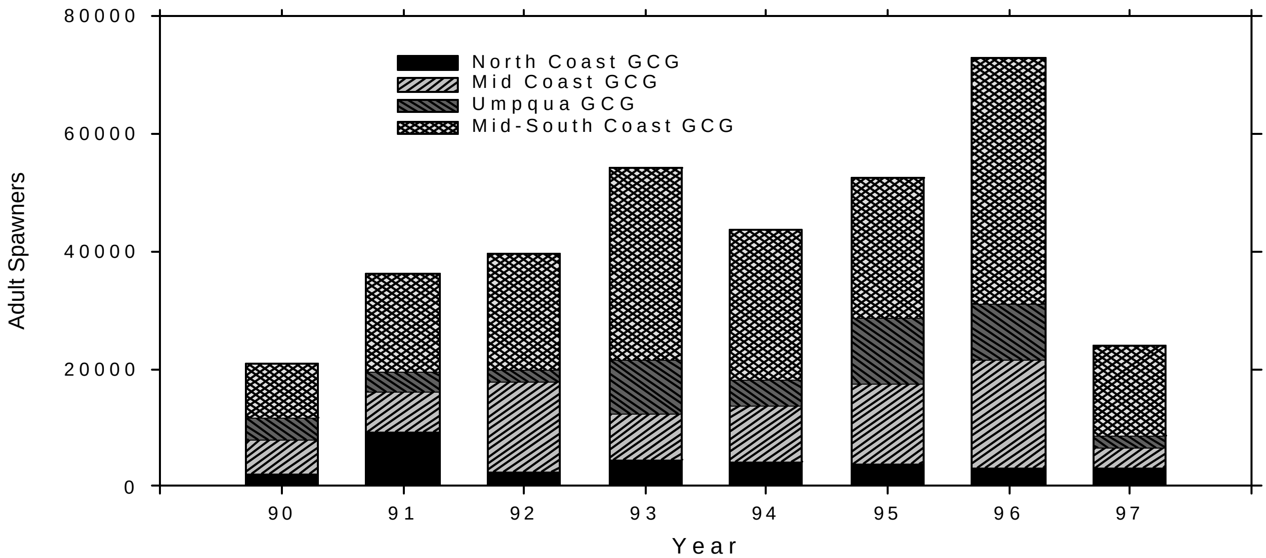

Figure 2. Estimated spawner abundance of coho salmon for individual Gene Conservation Groups (GCG's) within the Oregon Coastal Evolutionarily Significant Unit (ESU), 1990-97 (Jacobs 1998). Graph shows contribution of each Gene Conservation Group (GCG) to the total abundance of the Evolutionarily Significant Unit (ESU), including rivers and three coastal lake basins located within the mid-south Gene Conservation Group (GCG).

Numbers of OCN coho salmon returning to spawn have declined slightly since 1950 (data for 1972-1999 in Fig. 1), but the pre-harvest abundances of ocean recruits (estimates of mature fish in the ocean) has declined markedly over the same period, reaching the lowest levels on record in 1997 and 1998. The difference between the number of spawners in the streams and the number of ocean recruits is an estimate of ocean mortality due to both harvest and natural mortality.

Coho salmon in Oregon generally have a three-year life history. At any time, there are three generations of fish in freshwater or the ocean. If abundances of adults are less than the numbers of parents that produced them for three successive years, it indicates that the numbers of fish in three generations have declined. Since 1997, the number of OCN coho ocean recruits produced by a given brood year has been less than the number of spawners that produced them (Fig. 2). This indicates that all three brood years (1997, 1998, 1999) of OCN coho salmon have not replaced themselves and have declined since 1996 (PFMC-Scientific and Statistical Committee 1999).

These trends for OCN coho salmon stocks resulted in the Endangered Species Act (ESA) listing of the Oregon Coast and the Southern Oregon/Northern California Evolutionarily Significant Units (ESU's) by NMFS as “threatened”. The Endangered Species Act (ESA) defines a threatened species as any species or distinct population segment which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. ODFW has identified 128 coho salmon populations that make up the total OCN coho salmon stock.

A review of the status and management of Pacific salmon by the National Research Council (NRC 1996) concluded that declines were caused by an array of human activities, including forest practices, agricultural practices, livestock grazing, dams, hatchery management, and commercial and sport harvest, as well as ocean conditions. Their final conclusions were that there are too few spawners and that escapements should be increased. The Oregon Plan also cites these reasons for decline and lack of recovery of OCN coho salmon. The National Research Council's report (1996) noted that reducing fisheries harvest to increase numbers of returning spawners (escapement) “will disrupt fisheries, industries, and communities, but it is necessary for restoring production."

In 1994, retention or direct harvest of coho salmon in commercial and sport fisheries in the ocean off the coast of Oregon was eliminated. In 1999 and 2000, a selective fishery for hatchery coho was permitted along the Oregon Coast. Abundances of neither ocean recruits nor spawners have increased after the closure of ocean coho salmon harvest from 1994 to 1998.

Harvest management issues are complex. In addition to levels of direct harvest, other sources of mortality of coho salmon caused by harvest of other species or stocks in mixed fisheries must be considered. Recent programs to mark all hatchery coho salmon under the Oregon Plan are intended to allow selective fisheries on hatchery coho, provide more accurate estimates of hatchery and wild fish in the harvest and escapement, and protect wild salmon stocks. However, these selective fisheries do cause some level of mortality on wild fish that are caught and released, and this mortality must be included in estimates of harvest impacts.

IMST Project on Harvest Management

The IMST undertook a study of harvest management for OCN coho as part of our effort to establish the scientific basis on which harvest of fish could be managed in a manner that facilitates the recovery of stocks of wild salmonids (the mission of the Oregon Plan).

This Technical Report focuses on management of salmon harvest by the State of Oregon and the Pacific Fishery Management Council (PFMC) and analysis of salmonid population dynamics under the Oregon Plan. Its scope is the influence of harvest management on stocks of wild coho salmon in Oregon, including direct effects from harvest of wild coho salmon, indirect effects from the selective harvest of coho salmon or fisheries for other species, modeling of salmon populations, assessment of risk of extinction, and monitoring activities that influence harvest decisions.

The science questions we address and the recommendations we make are presented within the context of the technical basis for actions identified by the Oregon Plan. The basis for commercial harvest under the Oregon Plan is Amendment 13 to the Pacific Coast Salmon Plan: Fishery Management Regime to Ensure Protection and Rebuilding of Oregon Coastal Natural Coho Incorporating the Regulatory Impact Review, Initial Regulatory Flexibility Analysis, and Environmental Impact Statement (October 1997).

The work of IMST on this project was greatly facilitated by Oregon Department of Fish and Wildlife (ODFW), National Marine Fisheries Service (NMFS), and Pacific Fishery Management Council (PFMC). Selected publications provided by these groups include:

1. Pacific Fishery Management Council. 1999. Amendment 13 to the Pacific Coast Salmon Plan: Fishery management regime to ensure protection and rebuilding of Oregon coastal natural coho. Portland, Oregon.
2. Nickelson, T. E., J. W. Nicholas, A. M. McGie, R. B. Lindsay, D. L. Bottom, R. J. Kaiser, and S. E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Report to the Governor, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

3. Nickelson, T.E., and P.W. Lawson. Initial Draft. Population viability of coho salmon, *Oncorhynchus kisutch*, in Oregon coastal basins: application of a habitat-based life-cycle model. Oregon Department of Fish and Wildlife, Corvallis, Oregon. 30 p.
4. Nickelson, T.E., and P.W. Lawson. 1998. Population viability of coho salmon, *Oncorhynchus kisutch*, in Oregon coastal basins: application of a habitat-based life cycle model. Canadian Journal of Fisheries and Aquatic Sciences 55:2383-2392.
5. Oregon Department of Fish and Wildlife and National Marine Fisheries Service. October 1998. Final assessment of risk associated with the harvest management regime of the Thirteenth Amendment to the Pacific Coast Salmon Plan. Portland, Oregon.
6. McIsaac, D.O. 1997. Draft report on proposed new spawner escapement rebuilding criteria and fishery management regime for coastal natural coho salmon. In: Oregon Coastal Salmon Recovery Initiative, Section 4, Attachment 2. Portland, Oregon
7. Natural Resources Consultants, Inc. August 1998. NRC NEAP research study summaries. 1996-97 sport hooking mortality, 1997 commercial troll hooking mortality, and 1995-97 commercial troll coho encounter studies. Report to PFMC Salmon Technical Team.

IMST also received helpful briefings on modeling from Tom Nickelson (ODFW), Peter Lawson (NMFS), and Gretchen Oosterhout (Decision Matrix, Inc.). Doug McNair (Natural Resources Consultants, Inc.) briefed the IMST on research on hooking mortality and encounter rates. Don McIsaac, Sam Sharr, and Chuck Tracy provided descriptions of the State and PFMC harvest management process. Paul Englemeyer (National Audubon Society) provided information on conservation strategies and PFMC management issues.

The IMST convened a workshop to explore definitions and criteria for recovery of OCN coho salmon on August 4-5, 1999. The main purposes of the workshop were to 1) define the concept of recovery and 2) to identify criteria for evaluating recovery. IMST published the findings of the workshop on December 13, 1999 (IMST 1999), and some information from that report are included in this document.

Science Questions

There are a great many science questions that could be part of this project. From these, we selected five broad questions, which IMST considers to be most important in accomplishing the mission of the Oregon Plan. These questions contain sub-elements in which more specific issues are addressed. We include the questions here to provide direction in reading the balance of this report:

1. How have harvest management practices affected the status of OCN coho salmon stocks? Are current harvest management policies likely to contribute to rebuilding of OCN coho salmon stocks under the Oregon Plan for Salmon and Watersheds?
2. Are mortality estimates from non-retention fisheries accurate? Does this source of mortality affect the recovery of coho salmon?
3. Are models used to represent population dynamics of Oregon coho salmon and impacts of harvest scientifically rigorous? Are these models effectively integrated into management, policy analysis and decision-making?
4. Are uncertainties in rebuilding OCN coho salmon stocks and the risks of extinction adequately addressed in coho salmon management? Are scientifically based strategies for extinction risk assessment effectively incorporated into salmon management to facilitate accomplishment of the mission of the Oregon Plan for Salmon and Watersheds?

5. Does the monitoring program provide information that is necessary to accomplish the mission of the Oregon Plan for Salmon and Watersheds? What measurements or analyses need to be included in the monitoring program to make it more scientifically credible and relevant to management and policy?

Organization of this Report

This is a long and complex report, reflecting the breadth and complexity of the issues involved. It is divided into an executive summary, five sections of text, a section of references and six appendices. The following explanation of its organization is to help readers direct their attention to the elements that are of greatest interest.

Executive Summary

Section I. Introduction

The introduction provides the history and context for the report, and identifies the major science questions addressed by the report.

Section II. Coho Salmon Stocks and Their Management

A brief description of coho salmon stocks and how they are managed.

Section III. Science Questions and Answers

This section includes the specific questions IMST addresses, a summary of relevant information for each question and our answers to them. This provides the basis for our conclusions and implications for policy and the specific recommendation of the IMST.

Section IV. Conclusions and Recommendations

This section draws the major conclusions from the answers to the science questions. Each conclusion leads to one or more specific recommendations of the IMST.

Section V. Implications for Policy

This section is at the interface between science and policy. In it we describe what we see as the implications for policy of our conclusions and recommendations. It is meant to help those addressing policy to do so in ways that are as consistent as possible with what is known from science.

Section VI. References

Appendices

There are six appendices intended to supplement the information that is in the body of the report. They are:

A. Chronological history of spawning escapement and harvest management goals for Oregon Coastal Natural coho salmon stocks in coastal basins.

B. Processes contributing to final harvest management decisions.

C. Harvest matrix from Amendment 13 to Pacific Coast Salmon Plan.

D. Proposed revisions to the harvest management matrix in Plan Amendment 13.

E. IMST letter to Kay Brown, ODFW, regarding harvest level establishment for the PFMC process.

F. October 31, 2000, testimony of Dr. Stanley Gregory, IMST, to the Pacific Fisheries Management Council.

COHO SALMON STOCKS AND THEIR MANAGEMENT

Definitions of coho salmon stocks, populations, and management groups

A confusing array of terms is used to describe different groups of coho salmon populations along the Oregon coast. This report focuses on Oregon coastal natural (OCN) coho salmon and lower Columbia River salmon. OCN coho salmon are an aggregate of all wild coho salmon populations that originate in coastal streams between the Columbia River and Cape Blanco in southwest Oregon. OCN coho salmon include salmon rearing in streams and rivers, referred to as OCNR for river, and those rearing in freshwater lakes, which are termed OCNL for lakes. Lower Columbia River coho salmon are the aggregate of the six wild salmon populations that spawn in tributaries of the Columbia River, recognized by ODFW under Oregon's Threatened and Endangered species law (Chilcote 1998).

In general, "Oregon coastal coho salmon" refers to the combined numbers of wild and hatchery fish produced in rivers and lakes along the Oregon coast. The term "Oregon coho salmon" includes all coho salmon, both hatchery and wild, from the Oregon coast and the Columbia River.

Early attempts at developing a technical basis for harvest management focused on an index of ocean survival based on hatchery coho salmon in a management zone from southern Washington (south of Leadbetter Point) to northern California. This index is known as the Oregon Production Index (OPI) and is used to describe all wild and hatchery coho salmon within this specific management zone.

Coho salmon management

The Oregon Plan was created to reverse the clear declines in coastal salmon populations and to prevent additional extinctions of coastal stocks (Oregon Plan 1997). The State is faced with serious questions about risk of extinction of populations, major factors contributing to declines, goals for resource decisions, guidance for public and private actions, and design of monitoring. Assessment and future projections of the status of salmon stocks are a central requirement in each phase of the Oregon Plan.

The federally mandated Pacific Fishery Management Council (PFMC) was established by the Magnuson Fishery Conservation and Management Act of 1976 and by the Sustainable Fisheries Act of 1996. Under the PFMC, representatives of the public, industry, and state agencies from Oregon, Washington, California, the federal government, and Treaty Indian Tribes manage harvest of salmon in coastal marine waters. The State of Oregon manages most nearshore and inland fisheries but co-manages many of the fisheries in the Columbia River Basin together with the State of Washington and Treaty Indian Tribes. Recent salmon harvest management for ocean fisheries that are governed by the PFMC has been defined by Amendments 11, 13, and 14 to the 1984 Coastal Salmon Management Plan. Amendment 13 was adopted by the PFMC in 1997 and approved by the Department of Commerce in 1999 following the completion of a PFMC-sanctioned risk assessment. Amendment 13 is a recovery and rebuilding plan for OCN coho salmon that "1) defines individual management criteria for four separate stock components, 2) sets overall harvest exploitation rate targets for OCN coho salmon that significantly limit the impact of fisheries on the recovery of depressed stock components, 3) promotes stock rebuilding while allowing limited harvest of other abundant salmon stocks during critical rebuilding periods, and 4) is consistent with the Oregon State recovery plan" (Draft Final Pacific Coast Salmon Plan, August 1999).

Measures recommended for annual salmon management are developed through a sequence of analyses and meetings. A detailed schedule for this process is adopted by the PFMC in November of each year. Reports on the previous ocean salmon fishing season and estimates of expected salmon abundance for the coming season are released publicly by late February. PFMC develops fishery management options in March and adopts final recommendations in April.

The Oregon Department of Fish and Wildlife (ODFW) recommends harvest practices to the Oregon Fish and Wildlife Commission (OFWC). The OFWC provides guidance on the negotiating framework used by the Oregon delegation to the PFMC. Harvest practices are the product of the application of the Oregon Plan, the Endangered Species Act (ESA), negotiations with Treaty Tribes, and deliberations of the PFMC (see section on Harvest Management). A brief history of salmon management for coastal Oregon is outlined in Appendix A.

What is Meant by the Term "Recovery"?

In spite of the fact that recovery of depressed stocks is the primary goal of the Oregon Plan and a legal mandate of the PFMC for some species of salmonids, the IMST has found no explicit statement of the definition of "recovery". Currently the triggers for changing the levels of sport and commercial fishing harvest are the only criteria being used to determine whether specific stocks meet the goal of rebuilding stocks. Harvest management decisions have the most immediate impact on spawner abundance and are therefore critical to the recovery of depressed stocks of wild salmonids in Oregon. It is essential therefore that the meaning of recovery be defined in measurable terms to guide harvest management decision-making. Measurable goals for recovery of depressed stocks of OCN coho salmon are needed to provide a technically strong basis for harvest management decisions.

For the purposes of this report until a formal definition is adopted by the State of Oregon, the IMST will use the following definition:

> A recovered population must be naturally self-sustaining over prolonged periods of poor climatic and environmental conditions at the level of individual basins. Wild fish must be sufficiently abundant, productive, diverse (in terms of life histories), and widely distributed that the resource as a whole is self-sustaining into the future. The spawning and rearing habitat will be of sufficient quality and quantity to support sustainable populations. Recovered salmonid populations must be sufficiently abundant to provide environmental, cultural, and economic benefits. Under all conditions, the population should be large enough and diverse enough at each life history stage such that:
>
> - Spawning escapements reflect historical temporal and spatial distribution patterns,
> - Genetic diversity is maintained, preserving as many of the historically observed phenotypes as possible,
> - Adult returns are adequate to fulfill necessary ecosystem functions.

For additional information related to developing a definition of recovery, a subsequent report will be released by the IMST. The IMST recommends that the State of Oregon define in measurable terms what is meant by the "recovery" of depressed stocks of salmonids.

The timeframe and abundance and spatial distribution of OCN coho salmon stocks are critical elements of meaningful measures of recovery. Harvest policies should be revised to require responses over sufficient time to indicate real population trends. We offer the following criteria as possible examples to be incorporated into the decision process whereby harvest levels are changed:

- **Criterion 1.** *Stock Abundance*. Stock abundance has achieved a defined Minimum Sustainable Escapement (MSE) before harvest impacts can exceed 10-13%.
- **Criterion 2.** *Duration of Recovery*. Stocks have achieved greater than 1:1 spawner-to-spawner replacement for each brood year over at least three brood cycles.
- **Criterion 3.** *Spatial Distribution*. Stocks have achieved two consecutive generations of recovery (spawning recruits/parental adult of >1.5) with seeding above level 2 (75% seeding of available habitat).

SCIENCE QUESTIONS

Following are the five science questions addressed by IMST. The answers to these questions lead to the conclusions and recommendations in this Technical Report.

Question 1: How have harvest management practices affected the status of OCN coho salmon stocks? Are current harvest management policies likely to contribute to rebuilding of OCN coho salmon stocks under the Oregon Plan for Salmon and Watersheds?

Historical trends in salmon harvest

There is no question that over harvest by both commercial and sport fishing has significantly contributed to the decline of coastal salmon. The Oregon Plan (1997) stated that:

> "Historically, over harvest has been a significant factor in the decline of coho salmon. Excessive catch and/or harvest, times and areas open for harvest, mixed stock and targeted fisheries, and gear used have all been substantial contributing factors."
>
> "The problems of over exploiting less productive stocks and species in mixed-stock fisheries and of selectively fishing populations and species have been widely recognized but poorly resolved by society. Mortality associated directly and indirectly with fishing can eliminate populations, reduce numbers within populations, alter or eliminate life history patterns, reduce fitness, and mask population trends. All of these effects may adversely affect the sustainability of wild salmon populations and should be evaluated in an assessment of extinction risk."

Exploitation rates over the last century have been far greater than current estimates of acceptable impacts on coho salmon. Exploitation rates peaked at roughly 90% of returning spawning adults in the mid-1970s (Table 1).

Table 1. Chronology of changes in harvest impact rates associated with commercial and recreational fisheries for Oregon Coastal coho salmon (Oregon Plan 1997).

Fishery	Time Period	Harvest Impact Rates
Coastal river and estuary gillnet	1890's-1920s	40%
Coastal river net and ocean troll	1930s-1940s	40-60%
Ocean troll/sport	1950s	60-80%
Ocean troll/sport	1960s	60-80%
Ocean troll/sport	1970-1983	60-90%
Ocean troll/sport	1984-1986	30-40%*
Ocean troll/sport	1987-1992	45-65%
Ocean troll/sport	1993	35%
Ocean troll/sport	1994-1999	8-13%**

* PFMC response to 1983 El Niño. In 1984, OCN coho salmon spawning escapement goal was identified for the first time in a new salmon fishery management plan.
** See detailed regional data for 1994-1999 in Table 2.

Amendment 13 and recent levels of harvest

Amendment 13 manages levels of harvest impacts based on estimates of ocean survival rates and spawner abundance. Amendment 13 includes harvest management options that are more protective of populations at low abundance than previous management approaches. The harvest matrix in Amendment 13 sets trigger points for relaxation of harvest restrictions as certain population attributes (e.g., ocean survival and spawner abundance) improve. Harvest rates are allowed to increase above the lowest levels of indirect mortality (impacts of non-retention sport and commercial harvest) when both spawning escapements and marine survival improve from low to medium or from medium to high levels, which are defined in the harvest matrix. This approach developed under Amendment 13 is a major step forward in salmon management and should be strengthened in the future.

The decision matrix of Amendment 13 (Appendix C) is based on a general precautionary approach. The recent OCN Work Group Report (2000) provides the best example of a robust precautionary approach and incorporates indicators of minimum escapement levels as recommended by the National Research Council (NRC 1996) (see matrix in Appendix D). NOAA developed criteria for a precautionary approach for managing Atlantic groundfish fisheries (Restrepo et al. 1998). The rebuilding plan identified in this NOAA report calls for explicit identification of: 1) stock size at maximum sustained yield; 2) a rebuilding period; 3) desired rebuilding trajectory; and 4) a transition from rebuilding regulations to more optimal management. The general precautionary approach identifies population and spawner abundance levels needed to sustain sufficient numbers of fish for population stability and harvest, allows enough time for populations to respond to relaxed pressures and improvements in habitat conditions, incorporates a plan for improving population abundances, and provides for caution when increases in harvest impacts do occur. This type of approach has not been fully implemented for rebuilding and adjusting harvest impacts on OCN coho salmon populations in Oregon.

Impacts of Harvest on OCN Coho Salmon Recovery

Under the current harvest management system and Amendment 13, harvest impacts on OCN coho salmon can range from less than 10-15% under conditions of low marine survival up to 35% if:

- two generations of spawner rebuilding have been demonstrated, and

- marine survival is adequate to support continued improvements in adult spawner returns for a third generation.

Since 1993, pre-season targets for total fishery impacts were 10%, 12%, and 13% in 1994-96, respectively. Increases in fishery impacts above the 15% level could be proposed only:

- after the lower spawner escapement rebuilding criterion has been achieved in at least the parent generation, and
- significant improvements in the next generation of spawner escapement can be projected as a result of improved marine survival.

The harvest matrix of Amendment 13 (Appendix C) depends on the level of spawner seeding of high quality habitat and estimates of marine survival of OCN coho salmon based on the smolt-to-jack survival of Oregon Production Index (OPI) hatchery coho. The spawner rebuilding levels are used as decision points in fishery management. The lowest level, a stock rebuilding level, represents 50% of the estimated number of adults to achieve full seeding of the high-quality freshwater habitat during conditions of poor ocean survival. At or below this level, harvest rates must be <10-15%. Higher fishery impacts (15-35%) are allowed when 75% of the high quality habitat is fully seeded (PFMC 1999).

The current policy of allowing increased harvest impacts at 50% of full seeding of the best available habitat (Level 1 in the Harvest Matrix, see Appendix C) is a policy decision. This decision was based on the expectation of a 50% increase in spawners in each subsequent generation, assuming a 3% marine survival rate. The technical basis for this criterion, whether valid or not, is not documented by either PFMC or ODFW.

The IMST believes that at recent low population numbers and lack of replacement of stocks and stock aggregates, fishery impacts on OCN coho salmon are very uncertain. Knowledge of population dynamics for coho salmon at extremely low populations is technically weak because of the lack of studies. Therefore, strongly conservative management criteria and explicit definition of "extremely low populations" are needed in such conditions (e.g., 10% of fully seeding high quality habitats).

Spawner abundances and marine survival have been extremely low and recruitment for all three recent brood years (1995, 1996, 1997) has been below replacement and at critical levels. Because of this IMST believes harvest management strategies should be adopted to reduce fishery impacts on OCN coho salmon to as close to zero as possible until established signs of recovery are observed. Consistent with this, we feel new criteria should be incorporated into the matrix of Amendment 13 to include "very low" OCN coho salmon parent spawner abundance and "very low" marine survival. Under these conditions, no coho fisheries should be allowed and fishery related impacts should be less than 8%.

A review by PFMC (1992) shows that in the 11 years from 1981 to 1991, ODFW met its escapement target for OCN coho salmon (200,000) only three times. Under Amendment 13, which regulates OCN coho salmon impacts by harvest impact rates not numbers of spawners, the number of spawners required to meet the 50% full seeding level of high quality habitat is 66,100 for all four stock components (similar to Gene Conservation Groups (GCG's)) combined. This number of spawners has been attained only once during the past 10 years, again indicating the lack of rebuilding of OCN coho salmon (Fig. 1, previous section). Therefore escapement goals for OCN coho salmon have not been achieved under Amendment 13.

While harvest impacts have been reduced dramatically (from 30%-90% prior to 1990 to 8-13% since 1994), generally escapement goals have not been achieved. Improved escapement is essential for the recovery of OCN coho salmon, and control of fishing mortality is the best available tool for achieving improved escapement. During periods of low ocean productivity the likelihood of accomplishing recovery is low under Amendment 13 because escapement of adult spawners is too low. At low marine survival rates, elimination or reduction of human-caused sources of mortality would reduce probability of extinction and would possibly allow modest recovery. It would increase the rate of recovery under higher ocean survival rates.

Use Of The Life-Cycle Model In Harvest Management Decisions

Analysis with the habitat-based life-cycle model of Nickelson and Lawson (1998) under poor ocean conditions (i.e., 1.8% marine survival) indicates that the current harvest management policies (Amendment 13) do not provide greater rates of stock recovery than the previous management policies (Amendment 11)(ODFW and NMFS 1998). Model projections of potential extinction rates are greater with harvest than with no harvest, but estimates of extinction rates do not differ between Amendments 11 and 13. This indicates that even low rates of harvest have the potential to adversely impact stocks, hence attention to indirect impacts that seem small in comparison to historical impacts is justified.

The predictive power of the life-cycle model is very low at 50% seeding—the level at which harvest impacts would be allowed to increase in the matrix. At 50% seeding, the actual smolt production was only about 40% of the predicted capacity (Figure 1 in Nickelson and Lawson 1998). The uncertainty in the model predictions is not taken into account in establishing the level 1 spawner abundance (PFMC 1997, p. 13). Widespread spawning distributions of coho salmon populations are needed to minimize risks of extinctions when the region shifts from climate regimes that are favorable for survival to conditions that result in low rates of ocean survival (IMST 1999).

Jack Predictor as a Basis for Estimating Marine Survival

At present, the smolt-to-jack survival of hatchery coho salmon in the Oregon Production Index (OPI) area is used to estimate the survival rates of OCN coho salmon in the following year. This prediction assumes a constant relationship between jacks and adult recruits the following year, as well as a constant relationship between the performance of hatchery fish and wild fish. However, the jack predictor, the survival of jacks-to-adult hatchery coho, has shown considerable variability in recent years, indicating that marine survival of hatchery fish is variable and is not always accurately predicted by jack returns.

Marine survival of wild coho salmon is estimated based on measurement of marine survival of hatchery fish (and assumed to be twice that of hatchery fish). Mortality rates in the ocean after jack returns may be variable from year to year and explain much of the interannual variability in ocean survival. The precision, variability and reliability of these predictions need to be considered for utilizing measurements on hatchery fish as a basis for making decisions regarding selective fisheries for hatchery coho and determining harvest impacts to wild coho.

Survival of wild coho salmon from smolts-to-adult is assumed to be greater than that of hatchery fish. Risk assessments by ODFW and NMFS (1998) assumed a survival ratio of 1.5. Although most studies assume that wild coho have higher survival than hatchery coho (Nickelson 1986; Emlen et al. 1990), this difference varies substantially among years and has been less pronounced during the years of generally low marine survival that occurred during the late 1980s and early 1990s in the Pacific Northwest (Coronado and Hilborn 1998). Along the Washington coast, the percentage of marked hatchery coho recovered sometimes exceeded that of wild coho salmon (D. Seiler, Washington Department of Fisheries and Wildlife, personal communication). Therefore the assumption of a greater wild:hatchery coho survival may significantly overestimate wild coho salmon survival and escapement.

Spatial characteristics of management

Four different geographic contexts for OCN coho salmon management are recognized under the Oregon Plan—Evolutionarily Significant Units (ESU's) developed by NMFS, Gene Conservation Groups (GCG's) developed by ODFW, basin management plans by ODFW, and four aggregate-stock components under Amendment 13 of the PFMC. Theoretically, goals for recovery can be applied effectively to these four different geographic contexts for spawner escapement and stock assessment. While they differ in spatial extent, they are largely hierarchical and can be nested (Robin Waples, NMFS, personal communication). However, a few productive large populations could mask the demise of numerous small, less productive populations.

Page 7 of Amendment 13 states, "Within the limits of our current understanding and available information, each stock component will be managed at an overall annual harvest exploitation rate that is sensitive to present spawner abundance criteria based on productive capacity of its freshwater environment and the expected marine survival for the returning adults." The four aggregate OCN coho salmon stock components designated in Amendment 13 are roughly similar to the four Gene Conservation Groups (GCG's) along the Oregon coast and the Columbia River Gene Conservation Group (GCG). However, Oregon coho salmon to date have been managed as a single aggregate. This may have resulted in higher impacts on wild stocks north of Cape Falcon that are most at risk.

Under Amendment 13, fishery impacts can be increased for specific stock components of coastal stock aggregates if they begin to rebuild faster than others. Because data are not available that allow different rates of marine harvest of OCN coho salmon components, opportunities for increased ocean harvest are constrained by the weakest component (Amendment 13, Table 6, footnote b). The PFMC's Salmon Technical Team emphasized this problem with Amendment 13. Since the Fishery Regulation Assessment Model (FRAM) does not evaluate impacts on each of the OCN coho salmon components, there is no assurance that exploitation rates will be constrained within allowable levels for each component. It is unclear if OCN coho salmon components have different ocean distributions than hatchery stocks. Most marked Oregon Coast hatchery stocks are caught over a broad geographic range, with most recaptures off Oregon (Weitkamp et al. 1995). Many OCN coho salmon populations are managed together as one aggregated unit. However, each population is a biological unit and should be managed separately. Therefore, decisions on ocean harvest should be linked to the status of the weakest stock component.

Trends in OCN coho salmon should also be considered on the population or basin level. A review of Pacific salmon by the National Research Council (1996) recommended application of the Minimum Sustainable Escapement (MSE) concept to minimize extinction risks of a population or metapopulation and to enhance recovery. Minimum Sustainable Escapement (MSE) identifies minimum abundances of adult spawners in freshwater streams that maintain minimum viable populations. Actual escapements of adult spawners would be expected to exceed Minimum Sustainable Escapement (MSE) levels. This approach has also been endorsed by Overholtz and Knudson (1999) to maximize recruitment. It would be a conservative estimate of abundances required to maintain populations and would recognize the well-documented weaknesses of limited historical records for setting escapement levels. "Estimates of minimum sustainable escapement should ideally include information about the composition of spawning populations, the maintenance of connections between demes, the role of carcasses as nutrient sources, for freshwater ecosystems, intraspecific competition in reproduction, mate selection, and gene flow . . ." (NRC 1996). Application of the Minimum Sustainable Escapement (MSE) concept provides a "safety net" to avoid unintended extinction of salmon stocks as a result of uncertainties in managing harvest by setting acceptable impacts as a percentage of OCN coho salmon abundance of ocean recruits. This could provide a safeguard against loss of stocks during periods of low freshwater or ocean survival.

A harvest management criterion (from monitoring results) could be the proportion of all habitats of monitored stream reaches that are occupied by spawners. This measure of escapement could be a critical index for the recovery of OCN coho salmon stocks. Setting Minimum Sustainable Escapement (MSE) levels would improve probabilities of recovery.

Factors related to productivity

Measures of populations and genetic composition often focus on numerical response of the salmon but ignore food resources and ecological processes that support the productivity of the populations and fitness of the individuals. The roles of salmon carcasses in stream productivity have been documented in recent studies (Brickell and Goering 1970; Kline et al. 1990, 1993; Bilby et al. 1996). The numbers of spawners affect the productivity and survival of young salmon. Escapement goals may need to include an additional number of spawners for ecological processes, in order to enhance productivity of the freshwater systems supporting salmon.

Current management includes the distribution of carcasses with no link to priorities or expected outcomes. Successful management of carcasses under the Oregon Plan will require explicit experimental measurement of the responses of salmon (at all life stages) to additional food resources from carcasses.

OCN Work Group Review of Amendment 13

An OCN Work Group (Sam Sharr, chair, ODFW; Curt Melcher, ODFW; Tom Nickelson, ODFW; Dr. Pete Lawson, NMFS; Dr. Robert Kope, NMFS; Dr. John Coon, PFMC) met from December 1999 through October 2000 to review the technical adequacy of Amendment 13. The Work Group presented its findings to the PFMC on October 31, 2000.

The OCN Work Group invited IMST members to observe the 2000 Review of Amendment 13 to the Pacific Coast Salmon Plan. The IMST reviewed the report and submitted written and oral testimony to the PFMC. Several aspects of the report directly addressed recommendations of the IMST contained in a letter to ODFW (September 9, 2000) and in this report on harvest management.

The report of the OCN Work Group established a new matrix with new categories for periods of "Very Low" and "Critical" spawner abundances (see Appendix D). IMST has strongly endorsed development of precautionary criteria for conditions of extremely low spawner abundance. Addition of the "Very Low" and "Critical" parental spawner categories to the matrix greatly strengthens the management of impacts on coastal coho salmon. These additions are consistent with the original framework of the Salmon Management Plan and incorporate aspects of the concept of "minimum sustainable escapement" that was recommended in a recent review of salmon management by the National Research Council.

The IMST has consistently supported the application of management decisions based on the status of the weakest subaggregate, which the 2000 Review has continued to endorse. A significant change is the elimination of the provision for limits on moving to higher harvest impacts when a basin exhibits less than 10% full seeding. IMST recognizes the arguments provided for the elimination of basin criteria, and the lack of precision in basin estimates of spawners is a valid concern. This change in Amendment 13 may be justifiable at this point and the additional levels of protection within the matrix may minimize undesirable impacts, but the IMST recommends continued development of methods and information to effectively manage salmon at the scale of basins or river networks. The IMST encourages the PFMC to consider future actions that would strengthen basin-level estimates of spawners and additional local data that would permit protection of smaller basins and their stocks in the future.

The OCN Work Group used the Nickelson/Lawson model for projecting risks of extinction. The IMST found the Nickelson/Lawson model to be scientifically rigorous and strengthens the PFMC process. The analyses conducted for the review were based on static, non-changing habitat conditions in the future. The OCN Work Group Review concluded that:

> *One of the key assumptions of the model is that the status of freshwater spawning and rearing habitat is stable. Hence modeling results and the predicted probabilities for recovery of OCN coho are explicitly linked to the maintenance or increased availability of high quality freshwater habitat. If the quantity or quality of available freshwater habitat decreases further it is unlikely that any harvest management at low level of spawner abundance will result in stable or increasing OCN abundance.*

We strongly encourage state and federal agencies to integrate current and future habitat conditions with the modeling of fishing impacts, ocean survival, and salmon populations. At present, the model incorporates dynamic ocean conditions and changing fisheries, which is a strength. Unfortunately, the future projections do not incorporate dynamic changes in habitat, either as a result of watershed restoration or future habitat degradation. A more dynamic view of habitat could be incorporated based on readily available land use/land cover information and projections of land use policies.

The 2000 Review addresses the most critical recommendations of IMST, but it did not address several major recommendations contained in the Harvest Management Report—longer timeframes required before major changes in harvest impacts, incorporation of ecosystem functions of carcasses in management targets, review of the Fishery Regulation Assessment Model (FRAM) model, use of dynamic landscape information in model projections. The OCN Work Group could provide an updated assessment in the near future and possibly incorporate issues that emerge from the regional response to their report

Conclusion

The IMST finds that harvest management has seriously affected stocks of wild coho salmon and contributed to the population declines that led to listing under the Endangered Species Act (ESA). The IMST also finds that a continuation of the Amendment 13 harvest policies has contributed only marginally to the rebuilding of salmon stocks under the Oregon Plan. Recovery and rebuilding of stocks are key goals of the Oregon Plan, but the meaning of these terms is not described in terms that provide a basis for assessing progress towards them or for implementing the adaptive management that is part of the Oregon Plan.

Question 2: Are mortality estimates from non-retention fisheries accurate? Does this source of mortality affect the recovery of coho salmon?

There are several terms used in this section that could cause confusion if the meaning is not clear. Specifically:

- Non-retention fishery – A fishery in which one or more species or type of fish landed is released.
- Selective fishery – A special form of non-rentetion fishery in which a selected portion of the population of a species is retained if caught, but other portions of the population are

released if they are caught (example – ocean sport fishery for hatchery (fin clipped) coho, with the release of any non-finclipped coho that are caught.

- Direct mortality – fish hooked, landed, retained and killed (as occurs in a retention fishery)
- Indirect mortality – mortality caused by fishing even though the fish is not retained (as occurs in a selective fishery for hatchery coho).
- Hook-and-release mortality - fish hooked, landed, released alive but the fish dies as a result. This is one form of indirect mortality.
- Drop-off mortality – fish hooked, but not landed (because it becomes unhooked), but the fish dies as a result. A second form of indirect mortality.

Non-retention Mortality

Selective recreational or commercial (troll) fisheries for salmon in the ocean, bays, and fresh water will encounter and kill wild salmon, including those listed as endangered or threatened. This is true even though ocean fisheries are specifically designed and intended to catch chinook salmon or fin-marked hatchery coho salmon. The magnitude of non-retention mortality can affect escapement and therefore spawner abundance and distribution, therefore the probability of extinction and/or the rate of recovery of depressed stocks. For these reasons, non-retention mortality is a critical factor to take into consideration in making harvest management decisions.

Non-retention mortality is a function of the (a) rate at which populations of interest are encountered in a fishery (the encounter rate) and (b) the resultant combination of hook-and-release mortality and drop-off mortality. The magnitude of this non-retention mortality is dependent on many factors, including the spatial and temporal distribution of the fish, water temperature, type of sport or commercial fishery, the type of fishing gear, and other factors.

Estimates of Non-Retention Mortality

Estimates for non-retention mortality of wild coho are based on estimates of hook-and-release mortality and estimates of encounter rates of wild coho by selective recreational and commercial (troll) fisheries. Non-retention mortality rates for OCN coho salmon have been assumed to be 13% (both drop-off mortality and hook-and-release mortality) in coho recreational fisheries and 31% in troll fisheries for chinook salmon. As a result of better data, the PFMC increased the estimate of non-retention mortality for selective coho recreational fishery from 13% to 19% for the Year 2000 fishing season. This decision is a prudent first step, but given the uncertainty of the estimate and the vulnerability of the most severely depressed stocks, continuing assessments of this non-retention mortality are needed.

<u>Estimates of Encounter Rates</u>

The number of wild fish encountered in a selective fishery affects the impact of that fishery on wild stocks. Encounter rates, which may have been underestimated (Natural Resources Consultants, Inc. 1998), depend on the ratio of wild to hatchery stocks, season of the year and location of the fishery, and marine distribution of the wild and hatchery fish. If hatchery (fin-clipped) fish are harvested, the ratio of wild to hatchery fish may increase over the season, increasing impact on wild fish later in the season.

<u>Estimates of Hook-and-Release Mortality</u>

Studies have provided a wide range of estimates of hooking and drop-off mortality. Different mortality rates are related to the location of the wound inflicted, size of fish, type of fishery, hooks and gear deployed, depth of fishing, water temperature, speed of retrieval of fish, etc. Both short-term (several hours) and long-term mortality have been estimated, but the meaning of the results of experiments to assess long-term or delayed mortality, measured by holding fish in tanks, pens, or restraining tubes, are uncertain. The results have been variable and often dependent on the holding methods. As a result of all these studies and their variability, it is clear that neither the accuracy nor the variability of non-retention mortality rates is well known (Natural Resources Consultants, Inc. 1998).

Estimates of Drop-Off Mortality

There is very limited data on which to estimate the mortality rate for wild fish that are hooked but are not landed and subsequently die from injuries or by predation. This is called drop-off mortality. At present the mortality rates assumed by PFMC include 5% as drop-off mortality.

Estimates of Total Indirect Harvest Impacts

Based on assumptions of encounter rates and hooking mortality rates, ODFW-PFMC estimates the indirect impacts on OCN coho salmon as part of the harvest management decision process. Since 1994, when the directed fishery for coho ended, pre-season estimates of these indirect impacts have ranged from 8.7% to 12.5% (Table 2). Impacts of fisheries north of Cape Falcon averaged 3.5%. Sport harvest south of Cape Falcon averaged 4.3%, and troll harvest in the same area averaged 2.4%. Commercial fisheries account for an average impact of 4.7% of the pre-season ocean adults, and sport harvest accounts for an impact of 6.8% of the preseason ocean adults.

Gear selection and deployment are important variables in the degree to which hook-and-release and drop-off mortality occur at any given encounter rate. Impacts on OCN coho salmon potentially can be reduced by changing methods of fishing (gear selection and deployment) and by reducing the encounter rates at locations and times when OCN coho salmon are concentrated. Decisions about both forms of harvest and assumptions about mortalities associated with catch-and-release of wild coho salmon are clearly important elements in harvest management.

Table 2. Preseason estimates of total impacts on OCN coho salmon for 1994-1999 expressed as a percent of the adult ocean population prior to harvest (data from Curt Melcher, ODFW). These are largely indirect impacts because of the reduction of directed harvest by PFMC.

Management Area	1994	1995	1996	1997	1998	1999	Average Impact	Regional Totals
Northern fisheries								
SE Alaska	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
Canada	2.29	2.45	1.51	2.93	0.21	0.22	1.60	
Puget Sound/SJF	0.22	0.23	0.14	0.41	0.42	0.80	0.37	
Treaty Troll	0.01	0.41	0.27	0.16	0.11	0.34	0.22	2.22
Fisheries north of Cape Falcon								
Sport	0.00	2.02	1.84	1.23	0.71	0.82	1.10	
Troll	0.00	0.08	0.20	0.01	0.03	0.55	0.15	1.25
Sport harvest south of Cape Falcon								
Cape Falcon-Humbug Mt.	0.06	0.40	0.85	0.46	0.98	0.79	0.59	
Humbug Mt.-Horse Mt.	2.54	1.15	1.54	0.58	1.51	0.68	1.33	
Fort Bragg	0.42	0.17	0.49	0.41	0.97	0.38	0.47	
S. of Point Arena CA	2.66	1.64	2.14	1.49	2.73	0.86	1.92	4.32
Troll harvest south of Cape Falcon								
Cape Falcon-Humbug Mt.	0.55	1.23	1.06	1.14	1.12	1.43	1.09	
Humbug Mt.-Horse Mt.	0.27	0.23	0.58	0.33	0.89	0.14	0.41	
Fort Bragg	0.05	0.04	0.37	0.02	0.05	0.01	0.09	
S. of Point Arena CA	1/	1/	1/	0.57	1.17	0.57	0.77	2.36
Buoy 10 fisheries	0.00	0.78	0.62	0.37	0.04	0.17	0.33	
Freshwater Sport	2.10	0.89	0.88	0.90	0.90	0.93	1.10	1.43
Total	11.1	11.8	12.5	11.0	11.9	8.7	11.6	11.6

Inadequacies of Estimates

Recent studies by Natural Resources Consultants, Inc. (1998) indicate that encounter rates and hooking mortality associated with commercial troll fisheries might be approximately 1.5 times greater than estimates currently being used by ODFW and PFMC. The Salmon Technical Team has reviewed recent data and rates. PMFC has adopted higher mortality rates, higher than previously used.

Consequences of underestimating non-retention mortality have not been evaluated in the life-cycle model. In addition, estimates of the risk of extinction should incorporate the observed range of estimated encounter rates and hooking mortalities.

Double-index tagging

Double-index tagging is a research strategy that can be used to improve our understanding of the mortality of unmarked fish in a selective coho fishery. ODFW is conducting "double-index" tagging of some hatchery fish. This consists of tagging two groups of hatchery fish, an index group (marked with an adipose fin clip and a coded wire tag) and a double-index group (no adipose fin clip and a coded wire tag). This non-adipose-fin-clipped group therefore more closely mimics wild fish. These two groups are released at the same time. Differences in the return rate of these two groups can be used to improve estimates of non-retention mortality. No difference in the return rate of these two groups, for example, indicates that selective fisheries did not reduce total fishing mortality of wild fish. Higher return rates of the double-index group, on the other hand, indicate improved survival of wild fish. Therefore, an expanded program utilizing "double-index" tagging will permit more direct evaluation of the mortality rate of unmarked fish in selective coho fisheries.

Marking of All Hatchery Fish in the Columbia River

According to the Pacific States Marine Fisheries Commission (PSMFC) database for 1997, 1998, and 1999, 10%, 4.2%, and 11.6% of the coho salmon released from hatcheries along the Columbia River were specifically indicated as having no external mark (percentages corrected for double-index and shed tags). However, the percentage of unmarked fish with no indication of external marks was considerably higher for these same years: 20.5%, 10 %, and 18.9%. Unmarked hatchery fish, which originate from hatcheries operated by ODFW, WDFW, USFWS and Yakama Tribes, confound estimates of encounter rates, hook-and-release mortality rates, and efforts to study differences in the distribution of OCN and hatchery coho salmon at sea. The inconsistency in marking hatchery fish makes it impossible to accurately estimate the impacts of harvest on wild fish in a fishery where there are both hatchery and wild stocks. Therefore, the IMST concludes that all hatchery coho in the Columbia River basin should be marked.

Conclusion

The IMST finds that there is wide variability in the estimates of mortality from non-retention fisheries, reducing the reliability of any given estimate as an indicator of such mortality. A lack of data precludes a confident determination of the impact of this mortality on recovery of stocks of wild salmon, but for severely depressed populations even a low incidence of mortality from a non-retention fishery can significantly slow recovery.

Question 3: Are models used to represent population dynamics of Oregon coho salmon and impacts of harvest scientifically rigorous? Are these models effectively integrated into management, policy analysis, and decision-making?

Importance of Population Modeling

Models are important parts of conservation plans because they explicitly relate our knowledge and data on all aspects of salmon life history. Modeling of salmon population abundance and analysis of the risk of extinction (population viability analysis), along with related conservation efforts, are central tools of the Oregon Plan (ODFW-PFMC 1997).

The Oregon Plan (1997) notes that:

> "Beginning in the early 1980s, OCN coho salmon stock recruitment models for estimating pre-season abundance have evolved and been tested. These modeling efforts, and development of companion pre-season coho stock assessment models evaluating harvest impacts, are critical methodologies in providing the necessary foundation on which to manage OCN coho salmon harvest impacts in PFMC area fisheries. Pre-season predictors have been historically based on spawner recruit relationships, maximum sustained yield, and "steady state" parameters for marine and freshwater survival and have not been adequate to manage OCN coho salmon. It is important to evaluate variation in the stock-recruitment function for wild fish, varying environmental factors, statistically valid assessments of adult spawning escapement, and accurate data to assess incidental, bycatch, and hook and release data to determine total fishing mortality."

Review of Life-Cycle Model

Population models are important tools, but they cannot provide all the answers, and they may be inadequate to characterize risks of extinction or recovery responses. The life-cycle model developed by Nickelson and Lawson (1998) (subsequently referred to as the coho life-cycle model) provides a rigorous analytical tool for exploring the full life cycle (freshwater, estuarine, and marine life history stages) of coho populations. The model is based on empirical evidence from ODFW research, scientific literature, and regional research. However, several components are not represented in the model:

- predation
- disease
- straying between basins
- effects of hatcheries
- utilization of mainstem/floodplain habitats
- utilization of estuarine habitats
- influence of marine derived nutrients

There are several components that are aggregated and not explicitly identified:

- ocean-related mortalities/hooking mortality
- incidental catch
- directed harvest

There are several factors for which the empirical data are extremely limited:

- straying rates

- genetic effects on fitness in low populations
- egg-to-parr survival (over broad geographic extent)
- sedimentation effects on egg survival
- depensation and compensation at low population size
- effects of catastrophic events (e.g., floods, drought, mass failures)
- survival of "nomads"
- errors in habitat surveys

Even with these gaps in empirical data and weaknesses in the current model, life cycle modeling is a powerful conceptual tool for examining the consequences of human actions that greatly strengthens the technical foundation of the Oregon Plan.

In addition to the coho life-cycle model, another model of coho salmon populations, the Cumulative Risk Initiative (CRI) model, has been developed by NMFS but is not reviewed in detail here.

The IMST concludes that the life-cycle models, particularly the Nickelson-Lawson model, are a scientifically rigorous approach for integrating complex data on habitat, abundance, harvest, and spawning. State and federal agencies could use these tools more effectively by conducting detailed sensitivity analyses of model performance. The applications of the models would be strengthened by directly linking the models to landscape and monitoring data. Model performance could be explored by hindcasting or predicting past abundances based on historical information.

Model Improvement

The IMST believes that several specific actions will strengthen life cycle modeling in the future. The actions and the concerns of the IMST about each of the factors are described briefly below. In addition, evaluation of the consequences of different sources of error is relevant to all components of the model. Only limited analyses of errors or variance in estimates have been incorporated into the sensitivity testing of the model. The model does not explicitly identify a margin for uncertainty. Monte Carlo simulations (a modeling technique for randomized replication of model output) with error estimation are a rigorous approach for defining a margin for uncertainty. These have been used on a limited basis (ODFW and NMFS 1998) and could be used to test a wider range of conditions and questions. This critical process would improve application of the models and identify research and monitoring needs.

<u>Time delays and lag effects</u>

Although the life cycle models exhibit interannual lags in response, time delays or lag effects have not been explicitly incorporated in the models as specific functions. For example, several years are required for recolonization of low quality habitats, and recolonization is sensitive to straying rates. Lags exhibited by the model are not incorporated into the timeframe for decisions and the timeframe needed by PFMC and ODFW for establishing policies.

<u>Jack predictors</u>

Survival of hatchery jacks in the ocean is used to estimate marine survival for OCN coho salmon. Some applications of the model for risk assessment have assumed a wild:hatchery survival ratio of 1.5. Careful review of the performance of smolt-to-jack survival and the ratios of wild to hatchery survival would strengthen these applications of the model and the determination of potential harvest impacts under Amendment 13.

<u>Egg-to-parr survival rates</u>

Density-dependent rates of survival from egg to parr have extremely strong influences on model performance (Fig. 3). ODFW has developed a database of egg-to-parr survival for the Alsea Watershed streams and two sites in Lobster Creek in the Alsea basin. These data indicate that egg-to-parr survival increases dramatically (from 5-10% at high spawner densities to more than 50% at extremely low spawner densities) when habitats are not fully seeded, but the model is capped at 44% and cannot incorporate all of this increase. This abrupt increase in survival at low densities makes extinction far less likely.

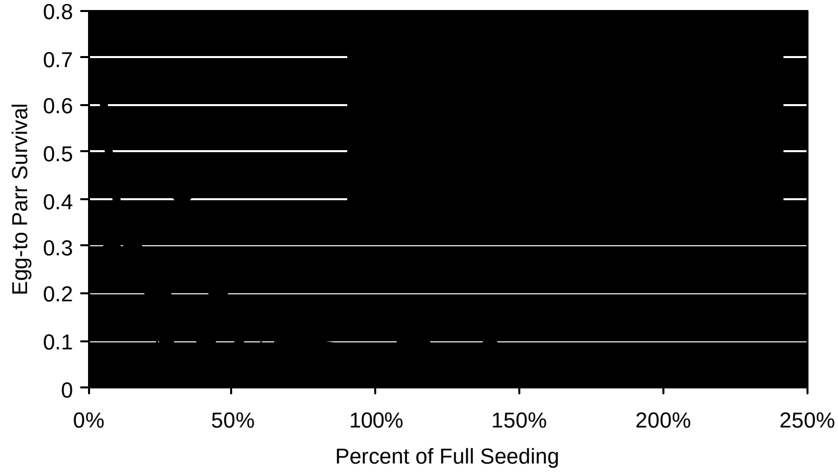

Figure 3. Relationship between egg-to-parr survival and percent of full seeding (based on number of spawners required for maximum production of summer juveniles on a Ricker curve) in the Alsea Watershed Study (Flynn Creek, Deer Creek, Needle Branch) and East Fork Lobster Creek and upper Lobster Creek in the Alsea River basin (data provided by Tom Nickelson, ODFW, personal communication).

Sensitivity analysis

As described above, the relationship between density and egg-to-parr survival strongly influences risk of extinction. Sensitivity analyses of the influence of this relationship on prediction of spawner abundance and risk of extinction are needed. The recent lack of replacement at low numbers of spawners in some streams may suggest that depensation is occurring.

Sensitivity analysis could also demonstrate the impact of levels of uncertainty in estimates of spawner abundance on application of the life-cycle model.

Effects of error in spawner estimation

Spawner estimation from the Stratified Random Sample (SRS) Program is an important component of model validation and projections of future spawner abundance. The 95% confidence intervals for spawner estimates average 80% at the basin level, 39% for Gene Conservation Groups (GCG's), and 25% for the entire coast. These estimates are based on approximately 240 surveys that were conducted from 1990 to1996 (Jacobs and Nickelson 1998). These error rates have not been incorporated into models to evaluate the potential margins for error that would be implemented under Amendment 13.

Straying rates

Recolonization is a natural process that includes straying, movement to avoid competition with other fish, and displacement by disturbances (e.g., floods, drought). Information on straying behavior and empirical data for straying rates are extremely limited. In extremely low populations, straying can introduce new genetic information into the population and contribute to the genetic diversity of the recovered population. Current models have used a single value of 5% straying, derived from studies in the Straits of Georgia, or used straying rates of 20% based on professional judgement.

Error in estimation of habitat quality

Predicted production from high, intermediate, and low quality habitat and utilization by spawners are critical aspects of the model and are directly linked to landowner efforts to restore habitat. A source of error that is often overlooked is the error in estimating habitat quality in the field. Variance in estimation of habitat conditions and subsequent habitat quality classifications can be determined from basin surveys. Such estimates of uncertainty could be incorporated into the Monte Carlo runs to determine appropriate margins for uncertainty.

Conclusion

The Stratified Random Sample (SRS) survey monitoring system, basin habitat surveys, life-cycle monitoring sites, and life-cycle models should be integrated to create a more scientifically sound decision-making context for salmon harvest management. Current research and monitoring are closely tied to model development and applications, but integration is based on the willingness and interests of researchers in ODFW and not part of an explicit analysis and assessment program. The IMST strongly endorses each of these measurement and analysis tools that ODFW and cooperating agencies have developed.

There is no centralized and focused attempt to

- further refine the coho life-cycle model,
- provide extensive sensitivity analysis,
- test the operation of the model to the monitoring program, and
- link the predictions provided by the model to the development of harvest management policy.

The State of Oregon has no centralized or explicitly coordinated program that links the coho life cycle model, ODFW monitoring, and State participation in PFMC decisions on annual harvest rates. The availability of these tools makes adaptive management possible. Oregon has a unique and powerful set of tools available for salmon assessment and management, but the fragmented administration, funding, reporting, and coordination significantly diminish its strength and effectiveness. The State of Oregon has captured a very small fraction of the potential application of models to the Oregon Plan. With adequate and centralized project administration, these integrated tools could serve as a national model for salmon management.

Question 4: Are uncertainties in rebuilding OCN coho salmon stocks and the risks of extinction adequately addressed in coho salmon management? Are scientifically based strategies for extinction risk assessment effectively incorporated into salmon management to facilitate accomplishment of the mission of the Oregon Plan for Salmon and Watersheds?

Assessment of Extinction Risk

Risk of extinction is a critical measure of the status of salmon stocks that can be used to make informed harvest management decisions. However, before risks can be quantified, measures of population viability and time frames for analysis (e.g., 100 years) must be identified. Criteria for assessing the risk of extinction for Pacific salmon stocks include population viability analysis, effective and total population size, extent of population decline, and demographic and genetic status of populations. These criteria are related to the concept of a minimum viable population size.

A *minimum viable population* is defined by Soule (1987) as a population that is sufficiently abundant and well adapted to its environment for long-term persistence without significant artificial demographic or genetic manipulations. Other definitions call for even more specific quantitative criteria. For example, Meffe and Carroll (1994) defined a minimum viable population as the "smallest isolated population size that has a specified percent chance of remaining extant for a specified period of time in the face of foreseeable demographic, genetic, and environmental stochasticities, plus natural catastrophes."

The *effective population size* is the population size that would produce the same levels of gene frequencies that are observed in a population of interest (Caballero 1994).

It is important to note that population viability and risk of extinction are based on measures of actual populations. These populations are defined as salmon that interbreed within a specific geographic region. The population is the fundamental unit of salmon genetics and demography (National Research Council 1996) and population persistence depends on an adequate return of spawners. Many populations of OCN coho salmon are at very low levels of spawner abundances, especially those in small streams (Fig. 4). This is of particular concern because small populations are more likely to become extinct from random fluctuations in environmental conditions than are large populations (Cass and Riddell 1999).

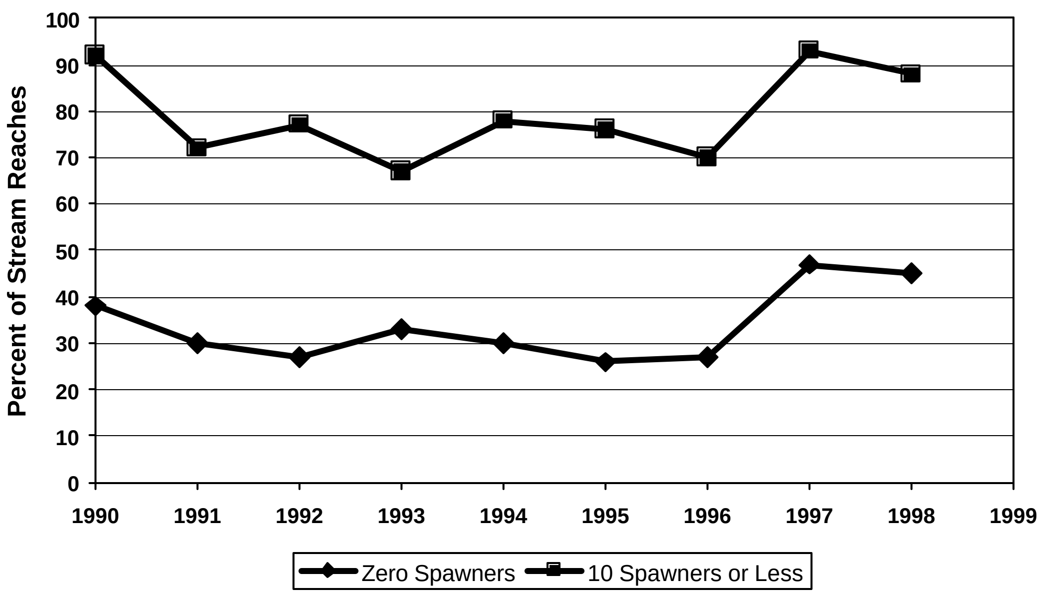

Figure 4. Percent of stream reaches with no spawners observed during repeated annual spawner surveys and percent of stream reaches with 10 spawners or fewer (data provided by Steve Jacobs, ODFW).

Assessment of risk of extinction is an essential element in the evaluation of recovery. In the context of the Endangered Species Act (ESA), recovery must be related to the risk of extinction. The coho salmon life-cycle model (Nickelson and Lawson 1998), as well as other models being developed, provide useful tools for quantifying risks of extinction (Allendorf et al. 1997; Wainwright and Waples 1998) and tracking changes in populations. However, the coho life-cycle model is in its early stages of development and there are high levels of uncertainty in its projections. Existing models (e.g., coho life-cycle model, stock recruitment model) currently portray different levels of risk for some coastal basins and consistent values for risks of extinction for other basins. If models are used to estimate risk of extinction, relationships among models, and assumptions of the models must be specified. Links between observations of characteristics of healthy stocks and critical monitoring elements are necessary to increase confidence in model results. Key indicators could be used to supplement model estimates or to replace a model when its performance is questionable.

A recent report to the PFMC assessed risks of extinction for OCN coho salmon stocks for a period of 99 years (33 generations) and provided a comparison of populations with no harvest to those subjected to recent management alternatives (ODFW-NMFS 1998; Nickelson and Lawson 1998). This assessment predicted that there is little difference in risk of extinction between harvest policies of Amendment 11 or the more recent Amendment 13 under poor ocean conditions. The analysis also predicted that the risk of extinction with no harvest impacts of any kind is 30-50% less than the risk with harvest under Amendments 11 or 13. OCN coho salmon populations in several tributaries of the north coast of Oregon exhibited much higher risks of extinction with no harvest impacts than mid-coast and south coast populations (Fig. 5). The figure does not show actual rates of extinction, but the risks of extinction over a 99-year period for stocks under different harvest alternatives. The report concluded, “if poor marine survival persists for many generations, no harvest management regime alone will restore OCN coho salmon.”

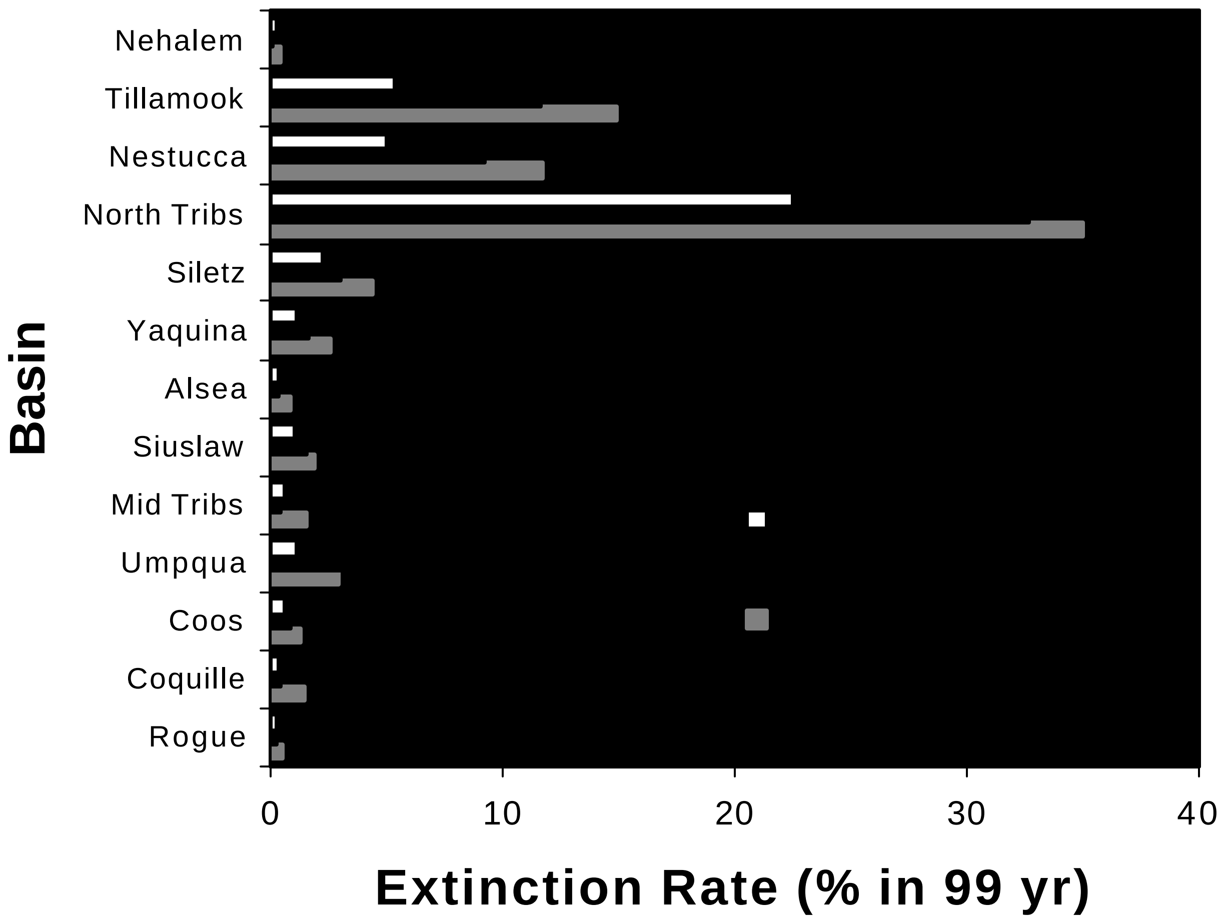

Figure 5. Estimates of risks of extinction for coastal coho salmon (ODFW and NMFS 1998). Exploitation rate refers to management strategies used in Amendment 13. Escapement rate refers to management of a specific number of returning spawners under Amendment 11.

Risk assessments have focused on aggregate OCN coho salmon populations or Gene Conservation Groups (GCG's) and do not project trends for individual populations, even though individual populations are the fundamental unit of salmon demography and genetics. Spawner escapements should be sufficiently large to insure genetically diverse populations with resilience to environmental and anthropogenic disturbance over long time periods.

Allendorf et al. (1997) concluded that an effective population size (Ne) <500 and a total population size per generation (N) of <2,500 are criteria for classifying salmon stocks as being at high risk of extinction. Waples (1990) suggested that 100 effective breeders/year are needed to maintain genetic variation in salmon populations in the short term, but this is not sufficient for the long term. Spawner abundance based on SRS surveys for six management districts (not populations) north of the Rogue River (1990-1997) were below 2,500 for all 8 years in the North Coast district, 7 of 8 years in the Tillamook district, 4 of 8 years in the Lincoln district, but above 2,500 in the Siuslaw, Umpqua, and Coos-Coquille districts (Jacobs and Nickelson 1998). Based on these estimates and criteria proposed by Allendorf et al. (1997), aggregates of populations along the north coast are at high risk of extinction and those in the mid-coast region are at moderate to low risk of extinction. Extinction risk would be even higher for each of the individual 128 populations recognized by ODFW within these districts, because each population represents a fraction of the aggregate within each management district. Therefore, populations in several major basins have been estimated to be fewer than 100 spawners in recent years. Populations in these basins would be considered to be at high risk of extinction under any criterion.

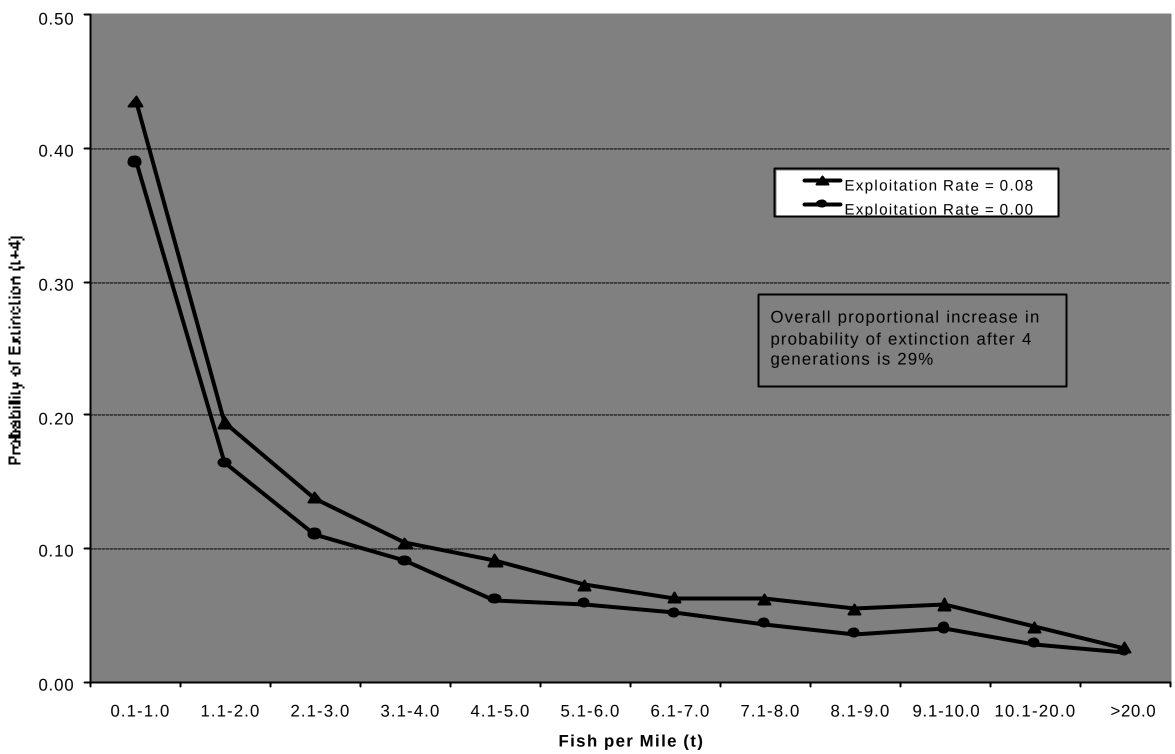

Figure 6. Probability of basin-level extinction in 4 generations as a function of spawner density for exploitation rates of 0.00 and 0.08. All Oregon coastal basins are combined. (Figure is from OCN Work Group (2000)).

Estimation of the risk of extinction requires an operational definition of minimum viable population size. In the ODFW-NMFS (1998) risk assessment for coastal coho salmon, functional extinction was set at 50 spawners per basin. When populations were less than 50 spawners, the population was considered extinct within the basin. Basin size was not considered in this analysis. For example, 50 spawners in the Umpqua basin would have the same outcome as 50 spawners in the Cummins Creek basin. However, the probability of spawners finding each other and successfully spawning would differ greatly in these two cases. The IMST concludes that numbers of spawners per mile may be a better index of risk than total number of spawners in a basin. Future assessments of extinction could be based on spawners per mile, which adjusts for extent of the stream network or basin size. The OCN Work Group (2000) conducted an analysis of risk of extinction and concluded that the risk of extinction increased markedly to more than 30% over 99 years at spawner abundances less than four spawners per mile (Fig. 6). This is consistent with targets for spawners used by Canadian fisheries managers (see below).

As Routledge and Irvine (1999) and Cass and Riddell (1999) point out, a safe spawner density for a large stream would be extremely risky for a small stream because of the smaller population size in the small stream. Higher densities of spawners (spawners per mile) are needed in small streams than in large streams to maintain a given level of risk. They concluded that stocks at low abundance can be driven rapidly to extinction by chance variation in recruitment when spawners are not replacing themselves. Bradford et al. (2000) concluded that on average a density of 19 female spawners per km is required to fully seed freshwater habitats with juvenile coho salmon in coastal streams along the west coast of North America. A conservation minimum spawner density of 3 females per km has been proposed for Canadian coastal waters (Stocker and Peacock 1988 as cited in Bradford et al. 2000).

Effect of Fisheries Management on Rate of Extinction

Influences of different fisheries management strategies on extinction rates are potentially important but poorly understood. Rate of extinction may be greater under a constant harvest rate policy than when a population threshold is specified below which the harvest rate is set to zero (Lande et al. 1995, 1997; Cass and Riddell 1999). This is an area of research that could be explored further with the coho life-cycle model.

Recommendations for Improvement of Extinction Risk Models

Modeling of extinction risk addresses several, but not all, criteria for recovery. Extinction risk models are weakly linked to genetic risk models. A metapopulation model is available and better models are being developed, but data are scarce (direction and magnitude of genetic exchange) and all units are treated as equal. Empirical analysis of stock performance related to extinction risk projections is needed but is currently non-existent or preliminary. In particular, observed attributes of healthy stocks need to be linked to model projections.

Several critical elements for assessing extinction risk and recovery require increased research effort, including:

- Future trends in distribution and quality of habitats need to be projected and used in assessment of extinction risk. Most assessments are based only on current habitat conditions. Habitat changes are likely to be at least as dynamic as other environmental factors and could possibly be more dynamic.
- Data on freshwater survival and production are critical but scarce.
- Assumptions about trends in marine survival need to be explicitly stated and evaluated with sensitivity analyses.
- Climate change is likely to affect marine *and* freshwater conditions and survival. These relationships and assumptions should be carefully evaluated. If significant interactions are detected, these influences should be incorporated into models and risk assessment.
- Application of *different* models will reveal both differences and consistencies, which may be useful in identifying critical processes, areas of major risk, and gaps in knowledge. Contrasts

between a population dynamics approach and a habitat-based approach could reveal important patterns or factors.

Conclusion

The IMST finds that assessing the risk of extinction is fundamental to the Endangered Species Act (ESA) and the success of the Oregon Plan. The risks of extinction models developed by ODFW and NMFS (1998) are rigorous, but can be improved. Further, we find that the models have not been used to their full potential in the Oregon Plan.

Question 5: Does the monitoring program provide information that is necessary to accomplish the mission of the Oregon Plan for Salmon and Watersheds? What measurements or analyses need to be included in the monitoring program to make it more scientifically credible and relevant to management and policy?

Overview of Current Monitoring Program

Current methods for surveying salmon spawner abundance are outlined in ODFW's Coastal Salmonid Population and Habitat Monitoring Program for coho, chum, and fall chinook salmon and in the Oregon Plan's Annual Report for 1998, Section I (1998). Briefly, index coastal streams have been sampled since 1950. A Stratified Random Sample (SRS) design was initiated in 1990 to estimate absolute spawner abundance. However, monitoring at the index sites was continued as well to provide data on long-term trends and to allow calibration between the two sampling designs. In 1997, the existing Stratified Random Sample (SRS) sites were expanded to increase precision of estimates within the Gene Conservation Groups (GCG's). Beginning in 1998, a rotating panel design was adopted to correspond to the 3-year coho brood cycle. Using this design, some sites are sampled every year, some every three or nine years, and some randomly selected each year. The new sites are randomly selected each year using methods developed by the Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency (EPA) for regional assessments. Monitored reaches encompass about 10% of the total estimated spawning habitat. This design enables statistical estimates of escapement for both trend (changes over time) and status (differences among Gene Conservation Groups (GCG's)). A total of 120 stream reaches will be sampled in each of the five coastal Gene Conservation Groups (GCG's).

Pilot surveys of spawning reaches are conducted during the summer months to verify accessibility of survey segments and to collect physical and biological data. During the spawning season (November to January), foot surveys are conducted on designated stream segments every 10 days or less. Live and dead coho salmon, jacks, and redds are counted and presence of steelhead is noted. All carcasses are examined for fin clips and coded-wire tags. Scales are also collected to estimate the number of hatchery fish spawning naturally. Spawner numbers are extrapolated between sampling dates, and the total numbers over the season are used as an estimate of total spawner abundance in the survey area.

Scientific Rigor of Current Monitoring Program

Monitoring is one of the few methods to evaluate the effectiveness of management actions such as restoration efforts, habitat improvements, and harvest restrictions conducted under the Oregon Plan. For monitoring to scientifically answer critical questions about the recovery of salmonid stocks, sampling and analysis must be reliable and systematic over many years (decades).

Even if spawner surveys are rigorous, monitoring of escapement trends is often too imprecise to detect changes in population numbers (Pella and Myren 1974), and it can be a misleading indicator of the response of populations to changes in freshwater habitat. Estimates of the changes in salmon escapement could be improved with consideration of other factors affecting escapement. Unless marine survival and harvest rates are constant throughout the monitoring period, changes in spawning population size will not provide a reliable index of changes in freshwater survival (Hilborn and Walters 1992; Kormen and Higgins 1997).

Jacobs and Nickelson (1998) described the methods for estimation of the 95% confidence intervals for the Stratified Random Sample (SRS) surveys by statistical methods and the relationships between number of surveys and the precision of spawner abundance estimates. From 1990 through 1996 (about 240 surveys), the precision of abundance estimates for each Gene Conservation Group (GCG) was about 39%. Precision targets were met only in the two northern Gene Conservation Groups (GCG's). With 30% precision, it would require spawner abundance within a Gene Conservation Group (GCG) to change by a factor of two to reliably detect changes in spawner escapement for a brood cycle. Results in Jacobs and Nickelson were used as a basis for increasing sample size to 480 surveys (120 per Gene Conservation Group (GCG)) to obtain target precisions of +/- 30% for individual Gene Conservation Groups (GCG's).

To determine if OCN coho salmon stocks are recovering, declining or stable, better precision of spawner abundances is obviously desirable. However, other factors should also be considered to determine if trends in escapement over time or differences in escapement among Gene Conservation Groups (GCG's) are due to restoration efforts and management actions or to natural fluctuations in freshwater or marine survival. To the extent possible, all factors that affect the survival of OCN coho salmon in the ocean need to be considered for each Gene Conservation Group (GCG). These factors are a composite of commercial and sport-harvest impacts, incidental hook-and-release mortality, and natural ocean mortality.

At present, PFMC uses an environmentally-based model related to ocean upwelling and sea surface temperatures to predict OCNR (Oregon Coastal Natural River) coho abundances. This model overestimated OCN coho salmon abundances for 1997 and 1998 (PFMC, Pre-season Report I, 1999). Before 1994, OCN coho salmon abundance was predicted with a modified Ricker spawner-recruit model that incorporated ocean survival of Oregon Production Index (OPI) hatchery smolt-to-jack survival of the previous year. In general, we see this shift in management to be more consistent with the recovery goals of the Oregon Plan.

Some estimates of ocean mortality will be available in the future for several OCN coho salmon stocks from the seven life-cycle monitoring sites along the coast where both smolt numbers and returning adults are being estimated. The value of these sites for estimating ocean survival should be assessed, because some of these sites may not be close to the ocean, traps have variations in capture efficiencies, and the streams where they are located may not be representative of their Gene Conservation Group (GCG). In addition, no site is located south of Cape Blanco. A site in this location is needed for comparison of status among Gene Conservation Groups (GCG's) and long-term monitoring of southern stocks.

The monitoring program is rigorous, but it needs to be more comprehensive and systematic. The life cycle monitoring sites are particularly important. Sites need to provide representative samples and be distributed among all Gene Conservation Groups (GCG's).

Monitoring and Salmon Recovery

At some point in the near future, the State will be required to evaluate the status and trends of coastal salmon and the success of the Oregon Plan. Development of an explicit definition of recovery and related criteria are essential for the development and rigor of the Oregon monitoring program. The process and criteria that will be used in that evaluation should be identified as soon as possible. The monitoring program should then be enhanced to provide the necessary information for the future assessment that will be required. Planned evaluation of status and trends should explicitly identify the statistical power to detect trends within reasonable time frames as part of the development of monitoring actions.

The Oregon Plan currently includes a monitoring plan, with annual reporting requirements, that addresses many of the elements that could define recovery (e.g., adult returns, juvenile out-migrants, smolt-to-adult survival rates, habitat assessments). The current monitoring approach was developed to assess many of the important attributes of OCN coho salmon stocks. Though not comprehensive or systematic, these measurements could be implemented rapidly and are likely to be key elements of a framework for recovery. As an interim tool, the current monitoring plan is rigorous and has identified several new approaches (e.g., life-cycle monitoring sites).

Several fundamental factors in salmon life history and survival—abundance, productivity, spatial and temporal structure, genetic diversity, and ecological functions—were identified in the IMST Recovery Workshop in August 1999 (IMST 1999). We briefly summarize the major issues related to design of a monitoring program for each of these factors.

Abundance

Abundances of juveniles, out-migrants, and adults are important measures of population status at the levels of watersheds, Gene Conservation Groups (GCG's), Evolutionarily Significant Units (ESU's), and harvest aggregates. Measurement of population status at all of these spatial scales is extremely difficult and costly. ODFW's existing spawner survey dataset is one of the best long-term records of OCN coho salmon abundance in the region, but it provides data for only one life-history phase. Small populations are likely to respond differently than large populations to human and environmental stressors. The potential for interactions among factors at low population abundance may lead to unexpected outcomes. Monitoring programs should attempt to represent distinct characteristics of stocks in long-term assessments.

Productivity

Characteristics of healthy stocks need to be identified so they can be compared with model or trend projections. Measures of productivity, such as number of smolts produced per female or adult to adult survival, provide important indications of trends in freshwater habitat conditions. Other measures, such as numbers of returning adults per smolt, may identify shifts in ocean regimes and potential harvest impacts. These measures require estimates of abundance at several life history stages. Such measurements require major sampling facilities, large staff and field crews, and rigorous analyses. As a result, the potential to gather such information at enough sites across the range of conditions in coastal basins is extremely limited.

Currently, this productivity information is being collected at life-cycle monitoring sites; however, additional sites would allow a broader spectrum of OCN coho salmon populations to be represented. Monitoring efforts must be carefully designed to be representative, efficient, and effective. These innovative monitoring sites need to be coordinated with local habitat measurements, basin habitat assessments, remote sensing, and monitoring of long-term land use, the use of hatcheries to provide marked fish that mimic wild fish to measure ocean survival, and experimental tagging of wild fish. Current staff and funding levels are inadequate to provide these critical functions.

Amendment 13 mentions, but does not explicitly address, the value of salmon carcasses in the nutrient cycle of streams. A monitoring program was designed to experimentally measure effects of carcasses on juvenile salmon and smolt production, but low numbers of spawners prevented its implementation. Currently, activities related to distribution of carcasses are random, limited, and not evaluated.

Spatial and temporal structure

The geographic distribution of salmon and the condition of their habitats are important measures of performance and potential for recovery of coho salmon populations. Distribution of juvenile and adult OCN coho salmon and habitat conditions across the landscape are part of the existing monitoring plan. Information about the distribution of spawners may reveal the degree to which available habitat is used and may serve as an important measure of the status of wild coho stocks. Benchmarks, such as 75% of the available habitat occupied, could serve as useful measures of recovery of OCN coho salmon. Definition and measurement of "available habitat" and "high quality habitat" are essential for incorporation of monitoring data into the decision-making process.

Along with measures of the distribution of salmon in different watersheds, the condition of freshwater habitat—current, historical, and future—across the landscape is an important and readily monitored measure of recovery. More dynamic and spatially descriptive measures of habitat are needed in all aspects of monitoring, modeling, and policy. Trends in relative abundances of different quality habitats are essential for determining the potential threats to stocks and the potential for recovery during favorable climatic conditions.

Development of both historical reconstructions and future projections of habitat conditions is essential for determining trends in OCN coho salmon and assessing their risk of extinction through models. Recent development of satellite remote-sensing technology makes monitoring of land use and land cover both effective and affordable. Increased spatial resolution is increasing the accuracy of such habitat-related assessments.

Diversity

Beyond simple population abundances, measures of the numbers and representation of life history types across the landscape are important elements of an analysis of long-term stock dynamics (Healey and Prince 1995). Life-history diversity is strongly linked to genetic diversity. The first rule in "intelligent tinkering" is to make sure you keep all the pieces (Leopold 1966), and maintenance of phenotypic and genetic diversity is critical in stock management. Such measures could include phenotypic/life history diversity, run timing, age structure, body size, juvenile out-migration, and ocean migration patterns.

Additional focused funding and staffing support are required for: 1) monitoring of fish abundance at all life stages; 2) habitat measurements at reach and basin levels; 3) measurement of ocean survival; and 4) application of existing models of habitat, production, harvest impacts, and risk of extinction. IMST strongly recommends expansion of the life-cycle monitoring sites currently being developed by ODFW. These sites provide important data on all life-history stages for selected sites along the coast. The sites may allow direct measurement of smolt-to-adult survival so that ocean survival and harvest impacts can be differentiated in assessment of population trends. Marking wild smolts is another method to obtain estimates of smolt-to-adult survival for OCN coho salmon. Coordination with hatcheries to provide marked fish that mimic the size and ocean entry timing of wild fish should provide an alternative measure of ocean survival of OCN coho.

Hatchery practices and hatchery fish can strongly affect behavior, fitness, migration timing, and genetics of coastal salmon. Understanding the relative abundance of fish of natural and hatchery origin is critical. Currently, mass marking programs allow the percentage of hatchery fish spawning with wild fish to be estimated during spawning surveys. While spawning surveys provide information on numbers and proportions of marked and unmarked spawners, they do not provide measures of the consequences of spawning between hatchery and wild fish. The relative reproductive success and mixing of natural and hatchery fish are important factors in stock status, but research on these issues is extremely scarce (Fleming and Gross 1993, Reisenbichler and Rubin 1999). Recent development of genetic markers and DNA analysis to identify progeny makes such studies possible. These would be an important addition to the proposed life-cycle monitoring sites.

Ecological functions

Traditionally, the ecological role of adult salmon, particularly as a nutrient source for freshwater communities and young salmon has been ignored in salmon monitoring (IMST 1999). Recent studies of the role of carcasses in nutrient cycling demonstrate the need for production well above minimum viable populations to support ecologically healthy and robust stocks. Although carcass distribution programs are being initiated in several Oregon coastal drainages, there are no scientifically sound experimental measures of the effects of salmon carcasses in coastal streams for OCN coho salmon. Studies conducted in other regions (e.g., Washington Coast Range and Alaska) suggest that OCN coho salmon populations may benefit from such programs. Functional aspects of salmon populations should be included in development of the monitoring program in addition to traditional measures of abundance.

The IMST finds that these fundamental factors in salmon life history and survival, identified at the IMST recovery workshop are scientifically sound and, if incorporated into the monitoring program, would provide Oregon with a rigorous monitoring program with output to guide harvest management decisions.

Conclusion

The IMST finds that Oregon has one of the most scientifically rigorous monitoring programs for anadromous spawner estimation, providing much relevant information for the Oregon Plan. However, monitoring is not adequate to reliably detect trends within individual basins. This is important for monitoring escapement, evaluating recovery, and estimating extinction risk over time and among Gene Conservation Groups (GCG's). The life cycle monitoring sites are particularly important aspects of the monitoring program. Future development of the monitoring program should incorporate key measures of abundance, productivity, spatial and temporal structure, genetic diversity, and ecological functions.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Question 1: How have harvest management practices affected the status of OCN coho salmon stocks? Are current harvest management policies likely to contribute to rebuilding of OCN coho salmon stocks under the Oregon Plan for Salmon and Watersheds?

The IMST finds that harvest management has seriously affected stocks of wild coho salmon and contributed to the population declines that led to listing under the Endangered Species Act (ESA). The IMST also finds that a continuation of the Amendment 13 harvest policies contributed only marginally to the rebuilding of salmon stocks under the Oregon Plan. Recovery and rebuilding of stocks are key goals of the Oregon Plan, but the meaning of these terms is not described in terms that provide a basis for assessing progress towards them or for implementing the adaptive management that is part of the Oregon Plan.

We agree with the following assessment from the Oregon Plan (1997):

> "Historically, over harvest has been a significant factor in the decline of coho salmon. Excessive catch and/or harvest, times and areas open for harvest, mixed stock and targeted fisheries, and gear used have all been substantial contributing factors."

> "The problems of over exploiting less productive stocks and species in mixed-stock fisheries and of selectively fishing populations and species have been widely recognized but poorly resolved by society. Mortality associated directly and indirectly with fishing can eliminate populations, reduce numbers within populations, alter or eliminate life history patterns, reduce fitness, and mask population trends. All of these effects may adversely affect the sustainability of wild salmon populations and should be evaluated in an assessment of extinction risk."

A review by PFMC shows that in the 11 years from 1981 to 1991, the ODFW escapement target for OCN coho salmon (200,000) was met only three times. Amendment 13 regulates OCN coho salmon harvest based on harvest impact rates, not the numbers of spawners that return to spawning grounds. The number of spawners required to meet the 50% full seeding level of high quality habitat is 66,100 for all four stock components combined. This number of spawners has been attained only once during the past 10 years, again indicating the lack of rebuilding of OCN coho salmon.

In spite of the fact that recovery of depressed stocks is the primary goal of the Oregon Plan and a legal mandate of the PFMC for some species of salmonids, the IMST has found no explicit statement of the definition of "recovery". Currently, the only criteria for determining whether specific stocks meet the goal of rebuilding stocks are the triggers for changing the levels of sport and commercial fishing harvest. Harvest management decisions have the most immediate impact on spawner abundance and are therefore critical to the recovery of depressed stocks of wild salmonids in Oregon. It is essential, therefore, that the meaning of recovery be defined in measurable terms to guide harvest management decision-making.

Based on these findings we conclude that:

- At recent low population numbers and lack of replacement of stocks and stock aggregates, fishery impacts on OCN coho salmon are very uncertain. Knowledge of population dynamics for coho salmon at extremely low populations is technically weak because of the lack of studies. Therefore, strongly conservative management criteria and explicit definition of "extremely low populations" are needed in such conditions (e.g., 10% of fully seeding high quality habitats). The proposed harvest matrix in the OCN Work Group report provides such an approach (see Appendix D). IMST strongly endorses the proposed changes to salmon management in this report.
- Measurable goals for recovery of depressed stocks of OCN coho salmon are needed to provide a technically strong basis for harvest management decisions. Measurable goals that are intuitively compelling to the public (e.g. number of spawners per mile, and proportion of streams with no spawners) are particularly valuable.
- Harvest impacts have been reduced dramatically (from 30%-90% prior to 1990 to 8-13% since 1994), an unprecedented advance in harvest management of Pacific salmon. Desired levels of escapement generally have not been achieved. Improved escapement is essential for the recovery of OCN coho salmon, and control of fishing mortality is the best available tool for achieving improved escapement.
- The likelihood of accomplishing recovery is low under Amendment 13 during periods of low ocean productivity because escapement of adult spawners is too low. At low marine survival rates, elimination or reduction of human-caused sources of mortality would reduce probability of extinction, and would possibly allow modest recovery. It would increase the rate of recovery under higher ocean survival rates.

- Widespread spawning distributions of coho salmon populations are needed to minimize risks of extinctions when the region shifts from climate regimes that are favorable for survival to conditions that result in low rates of ocean survival (IMST 1999).
- A harvest management criterion (from monitoring results) could be the proportion of all habitats of monitored stream reaches that are occupied by spawners. This measure of escapement could be a critical index for the recovery of OCN coho salmon stocks. Setting Minimum Sustainable Escapement (MSE) levels would improve probabilities of recovery.
- Current management includes the distribution of carcasses with no link to priorities or expected outcomes. Successful management of carcasses under the Oregon Plan will require explicit experimental measurement of the responses of salmon (at all life history stages) to additional food resources from carcasses.

Question 2: Are mortality estimates from non-retention fisheries accurate? Does this source of mortality affect the recovery of coho salmon?

The IMST finds that there is wide variability in the estimates of mortality from non-retention fisheries, reducing the reliability of any given estimate as an indicator of such mortality. A lack of data precludes a confident determination of the impact of this mortality on recovery of stocks of wild salmon, but for severely depressed populations even a low incidence of mortality from a non-retention fishery can significantly slow recovery.

Based on these findings we conclude that:

- Gear selection and deployment are important variables in the degree to which hook-and-release and drop off mortality occur at any given encounter rate. Impacts on OCN coho salmon potentially can be reduced by changing methods of fishing (gear selection and deployment), and by reducing the encounter rates at locations and times when OCN coho salmon are concentrated.
- The PFMC decision to increase the estimate of hook-and-release mortality from 13% to 19% for recreational selective coho fishery in 2000 is a prudent first step, but given the uncertainty of the estimate and the vulnerability of the most severely depressed stocks, continuing assessments of this mortality are required.
- An expanded program of "double-index" tagging will permit a better evaluation of the mortality rate of unmarked fish in selective coho fisheries.

Question 3: Are models used to represent population dynamics of Oregon coho salmon and impacts of harvest scientifically rigorous? Are these models effectively integrated into management, policy analysis and decision-making?

The IMST finds that the coho life-cycle model developed by Nickelson and Lawson (referred to as the coho life-cycle model) represents a scientifically rigorous approach and is a valuable analytical tool for evaluating the full life cycle of coho populations. However, it needs to be improved and it needs to be well integrated into policy and management decision-making.

Based on these findings we conclude that:

- The coho life-cycle model is rigorous and useful for examining the consequences of human actions on the population dynamics of coho salmon. Other models being developed should be viewed as independent checks of the coho life-cycle model. These models greatly strengthen the technical foundation of the Oregon Plan, and state and federal agencies should explicitly use them in the decision process.

- There are several components that (a) are not represented in the model, (b) use aggregated data or (c) lack empirical data. As model development continues these components should be addressed. Future model development and application should consider (a) scarcity of data, (b) aggregated functions that should be articulated separately, and (c) local and regional variability. The modeling effort could be linked to design of future monitoring. We note that even with these gaps and weaknesses, the life-cycle models are a powerful tool for policy and management.
- There is no centralized and focused attempt to develop the coho life-cycle model, provide extensive sensitivity analysis, and link the operation of the model to the monitoring program and development of harvest management policy. The Stratified Random Sample (SRS) survey monitoring system, basin habitat surveys, life cycle monitoring sites, and life-cycle models should be integrated to create a more scientifically sound decision-making context for salmon harvest management. Current research and monitoring are closely tied to model development and applications, but integration is based on the willingness and interests of researchers in ODFW and not part of an explicit analysis and assessment program. The IMST strongly endorses each of these measurement and analysis tools that ODFW and cooperating agencies have developed.
- The State of Oregon has no centralized or explicitly coordinated program that links the coho life-cycle model, ODFW monitoring, and State participation in PFMC decisions on annual harvest rates. The availability of these tools makes adaptive management possible. Oregon has a unique and powerful set of tools available for salmon assessment and management, but the fragmented administration, funding, reporting, and coordination significantly diminish its strength and effectiveness. The State of Oregon has captured a very small fraction of the potential application of models to the Oregon Plan. With adequate and centralized project administration, these integrated tools could serve as a national model for salmon management.

Question 4: Are uncertainties in rebuilding OCN coho salmon stocks and the risks of extinction adequately addressed in coho salmon management? Are scientifically based strategies for extinction risk assessment effectively incorporated into salmon management to facilitate accomplishment of the mission of the Oregon Plan for Salmon and Watersheds?

The IMST finds that assessing the risk of extinction is fundamental to the Endangered Species Act (ESA). The risks of extinction models developed by ODFW and NMFS (1998) are rigorous, but can be improved. Further, we find that the models have not been used to their full potential in the Oregon Plan.

Based on these findings we conclude that:

- Many populations of OCN coho salmon are at critically low levels of abundance, with the highest risks of extinction in the North Coast Gene Conservation Group (GCG). Metapopulation structure and basin-scale abundance need to be considered in modeling and assessment of extinction risk and recovery rates, and in the design of harvest management. Small populations are more likely to become extinct from random fluctuations in environmental conditions than are large populations.
- Existing models may be inadequate to fully characterize risks of extinction for individual populations within aggregates of populations (Allendorf et al. 1997; Wainwright and Waples 1998). Therefore, other approaches for population evaluation and risk assessment are also needed.

Question 5: Does the monitoring program provide information that is necessary to accomplish the mission of the Oregon Plan for Salmon and Watersheds? What measurements or analyses need to be included in the monitoring program to make it more scientifically credible and relevant to management and policy?

The IMST finds that Oregon has one of the most scientifically rigorous monitoring programs for anadromous spawner estimation, providing much relevant information for the Oregon Plan. However, the monitoring is not adequate to reliably detect trends within individual basins. This is important for monitoring escapement, evaluating recovery, and estimating extinction risk over time and among Gene Conservation Groups (GCG's).

Based on these findings we conclude that:

- The monitoring program is rigorous but it needs to be more comprehensive and systematic. Future development of the monitoring program should incorporate key measures of abundance, productivity, spatial and temporal structure, genetic diversity, and ecological functions. The life cycle monitoring sites are particularly important.
- Estimates of ocean mortality (natural and fishing-induced) of wild salmonids are necessary to partition ocean and freshwater survival rates. The State needs better estimates of the ocean distribution of stocks and ocean survival of wild fish, which could be done by marking wild coho (coded wire tags or use of genetic markers) in concert with the life cycle monitoring sites.

Overall Conclusions:

Based on these findings and the individual conclusions based on the science questions the IMST reaches the following overall conclusions.

- Numerous assessments, including the Oregon Plan (1997), have concluded that historical harvest rates have been too high and have contributed to the decline of OCN coho salmon. Harvest management decisions can have immediate and direct influence on spawner abundance. This makes all harvest management decisions critical for both the survival and the recovery of remaining wild stocks.
- In recent years, poor ocean conditions have prevented recovery. Sound harvest management in combination with effective habitat restoration and hatchery management can strongly influence the rate at which populations of wild salmonids recover (when climate-related conditions for ocean survival improve).
- Major advances have been made in management of salmon harvest and monitoring of adult escapement in Oregon since the mid-1980s. The current direction and innovations in management should be continued and strengthened by the State. In particular, the coho life-cycle model and spawner monitoring surveys are scientifically rigorous and represent some of the most advanced salmon management tools in North America.
- The State of Oregon needs to explicitly define recovery of depressed salmon stocks and criteria for evaluating recovery.
- The recovery of wild salmonids under the Oregon Plan may require 1) development of a coordinated program of modeling and monitoring of salmon populations, habitat, and harvest and 2) revision of the current policy framework and fishery management programs to meet the criteria for recovery.

RECOMMENDATIONS

The findings and the conclusions of the IMST are the basis for the following specific recommendations of the IMST. The first two recommendations are to the State of Oregon, and Recommendation 2 includes a specific recommendation to ODFW. All other recommendations are to ODFW. In some cases recommendations involve decisions in which the State collaborates with others (such as PFMC). In these instances, the IMST recommends that ODFW advocate that its collaborators adopt the essence of the recommendation in the interest of accomplishing the mission of the Oregon Plan.

14. **The IMST recommends that the State of Oregon define in measurable terms what is meant by the "recovery" of depressed stocks of salmonids.**

    Without a measurable definition, there is no technical basis on which progress towards accomplishing the mission of the Oregon Plan can be assessed. This severely limits the application of the principles of adaptive management, and the prioritization of recovery and research initiatives. Criteria for recovery need to incorporate demographic and genetic factors. A scientific workshop may be helpful in developing these criteria.

15. **The IMST recommends that the State of Oregon provide the legislative and executive support to enable ODFW to adopt the use of an explicit analytical process as part of the decision process for harvest levels. Further, we recommend that ODFW use the results from the analytical process in representing the State of Oregon to the PFMC.**

    We consider the adoption and use of an explicit analytical process as part of the decision process for harvest levels to be technically and scientifically critical to accomplishing the goals of the Oregon Plan. We believe implementation of this recommendation by ODFW requires that the executive and legislative leadership of the State explicitly endorse the concept and provides the financial resources needed.

    The process should incorporate:

    - Monitoring results (includes harvest records)
    - The coho life-cycle model results

    It should take into consideration:

    - The dynamic and changing landscape conditions that reflect potential habitat restoration
    - Human-related degradation and restoration
    - Natural disturbances in terrestrial and fresh water environments
    - Ocean condition and climatic regime changes

    The analysis process should link spawner surveys, habitat surveys, marine survival or impacts and model projections. It should also be spatially explicit to the greatest degree allowed by the data and model structure.

    The IMST believes these are important because the use of dynamic conditions for both ocean and freshwater environments will provide more realistic projections of future population trends and risks of extinction. As an example, we feel it is important to compare data from ODFW on the numbers of OCN adult spawners in each of the stock component units to see how they compare with the 50% full seeding at low marine survival. Earlier data show that we are below these levels given in Amendment 13, especially for the northern component. This emphasizes the importance of this analytical process as a basis for harvest management decisions and the extinction risk assessment modeling.

Such integration also recognizes regional goals to protect and restore watershed conditions along the Pacific Coast. This process would require effective focus on the process that coordinates these separate activities and integrates their findings into a recurring report on the status of salmon and the impacts of various sources of mortality. This will require more extensive application of sensitivity analysis and risk analysis.

We feel it is essential to the Oregon Plan that this analytical process also be used by PFMC.

The IMST Recommends that the Oregon Department of Fish and Wildlife:

16. Evaluate the ability of the current monitoring and research programs to provide data required for life-cycle modeling and to measure the following:

- **Recolonization of habitats as stocks recover**
- **Straying rates**
- **Distribution and abundance of spawners across their range**
- **Degree of unoccupied habitats, and**
- **Ocean survival (both within and among Gene Conservation Groups (GCG's)).**

These measures are needed over a range of survival conditions.

The Stratified Random Sample (SRS) surveys should be expanded to accomplish the desired measurement objectives and improve estimates of spawners within the Gene Conservation Groups (GCG's). It is important to develop and analyze data on variation in spawner numbers by basin. The trends/variation of spawner numbers in small tributaries are important because of the increased risk of extinction in smaller populations. Because many populations of OCN coho salmon are at critically low levels of abundance, Stratified Random Sample (SRS) surveys should be conducted in basins with life cycle monitoring sites, and in other reference basins to better assess population sizes and extinction risks. Distributions within a basin and estimates of spawners per mile within spawning habitats of various qualities should be measured in addition to total basin abundance.

The current Stratified Random Sample (SRS) survey is a labor-intensive effort across a large geographic area. Coordination, management, data analysis, and reporting will be challenging and will require resources and management assistance.

These data will be helpful in evaluating the recolonization, straying rates, distribution and abundance of spawners and occupation of habitat called for in this recommendation.

The life cycle monitoring effort should be expanded to cover a greater extent of Oregon coastal and lower Columbia River coho salmon stocks. Stratified Random Sample (SRS) surveys should be increased in the basins with life cycle monitoring sites (and where smolt trapping occurs) to provide estimates of marine and freshwater mortality. Within these sites and additional associated monitoring sites, surveys of habitat conditions should be related to trends of spawner abundance by basin.

17. Strengthen life-cycle modeling.

Current life-cycle models are rigorous analytical tools for evaluating coho salmon populations. However, additional components could add to the rigor of models. These include:

- Incorporation of time delays and lag effects into models.
- Improvement in measurement of smolt-to-jack survival to estimate the marine survival of OCN coho salmon.
- Incorporation of fluctuations in egg-to-parr survival into models.

- Incorporation of error in spawner estimation into models.
- Measuring straying rates more accurately and incorporating them into models.
- Incorporating error in the estimation of habitat quality into models.
- Incorporating the use of marginal habitat into the model.
- Increased sensitivity analyses.

Models have their limitations. Evaluations of model performance should incorporate real-world checks that compare empirical observations of stream habitat condition to salmon abundance and distribution. Criteria for healthy salmon stocks and healthy streams need to be developed to serve as these "real world" checks on the predictions of simulation models.

Decision-making needs to incorporate information from the models, taking into consideration the evaluation of model performance (see above). The State should use compelling intuitive measures (such as the percent of streams with no spawners, or the number of spawners per mile) in describing the outcomes of the analytical process to the public.

18. Strengthen extinction-risk modeling.

Modeling of extinction risk addresses several, but not all, criteria for recovery. There are high levels of uncertainty in life-cycle model projections. If models are used to estimate extinction risk, the relationship among models and assumption of the models must be specified. Empirical analysis of stock performance related to extinction risk projections is needed but is currently non-existent or preliminary. In addition, extinction risk modeling should incorporate the observed range of estimated encounter rates and hooking mortalities rather than average values or current best estimates. Sensitivity analysis will strengthen the understanding of and application of the results of risk-extinction models (see strengthen life-cycle modeling - Recommendation 4).

19. Adopt harvest management strategies that reduce fishery impacts on OCN coho salmon to as close to zero as possible when survival and spawner abundances are at critically low levels (OCN Work Group Report 2000) until established signs of recovery are observed. ODFW should advocate this same position to PFMC.

This recommendation applies to those policy and management decisions that affect the fisheries that are the sole responsibility of ODFW, those they co-manage with other entities, and those they participate in with the PFMC. The importance of this recommendation is reinforced because spawner abundances and marine survival have been extremely low and recruitment for all three recent brood years (1995, 1996, 1997) has been below replacement and at critical levels.

20. Advocate to PFMC that new criteria be incorporated into the matrix of Amendment 13 to include "very low" OCN coho salmon parent spawner abundance and "very low" marine survival.

Under these conditions, no coho fisheries should be allowed and fishery related impacts should be 0-8%, but as close to zero as possible.

21. Develop harvest management criteria that include consideration of the distribution of spawners and the percentage of streams or basins with viable populations of spawners within sub-aggregate units. ODFW should advocate this same position to PFMC.

The objective of this recommendation is to accomplish a more rapid recolonization of the available habitat during improved conditions of ocean survival.

22. Use the Minimum Sustainable Escapement (MSE) concept to augment the use of harvest impacts in estimating harvest related OCN coho mortality. ODFW should advocate this same position to PFMC.

This could provide a safeguard against loss of stocks during periods of low freshwater or ocean survival. The National Research Council (1996) recommends this methodology to minimize extinction risks of a population or metapopulation and to enhance recovery. The "critical" and "very low" parental spawner categories proposed by the OCN Work Group are consistent with this concept.

23. Adopt a decision process that enhances recovery over longer periods of time and includes consideration of the spatial distribution of stocks. ODFW should advocate this same position to PFMC.

The timeframe, abundance and spatial distribution of OCN coho salmon stocks are critical elements of measures of recovery. Harvest policies should be revised to require responses over sufficient time to indicate real population trends. We offer the following criteria as possible examples to be incorporated into the decision process whereby harvest levels are changed.

Criterion 1. Stock Abundance. Stock abundance has achieved a defined Minimum Sustainable Escapement (MSE) before harvest impacts can exceed 10-13%.

Criterion 2. Duration of Recovery. Stocks have achieved greater than 1:1 spawner-to-spawner replacement for each brood year over at least three brood cycles.

Criterion 3. Spatial Distribution. Stocks have achieved two consecutive generations of recovery (spawning recruits/parental adult of >1.5) with seeding above level 2 (75% seeding of available habitat).

24. Link decisions on ocean harvest to the status of the weakest stock component. Advocate that PFMC use this same approach.

Amendment 13 is clear on this point —" opportunities for increased ocean harvest may be constrained by the weakest component. In the foreseeable future, the northern stock component may dictate low harvest levels in marine fisheries for all components" and "In the event that a spawner criteria is achieved, but a basin within the stock component is identified to have a severe conservation problem, the next tier of additional harvest would not be allowed in mixed-stock fisheries for that component, nor additional impacts within the basin".

Oregon currently adheres to this requirement, but pressures to allow fishing by sport or commercial fishermen create challenges for following this policy.

25. Determine the relationship between the response of salmon juveniles and their food webs to carcass abundance and distribution, and determine the processes by which these relationships operate.

Scientific experiments are needed to establish this relationship and to determine the processes that are involved. Determining the processes is critical to understanding what is occurring and to be able to extrapolate relationships to other settings and situations. Knowledge from the processes and relationships will provide the scientific basis for adjusting harvest management to accomplish desired goals of carcass abundance and distribution.

Strategies for stock recovery need to recognize the various roles of salmon carcasses in the production of smolts in freshwater habitats. As an example, management criteria could identify minimum numbers of spawners per mile of stream to provide the food base necessary to support young salmon, and this can then be incorporated into the harvest management decision process.

26. Advocate that PFMC obtain more accurate estimates of hook-and-release mortality of OCN coho salmon to better assess the impacts of the fishery.

Encounter rates for OCN coho salmon vary with the different fisheries, regions of the ocean and at different times of the year. Hooking mortality varies with the type of fishing gear and how it is deployed. Sensitivity analysis can help evaluate the potential impacts of non-retention fisheries that are greater than those currently used in harvest management for OCN coho salmon stocks in general, and on North Coast components and Lower Columbia River wild stocks in particular. Analysis of hook-and-release mortality should continue after 2000 because uncertainty is high and ocean conditions are highly variable.

There are three subparts to this recommendation.

13a. Support PFMC's review of hook-and-release mortality.

It is essential that PFMC continue to evaluate the impact of hook-and-release mortality, taking into account encounter rates as well as the rate of mortality that ensues.

13b. Continue and expand double-index tagging of hatchery fish during years when selective coho fisheries are implemented.

Double-index tagging is a technique that can provide estimates of non-retention mortality. These experiments should be carefully designed to provide statistical tests of the differences in recovery rates. In order to account for differences in recovery rates of marked and unmarked fish, accurate data are needed on exploitation rates in both commercial and recreational fisheries.

13c. Continue monitoring of the encounter and retention of marked and unmarked fish in any selective fisheries (e.g., Buoy 10, the Ocean Recreational, terminal fisheries for fish released from net pens in the Columbia River estuary).

14. Continue to determine compliance rates with respect to release of unmarked coho salmon.

Compliance rates for release of all coho salmon with adipose fins (wild coho) and methods for their analysis are an important element in the public's trust and confidence in selective fisheries. Additional review of estimates and methods of determining compliance rates in selective fisheries in the ocean, bays, and rivers is needed. Both troll and recreational fishery seasons and fishing methods should be formulated to minimize impacts on OCN coho salmon.

17. Manage all wild coho salmon in Oregon---lower Columbia River, north coast, central coast, and south coast stocks---under the same principles and with the same goals. ODFW should advocate this same position to all entities with whom they collaborate in the management of coho salmon stocks.

There is no scientific basis for treating lower Columbia River coho salmon separately from coastal coho salmon.

18. Tag all hatchery coho in the Columbia River. ODFW should advocate this same position to all co-managers in the Columbia River basin (e.g. State of Washington, Tribes and federal agencies), and also determine from Pacific States Marine Fisheries Commission (PSMFC) the number of untagged fish that have adipose fins.

This should be done by all agencies responsible for management of lower Columbia River coho salmon. Currently estimates of harvest impacts are biased if all hatchery fish are not fin clipped. This result adds an additional source of uncertainty to the estimates of harvest impacts.

Currently the number of unmarked hatchery fish in the "catch" is impossible to ascertain and this number varies from year to year.

POLICY IMPLICATIONS

Reports of the IMST focus on technical issues related to the implementation and effectiveness of the Oregon Plan and attempt to avoid matters of policy. Technical issues are not independent of policy decisions. We have identified several aspects of policy relevant to state agencies that arise from the technical recommendations in this report.

- **Development of an independent Coordinated Program for Status and Trends in Salmonid Populations.**

  The State of Oregon has charged several state agencies (e.g., ODFW, Oregon Department of Environmental Quality (DEQ), OFWC, Oregon Watershed Enhancement Board (OWEB)) and federal cooperators (e.g., NMFS, USFWS) with the development of a life cycle model for coho salmon, monitoring of habitat and fish populations, and management of sport and commercial harvest. ODFW is charged with representing the State of Oregon and the Oregon Plan for Salmon and Watersheds in the negotiations about salmon harvest with the PFMC. Support for staff and operations in most cases are not attached to the separate efforts or their integration. Currently, these efforts are carried out under separate programs within these agencies with no explicit coordination or delivery of products.

  Coordinated analysis of harvest management, monitoring, model applications, and risk assessment would create a more scientifically sound decision-making context for salmon harvest management and allow management to adapt and improve more quickly. Unfortunately, Oregon does not have an explicit program or project that integrates the monitoring program, operation of the life cycle model, and the development of harvest management policy. The efforts in Stratified Random Sample (SRS) monitoring system, basin habitat surveys, ocean regime information, life cycle monitoring sites, and life-cycle models would be strengthened if they were integrated into an on-going program of assessment and integration of information and future stock projections. This process would require effective focus on the process that coordinates these separate activities and integrates their findings into a recurring report on the status of salmon and the impacts of various sources of mortality. This will require more extensive application of sensitivity analysis and risk analysis. Integration of these tasks will be challenging and will require resources and management assistance.

  IMST encourages the State to develop a coordinated program that links monitoring of habitat conditions and fish populations, ocean regime information, harvest management, and life-cycle modeling. This would be a specific program with a clearly identified mission, participants, tasks, products, and budget to accomplish the integration and coordination. The characteristics of such a group would include 1) administrative independence from any single agency, 2) identity and responsibility to represent the State's technical assessment of the status and trends in salmon and future projections of risk, 3) an open and transparent process, 4) regular delivery of products, 5) a location that enhances interaction in the Oregon plan, and 6) technical and policy oversight committees to advise the program. The tasks and products of the program would provide the technical basis for the State's position on management decisions on salmon. As such, their reports would be used by ODFW and the OFWC in negotiations related to salmon under both PFMC and the Columbia River Compact. The program might be located near state government in Salem (OWEB), a state university (the proposed Natural Resources Institute at OSU), or a multi-institutional research laboratory (Hatfield Marine Science Center).

- **Increased funding and staffing for expansion of the life cycle monitoring sites.**

  Current funding and staff for the life cycle monitoring sites are inadequate to adequately benefit from their contribution to the Oregon Plan and require the attention of state decision makers. The IMST strongly endorses the creation of life cycle monitoring sites by ODFW. Life history monitoring sites need to be developed for the full extent of Oregon coastal and lower Columbia River stocks. Increased Stratified Random Sample (SRS) surveys in the basins with life-history monitoring sites and where smolt trapping will provide estimates of marine and freshwater mortality. Within these sites and additional associated monitoring sites, surveys of habitat conditions should be related to trends of spawner abundance by basin. Currently, the number and location of sites are determined by available resources within ODFW. Habitat measurements are not covered under existing budgets, and assessment of watershed conditions are not included in the program. There is no explicit program for incorporating results of the fish populations, habitat conditions, and ocean dynamics through the life-cycle model (see Point 1).

- **Development of a process for achieving technical review of proposals for harvest management directions under PFMC prior to public review periods.**

  ODFW recommendations to OFWC and the PFMC must be consistent with science and the goals of the Oregon Plan. Inputs from IMST will be more effective if the IMST is allowed to advise or review options that affect recovery of Oregon salmonids early in the process. During the last two years, IMST comments on the proposed alternative for harvest impacts and selective fisheries have been viewed as political, poorly timed, or inappropriate. We recommend that ODFW develop options for soliciting scientific input earlier in the process. IMST could be more effective if given an opportunity to review PFMC proposal before options go to "press". IMST could work with ODFW and the OFWC to develop a process for reviewing their proposals prior to the public review period.

- **Development of a Precautionary Policy for salmon management during periods of low population abundance that could be used as guidance for policy makers and could be communicated to the public to reduce confusion and frustration.**

  Responses of salmon populations during periods of low abundance are extremely variable because of subtle effects of timing of events or strengths of different limiting factors. The much higher variability during these periods presents major challenges for management of coho salmon under the Oregon Plan (OCN Work Group 2000). Fish returning to coastal streams may greatly exceed pre-season projections or they may be far lower than pre-season projections. Decision makers are under enormous pressure to allow Oregonians to harvest salmon, either commercially or through sport fishing. Economic opportunities and recreation in coastal Oregon are closely tied to access for harvesting salmon. Any positive signal, either in environmental conditions or fish numbers, are seen as an opportunity to increase fishing on wild and hatchery coho salmon. Misinterpretation or errors in projections can result in local extinctions under conditions of low abundances.

  Responses of salmon under these low levels of spawners are highly uncertain because of 1) the highly variable population responses under these conditions and 2) weak or scarce technical information on performance of low populations. When marine survival increases but spawner abundances are low, recruitment may either be high or extremely low. If more fish return than expected and harvest is held to low levels, social pressures on decision makers are high. If less fish return than projected and harvest impacts are increased, potential for extinctions increase sharply.

Oregon policy makers need to recognize the greater uncertainty of management tools under periods of low salmon populations. Hindsight after adults have returned to coastal streams may allow the public to second guess conservative harvest policies adopted by decision makers, but the protection and long-term maintenance of coastal coho salmon require the State to exercise precautionary approaches before increasing harvest impacts. Communication and education about a Fundamental Precautionary Policy could inform the public about the need for more cautious actions under the greater uncertainty associated with the responses of salmon populations at low abundance.

- **Mark all hatchery coho salmon in the Columbia River system through established management agreements and processes.**

  The Oregon Plan called for marking of all hatchery coho salmon to improve technical information on the status and interactions with both wild and hatchery salmon. This information is critical for determining encounter rates with wild fish during selective fisheries, ocean migration and survival studies (e.g., Global Ocean Ecosystems Dynamics Research Program [GLOBEC]), and proportions of wild and hatchery fish in freshwater and marine habitats. Several sources of hatchery coho salmon in the Columbia River (tribal hatcheries, Oregon hatcheries providing coho for tribes, some federal hatcheries) are not marked. In this report, IMST has recommended that harvest management strategies should address both lower Columbia stocks. These stocks are listed as endangered by the State of Oregon and being considered as a candidate for Endangered Species Act (ESA) listing by NMFS. Many of the populations of wild coho salmon in the lower Columbia River have been locally extirpated over the last fifty years.

  Under the Columbia River Compact, states develop policies that govern management of coho salmon within state waters and should provide protection for the few remaining wild populations of coho in the lower Columbia. In addition, the Columbia River Management Plan is being renegotiated under U.S. versus Oregon, and all states, federal agencies, and tribes are included in that negotiation. We recommend the State of Oregon to actively negotiate with its co-managers in the Columbia River to achieve marking of all hatchery salmon to improve the effectiveness of the Oregon Plan.

IMST recognizes that these five points call for changes in policy, funding, and public education. These are matters of policy that are based on technical conclusions and recommendations in this report and are directly linked to the success of the Oregon Plan.

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Appendix A:

Chronological history of spawning escapement and harvest management goals

APPENDIX A: Chronological History Of Spawning Escapement And Harvest Management Goals For Oregon Coastal Natural (OCN) Coho Salmon Stocks In Coastal Basins (personal communication, Rod Kaiser, ODFW).

Prior to 1960

Before 1960, most of the coho harvested along the Oregon coast were of natural origin. Hatchery production was small or non-existent for Columbia River and coastal basins. No OCN coho salmon harvest or management goals existed, and ocean fisheries were managed by individual states with a few selected interstate agreements.

1960's and mid 1970's

In the 1960's, ocean harvest was increased and hatchery production in both the Columbia River and coastal basins was expanded. At this same time, major changes in both freshwater and marine habitat and oceanic conditions caused significant declines in OCN coho salmon abundances. Ocean fisheries were not managed for wild stock escapement goals, and catch was not allocated among different fishing groups. These weakly controlled fisheries caused increasingly heavier exploitation and impact on OCN coho salmon stocks, which became a smaller portion of the catch (10-20%) as a result of increased hatchery releases. The fleet size of the commercial fisheries increased to harvest the hatchery-produced coho (ocean harvest rates of over 80% in some years). The current decline in OCN coho salmon abundance began in the early 1970s.

1976 Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act of 1976 established a framework for federal management over fisheries within 3 to 200 miles of U.S. coasts and created regional management councils. Oregon, Washington, and California developed and coordinated state management plans and objectives. The first salmonid fishery management plan was adopted in 1977-78 to oversee ocean salmon fisheries. The plan was amended in succeeding years through 1983 when a new salmon framework management plan created with both inflexible elements that require PFMC plan amendments and yearly flexible guidelines that only require yearly PFMC management actions. While the PFMC addresses status of OCN coho salmon stocks each year during the early regulation setting process, action is limited to timing of harvest, area, and season length.

1978-1982

The first PFMC ocean salmon fishery management plan was approved in 1978. Under this plan, OCN coho salmon stock abundance is predicted annually using a regression of 3-year old coho adults (nearly all public hatchery fish) based on returning 2-year old jacks to Oregon Production Index (OPI) area hatcheries (Columbia River and Oregon coast). The Oregon Production Index (OPI) encompasses 1) all ocean coho catch from SW Washington/north Oregon coast area (Columbia River ocean area) south through California, 2) Columbia River and Oregon coast freshwater sport catch, 3) Columbia River gillnet catch, 4), hatchery returns for coastal Oregon, and 5) Columbia River Bonneville Dam counts. The Oregon Production Index (OPI) is not an absolute measure of all fish available, but it collectively accounted for 90-95 percent of all regional Oregon Production Index (OPI) area coho stocks during those years. The Oregon Production Index (OPI) does not include OCN coho salmon spawning escapement and coastal hatchery strays. Private hatchery-produced coho were accounted for separately beginning in 1982; they were predicted separately based on production and survival rates. While OCN coho salmon were a primary concern to PFMC and Oregon during this period, no specific OCN coho salmon rebuilding plan existed prior to 1979. The OCN coho salmon escapement "goal" was assumed to be part of the larger Oregon Production Index (OPI) ocean escapement goal determined in the preseason by the PFMC's Salmon Plan Development Team and was intended to accommodate state management of waters inside the 3-mile limit, treaty needs, hatchery escapement, and OCN coho salmon escapement.

1979

Oregon established a rebuilding goal, coastwide, of 200,000 OCN coho salmon adult spawners, based on full seeding of available stream habitat. A standard spawner escapement of 29 adult spawners/mile was designated based on standard index stream surveys. A rebuilding schedule was established for each brood cycle (three consecutive years) to incrementally increase spawning goals from the initial broods of 1979, 1980, and 1981. The projected OCN coho salmon adult spawning escapement to optimize natural production at 200,000 for each brood cycle began in 1987, 1988, and 1989. A phase-in period was incorporated because of the severe and immediate impact on coastal ocean salmonid fisheries and dependent coastal community economies.

1983

For the first time in coastal salmon management, the PFMC set the Oregon Production Index (OPI) area ocean harvest for all users in direct relation to the OCN coho salmon escapement goal as set by ODFW. The Salmon Plan Development Team used ODFW's 140,000 OCN coho salmon yearly spawning escapement goal for 1983 from their 10-year rebuilding plan (1979-1989). The Salmon Plan Development Team developed a linear regression (1977-1982) that related total Oregon Production Index (OPI) area ocean coho escapement to OCN coho salmon spawning escapement. The procedure determined the Oregon Production Index (OPI) area ocean escapement needed to meet the OCN coho salmon yearly ocean escapement and the annual spawning goal. For 1983, they estimated that 492,000 total coho ocean escapement were needed in the Oregon Production Index (OPI). This estimate is based on a total preseason Oregon Production Index (OPI) recruitment to the fishery of 1,554,000 fish (excluding private hatchery fish). This translates into a harvest rate of 68% on OCN coho salmon. The Salmon Plan Development Team added another 10% to the Oregon Production Index (OPI) preseason abundance to adjust for the OCN coho salmon escapement portion to the total recruitment because OCN coho salmon escapement was not part of the preseason Oregon Production Index (OPI) calculation/relationships. This lowered the harvest rate to 61%.

1984

An alternative preseason stock prediction for the Oregon Production Index (OPI) area was developed and partitioned for public hatchery, private hatchery, and OCN coho salmon. ODFW developed a forecasting method for OCN coho salmon stocks based on 2-year wild jack counts observed in stream spawning surveys. The ODFW and Washington Department of Fisheries (WDF) used the WDF/NBS (National Biological Service) catch regulation harvest assessment model to evaluate PFMC area coastwide catch impacts on OCN coho salmon escapement. The PFMC adopted the ODFW procedure for forecasting and impact analysis for 1984 assessment.

1985-1986

A preseason OCN coho salmon forecast was developed for 1985 and 1986 and was used by PFMC. It estimated coastal OCN coho salmon smolt production from parental spawners and applied an estimate of ocean smolt-to-adult survival rate to determine adult recruitment to the fishery. Smolt production was based on a historical relationship between spawners and smolts produced in Deer Creek, a tributary to the Alsea River. This adult to smolt relationship was based on 14 years of observation and was considered to be representative for other Oregon coastal streams. During the preseason period, the WDF/NBS stock catch regulation assessment model was used to assess ocean harvest options and the final adopted regulations.

1986

ODFW proposed a yearly goal for OCN coho salmon spawner escapement that will range from a minimum of 135,000 to a maximum of 200,000 spawners depending on the preseason stock size. This became Amendment 7 to the salmon Fisheries Management Plan for the 1987 season process. For OCN coho salmon abundance between 270,000 and 400,000 fish, the adult spawning goal was to be one half the abundance; at abundances above 400,000, the long-term goal was 200,000. This changed the yearly goal of 200,000 spawners under the previous fixed goal of 200,000 spawners. The new goal was commonly known as the "sliding scale" amendment. This yearly "sliding scale" goal remained in place until further amended by Amendment 11 in December 1993 for the 1994 season.

1987

The PFMC's Salmon Plan Team predicted a "single" estimate of Oregon Production Index (OPI) area coho abundance for Oregon Production Index (OPI) public hatcheries and OCN coho salmon combined catch and escapement. For preseason assessments of harvest options, the PFMC used ODFW's independent forecast for 1987 preseason abundance for OCN coho salmon based on the spawner-recruit relationship for Alsea River, Deer Creek coho data, expanded for coastal streams to determine total smolt output, and applied an ocean survival factor for smolts to adults.

1988

OCN coho salmon predicted by a parent/recruit predictor comparing OCN coho salmon recruits from most coastal river basins to the coastwide parent brood size adjusted by an estimate of smolt-to-jack ocean survival for hatchery smolts the previous year. This approach basically was a modified Ricker spawner-recruit model.

1989-1992

Coastal OCN rivers coho predictor essentially was the same as for 1988.

1993

Coastal OCN rivers coho predictor was the same as for the 1988-1992 period with one addition. A database for OCN coho salmon spawning escapement for different river basins began to use a more extensive (and accurate) stratified random survey design data. Surveys were conducted from more intensive and extensive surveys beginning in 1990. The PFMC, Oregon staff, and the Salmon Team "calibrated" the OCN coho salmon predictor in the 1993 preseason harvest assessment modeling process, known as a scaling procedure, until completion of a study. Subsequent analysis recalibrated the older less extensive surveys using the new data set.

1994

An alternative OCN model was used because of El Niño impacts on ocean survival. Since the current OCN model did not incorporate environmental variability, an environment-based model was chosen to predict 1994 OCN rivers coho. The model related upwelling, sea surface temperatures, and year to predict abundance, but did not include any parameter relating spawner escapement.

APPENDIX B:

PROCESSES CONTRIBUTING TO FINAL HARVEST MANAGEMENT DECISIONS

APPENDIX B: PROCESSES CONTRIBUTING TO FINAL HARVEST MANAGEMENT DECISIONS

Under the current policies of the PFMC and the Oregon Plan, harvest rates are determined through a complex process involving technical analysis, technical review, and public input. Each year, the State and PFMC committees begin their analyses in the fall and finalize the recommendations for the fishing season in April. Three Preseason Reports document the available information and results of various committees, public meetings, and assessments. A number of on-going processes during this period contribute to final management decisions:

- Annual ODFW analyses of the status of wild and hatchery populations based upon analysis of data from numerous monitoring programs during fall and winter
- Meetings of the Oregon Production Index Technical Team (OPITT), the Klamath River Technical Advisory Team (KRTAT) and others to compile data on fish populations and develop pre-season abundance projections
- The Salmon Technical Team (STT) publication of Ocean Fisheries Review and Pre-season I documents
- ODFW consultation with the Oregon Fish and Wildlife Commission (OFWC), the public, and the user groups about the status of coastal salmon populations, pre-season abundance projections, and likely constraints on fisheries to meet conservation, Endangered Species Act (ESA), allocation, and treaty obligations
- Formulation of a range of fishery options by user groups and interested public based on conservation, allocation, and treaty constraints outlined by ODFW and other co-managers in the PFMC process
- Presentation of proposed fishery options to the PFMC by the Salmon Advisory Subpanel (SAS) in March
- STT review of proposed fishery options for Endangered Species Act (ESA) compliance
- Optional Scientific and Statistical Committee (SSC) review and signoff on fishery options
- Public testimony to PFMC on fishery options
- PFMC approval of a suite of fishery options for consideration by the public and user groups
- STT publication of Pre-Season II summary of fishery options
- PFMC sanctioned public hearings on the fishery options
- Guidance to ODFW from OFWC regarding action on the proposed suite of fishery options
- Additional SSC and STT recommendations to the PFMC regarding proposed fishery options
- Public testimony to the PFMC on proposed fishery options
- PFMC deliberations and modifications of fishery options
- STT modeling and impact analyses of fishery options considered by the PFMC
- Final PFMC discussion, modification and adoption of a package of fishery options by the PFMC in April
- STT publication of Pre-season III summary of approved fishery options
- Review and signoff on PFMC-approved fishery options by the Secretary of Commerce
- OFWC review of PFMC fishery options for adoption in state waters

Appendix C:

Harvest matrix from Amendment 13 to the Pacific Coast Salmon Plan

APPENDIX C: HARVEST MATRIX FROM AMENDMENT 13 TO THE PACIFIC COAST SALMON PLAN

4.1 Council-Adopted Alternative

The Council recommends implementation of Alternative 1 with minor modifications to Table 6 as presented below in Table 12. The modifications include edits to Footnote b and the addition of Footnote c which incorporates some of the criteria formerly listed within the "Low" Parent Spawner Status cell of Table 6 (additions to the language in Alternative 1 are in bold type).

TABLE 12. Council-adopted, allowable harvest impact rate criteria for OCN coho stock components.

	SMOLT TO ADULT MARINE SURVIVAL[a/]		
	Low	**Medium**	**High**
PARENT SPAWNER STATUS[b/]	**ALLOWABLE TOTAL FISHERY IMPACT**		
HIGH Parent spawners achieved Level #2 rebuilding criteria; grandparent spawners achieved Level #1	= 15%	= 30%	= 35%
MEDIUM Parent spawners achieved Level #1 or greater rebuilding criteria	= 15%	= 20%	= 25%
Low Parent spawners less than Level #1 rebuilding criteria	= 15% = 10-13%[c/]	= 15%	= 15%

Stock Component Rebuilding Criteria:	LEVEL #1 (50%)	LEVEL #2 (75%)
Northern	10,900	16,400
North-Central	27,500	41,300
South-Central	25,000	37,500
Southern	2,700	4,100
Total	66,100	99,300

a/ See the discussion of marine survival under Section 2.2.1.3.

b/ In the event that a spawner criteria is achieved, but a *major* basin within the stock component is ***less than ten percent of the full seeding level***, the next tier of additional harvest would not be allowed in mixed-stock fisheries for that component, nor additional impacts within that particular basin (see Table A-3 in Appendix A for a list of ***major*** basins within stock components ***and Table A-2 in Appendix A for the spawners needed for full seeding at three percent marine survival).***

c/ This exploitation rate criteria applies when parent spawners are less than 38% of the Level #1 rebuilding criteria, ***or when marine survival conditions are at an extreme low as in 1994-1996 (<0.06% hatchery smolt to jack survival).***

The provisions in Footnote b were designed to protect weak portions of a stock component when there are serious disparities in the coho abundance levels of various major river basins within the component. Under Alternative 1, Footnote b did not contain a clear definition of what constituted "a severe conservation problem" or a "basin". The modifications to foot note b provide (1) a specific standard at which harvest impact increases for a stock component are prohibited—"less than 10% of full seeding in any major river basin", and (2) a reference in Appendix A to identify the full seeding level for each major basin.

Footnote c contains the triggering criteria of Alternative 1 (38% or less of full seeding) to limit the allowable harvest impact rate to 10-13% or less. In addition, Footnote c specifies that this harvest limitation also applies when marine survival conditions are at an extreme low as in 1994-1996.

Appendix D:

PROPOSED REVISIONS TO THE HARVEST MANAGEMENT MATRIX IN PLAN AMENDMENT 13

APPENDIX D: PROPOSED REVISIONS TO THE HARVEST MANAGEMENT MATRIX IN PLAN AMENDMENT 13 SHOWING ALLOWABLE FISHERY IMPACTS AND RANGES OF RESULTING RECRUITMENT FOR EACH COMBINATION OF PARENTAL SPAWNER ABUNDANCE AND MARINE SURVIVAL

Table D.1. Proposed revisions to the harvest management matrix in Plan Amendment 13 showing allowable fishery impacts and ranges of resulting recruitment for each combination of parental spawner abundance and marine survival (OCN Work Group 2000).

	Marine Survival Index (based on return of jacks per hatchery smolt)			
Parent Spawner Status [1/]	**Extremely Low** (<0.0008)	**Low** (0.0008 to 0.0014)	**Medium** (>0.0014 to 0.0040)	**High** (>0.0040)
High **Parent Spawners > 75% of full seeding**	**E** **≤ 8%**	**J** **≤ 15%**	**O** **≤ 30%**	**J** **≤ 45%**
Medium **Parent Spawners > 50% & ≤ 75% of full seeding**	**D** **< 8%**	**I** **< 15%**	**N** **< 20%**	**I** **< 38%**
Low **Parent Spawners > 19% & < 50% of full seeding**	**C** **≤ 8%**	**H** **≤ 15%**	**M** **≤ 15%**	**H** **≤ 25%**
Very Low **Parent Spawners > 4 fish per mile & < 19% of full seeding**	**B** **≤ 8%**	**G** **≤ 11%**	**L** **≤ 11%**	**Q** **≤ 11%**
Critical [2/] Parental Spawners ≤ 4 fish per mile	**A** **0 - 8%**	**F** **0 - 8%**	**K** **0 - 8%**	**P** **0 - 8%**

Sub-aggregate and Basin Specific Spawner Criteria Data

Sub-aggregate	Miles of Available Spawning Habitat	**100% of Full Seeding**	**"Critical"**		**Very Low, Low, Medium & High**		
			4 Fish per Mile	**12% of Full Seeding**	**19% of Full Seeding**	**50% of Full Seeding**	**75% of full Seeding**
Northern	899	21,700	3,596	NA	4,123	10,850	16,275
North - Central	1,163	55,000	4,652	NA	10,450	27,500	41,250
South - Central	1,685	50,000	6,740	NA	9,500	25,000	37,500
Southern	450	5,400	NA	648	1,026	2,700	4,050
Coastwide Total	4,197	132,100	15,636		25,099	66,050	99,075

1/ Parental spawner abundance status for the OCN aggergate assumes the status of the weakest sub-aggregate.

2/ "Critical" parental spawner status is defined as 4 fish per mile for the Northern, North-Central, and South-Central subaggergates. Because the ratio of high quality spawning habitat to total spawning habitat in the Rogue River Basin differs significantly from the rest of the basins on the coast, the spawner density of 4 fish per mile does not represent "Critical" status for that basin. Instead. "Critical" status for the Rogue Basin (Southern Sub-aggergate) is estimated as 12% of full seeding of high quality habitat.

APPENDIX E:

IMST LETTER TO KAY BROWN, ODFW

APPENDIX E: IMST LETTER TO KAY BROWN, ODFW, REGARDING HARVEST LEVEL ESTABLISHMENT FOR THE PFMC PROCESS

INDEPENDENT
MULTIDISCIPLINARY
SCIENCE TEAM
(IMST)

State of Oregon

September 6, 2000

Kay Brown
Oregon Department of Fish & Wildlife
2501 SW First Avenue
Portland, OR 97207

Dear Kay,

The IMST has examined the management of salmon harvest under the Oregon Plan for Salmon and Watersheds. Numerous assessments, including the Oregon Plan (1997), have concluded that historical harvest rates have been too high and have contributed to the decline of OCN coho salmon. Harvest management, therefore, is a critical element of the Oregon Plan for Salmon and Watersheds.

The IMST report on harvest management of OCN coho salmon includes important information about the regional process that establishes harvest levels. This report is in its final stages of preparation but will not be completed prior to the time when material is needed for the PFMC meeting in Sacramento.

We are using this letter to convey to the Oregon Department of Fish and Wildlife specific information on harvest level establishment that we feel needs to be included in the PFMC process. In this letter, we will provide only those conclusions and recommendations that are related to the PFMC process. It is our recommendation that this information and the specific recommendations made below be part of the position of ODFW as they represent the State of Oregon to PFMC.

General Findings

Recent severe declines in coho salmon make all management decisions critical for the survival of remaining stocks. Major advances have been made in regulation of harvest and monitoring of salmon harvest in Oregon since the mid-1980s. Reductions of harvest impacts under Amendment 13 have been substantial and have been essential to prevent extinction of coho salmon stocks along the Oregon Coast and lower Columbia River.

Several analytical tools and monitoring programs have strengthened salmon management in Oregon. In particular, the life-cycle model and spawner monitoring surveys are scientifically rigorous and represent some of the most advanced salmon management tools in North America.

Habitat degradation and over-harvest are two of the major factors in the long-term decline of OCN coho salmon. Poor ocean conditions in recent years have limited population responses to decreasing levels of salmon harvest. Habitat restoration and sound harvest management will strongly influence the rate at which salmon populations recover when climate-related conditions for ocean survival improve.

The State of Oregon and PFMC have not explicitly defined recovery of depressed salmon stocks and criteria for evaluating recovery. The various efforts to restore salmon may be disconnected and less effective until such explicit perspectives have been articulated. The IMST strongly encourages the development of a program that integrates life cycle modeling with the monitoring of salmon populations, habitat, and harvest. The goal is to synthesize information to strengthen the current policy framework and fishery management programs to meet the criteria for recovery.

Because OCN coho salmon stocks have declined to such low numbers and spawners have not replaced themselves in recent years, we are continuing to recommend adjusting fisheries impacts to the lowest levels possible. The IMST strongly endorses the development of critical conservation measures to be added to the harvest impact matrix of Amendment 13. We view the development of conservative measures for both axes of the harvest matrix as essential. In addition, indicators of extreme conditions may be needed as practical limits when severe conditions are observed. An example would be estimates of the percent of survey sites for which zero spawners were observed in any given year. These indicators would be consistent with Minimum Sustainable Escapement (MSE) approaches recommended by the National Research Council in its review of management of Pacific salmon.

The Year 2000 Review of Amendment 13 of the Pacific Fisheries Management Council offers an opportunity for the State of Oregon to evaluate management directions and future directions for salmon harvest management.

Specific Conclusions and Recommendations

The upcoming IMST report on harvest management will focus on the influence of harvest management on stocks of wild coho salmon in Oregon. The report identifies five specific science questions. Two of these are particularly relevant to the PFMC process.

Question 1: How has harvest management affected status of stocks? Are current harvest policies likely to contribute to rebuilding salmon stocks under the Oregon Plan for Salmon and Watersheds?

Conclusions

Past harvest practices clearly have over-harvested OCN coho salmon stocks and have contributed to the population declines that led to listing under ESA. Since 1994, harvest impacts have been reduced dramatically from impacts that ranged from 30%-90% prior to 1990 to 8-13% since 1994.

Modeling results predict that rapid rebuilding of OCN stocks under Amendment 13 will not occur if the ocean survival rates of the late 1990's continue, regardless of harvest impacts. However, the life cycle model predicts that populations would decline at a lower rate without any source of harvest, either directed or indirect (ODFW-NMFS 1998). At low marine survival rates, elimination or reduction of human-caused sources of mortality could reduce probability of extinction or possibly allow modest recovery and would increase the rate of recovery under higher ocean survival rates. However, under poor ocean conditions, significant recovery may not be possible even with minimal harvest impacts (ODFW-NMFS 1998) because escapement of OCN coho salmon is too low. In recent years, spawners have not replaced themselves. Management actions have not improved conditions after adoption of Amendment 13. Improved escapement is essential for a rapid recovery of OCN coho, and control of fishing mortality is the best available tool for achieving improved escapements and more rapid "recovery" of these stocks. Setting Minimum Sustainable Escapement (MSE) levels could improve probabilities of recovery.

Widespread spawning distributions of coho salmon populations are needed to minimize risks of extinctions when the region shifts from climate regimes that are favorable for survival to conditions that result in low rates of ocean survival (see IMST Recovery Report). Management criteria should be linked to monitoring results for the proportion of all habitats or monitored stream reaches that are occupied by spawners. This measure is a critical index for the recovery of OCN stocks.

At recent low population numbers and lack of replacement of stocks and stock aggregates, fishery impacts on OCN coho salmon are very uncertain. Knowledge of population dynamics for coho salmon at extremely low populations is technically weak because of the lack of research on these conditions. Strongly conservative management criteria and explicit definition of "extremely low populations" (e.g., 10% of fully seeding high quality habitats) are needed in such conditions.

Current management includes irregular and relatively haphazard distribution of carcasses with no link to priorities or expected outcomes. Successful management of carcasses under the Oregon Plan will require explicit experimental measurement of the responses of salmon at all life stages to additional food resources from carcasses.

These conclusions are particularly relevant to the PFMC process, and on that basis we make the following recommendations:

Recommendations

1. The IMST recommends that ODFW advocate that new criteria be incorporated into the matrix of Amendment 13 to include "very low" OCN coho salmon parent spawner abundance and "very low" marine survival.

This will strengthen the criteria designed for protection or recovery of populations under extreme conditions. Under these conditions, no directed coho fisheries should be allowed and fishery related impacts should be reduced to the lowest levels possible.

2. The IMST recommends that ODFW advocate the applicability of (a) the Minimum Sustainable Escapement (MSE) concept to augment the use of (b) the number of OCN ocean recruits in setting harvest impacts.

    This could provide a safeguard against loss of stocks during periods of low freshwater or ocean survival. The National Research Council (1996) recommends this methodology to minimize extinction risks of a population or metapopulation and to enhance recovery. Because spawner abundances have been extremely low and recruitment for all three recent brood years (1995, 1996, 1997) has been below replacement, fishery impacts should be as close to zero as possible until established signs of recovery are observed.

3. The IMST recommends that ODFW advocate that decisions to change harvest levels incorporate elements of stock abundance over longer periods of time and include consideration of the spatial distribution of stocks.

    The timeframe and spatial distribution of OCN coho salmon stocks is a critical aspect of measuring recovery. Harvest policies should be revised to require responses over sufficient time to indicate real population trends. We offer the following criteria as possible examples to be incorporated into the decision process whereby harvest levels are changed.

    Criterion 1. Stock Abundance. Stock abundance has achieved a defined Minimum Sustainable Escapement (MSE) before harvest impacts can exceed 10-13 %.

    Criterion 2. Duration of Recovery. Stocks have achieved greater than 1:1 spawner-to-spawner replacement for each brood year over at least three brood cycles.

    Criterion 3. Spatial Distribution. Stocks have achieved two consecutive generations of recovery (spawning recruits/parental adult of >1.5) with seeding above level 2 (75% seeding of available habitat).

4. The IMST recommends that ODFW advocate initiation of a scientific review of the Fisheries Regulation Assessment Model (FRAM) used to estimate harvest impact on OCN stocks components.

    Such a review might be incorporated into the Year 2000 review of Amendment 13.

5. The IMST recommends that ODFW advocate adherence to the policy that links decisions on ocean harvest to the status of the weakest stock component.

    Oregon currently adheres to this requirement, but pressures to allow fishing by sport or commercial fishermen create challenges for following this policy.

6. The IMST recommends that ODFW advocate determining the relationship between the response of salmon juveniles and their food webs to carcass abundance.

    Criteria should be developed that consider the impacts of harvest management on carcass abundance and distribution. Strategies for stock recovery need to recognize the role of food resources and carcasses in production of smolts in freshwater habitats. As an example, management criteria could identify minimum numbers of spawners per mile of stream to provide the food base necessary to support young salmon.

Question 2: Are estimates of mortality from non-retention fisheries accurate and does this source of mortality affect recovery of salmon?

Conclusions

Current estimates of mortality from non-retention fisheries are highly variable, subject to substantial uncertainty, and cannot be characterized as accurate. Experimental methods are limited and subject to many sources of error. Even low incidental mortality rates of OCN coho salmon could significantly slow recovery for depressed stocks. Scientific review of hook and release mortalities should be an on-going process, as environmental conditions change.

Recommendations

7. The IMST recommends that ODFW support PFMC review of hook & release.

    This is a key factor for impact analysis of fisheries. Analysis of hook & release mortality should continue after 2000 because uncertainty is high and ocean conditions are highly variable.

8. The IMST recommends that ODFW advocate determination of the degree to which plausible extremes in mortality and in spatial and temporal variation can influence the risk of extinction.

    Hooking mortality and encounter rates are variable, and sensitivity analysis can help evaluate their impact on probability of extinction. Highly sensitive parameters should be strengthened by monitoring, especially by double-index tagging.

Question 3: Are models used for exploring management questions about Oregon coho salmon scientifically rigorous? Are these models effectively integrated into management and policy analysis and decision-making?
Conclusions

The life cycle models developed by ODFW and NMFS (Nickelson and Lawson) are rigorous, but are not being used to their full potential. This model can be strengthened, and additional models can be developed to provide the ability to confirm model performance and identify areas of uncertainty.

Several features of the model and information base that could be improved in future model development and applications are 1) scarce data, 2) aggregated functions that should be articulated separately, and 3) incorporation of variability (locally and regionally; short term and long term) into model projections. Currently modeling by PFMC and ODFW uses a static view of future landscape conditions. Restoration of freshwater habitats and future disturbance processes are not considered. Current analyses are dynamic in terms of ocean conditions and fish populations, but they treat watersheds and freshwater habitat as fixed and unchanging.

Coordinated analysis of harvest management, monitoring, model applications, and risk assessment would create a more scientifically sound decision-making context for salmon harvest management and allow management to adapt and improve more quickly. Unfortunately we do not find a concrete link between the operation of the model, the monitoring program and the development of harvest management policy. The efforts in SRS monitoring system, basin habitat surveys, life cycle monitoring sites, and life-cycle models would be strengthened if they were integrated into an on-going program of assessment and integration of information and future stock projections.

Recommendations

9. The IMST recommends that ODFW advocate that PFMC use an explicit analytical process that incorporates monitoring results, harvest records, and the life-history model as part of the decision process for harvest levels.

    This analysis should link spawner surveys, habitat surveys, marine survival or impacts and model projections. It should also be spatially explicit to the greatest degree allowed by the data and model structure.

10. The IMST recommends that ODFW advocate that PFMC incorporate dynamic and changing landscape conditions in the analytical process to reflect potential habitat restoration, human-related degradation, and natural disturbances.

    Use of dynamic conditions for both ocean and freshwater environments will provide more realistic projections of future population trends and risks of extinction. Such integration also recognizes regional goals to protect and restore watershed conditions along the Pacific Coast.

We hope this information will be helpful as ODFW represents the State of Oregon to the PFMC. By copy of this letter we are notifying Director Greer, ODFW Commissioners and PFMC of the IMST scientific recommendations in this matter.

Sincerely yours,

Logan A. Norris
Chair, IMST

cc: Director Jim Greer, ODFW
ODFW Commissioners
Don McIsaac, PFMC
Roy Hemmingway, Manager,
Oregon Plan
IMST

APPENDIX F:

OCTOBER 31, 2000, TESTIMONY OF DR. STANLEY GREGORY, IMST, TO THE PFMC

APPENDIX F: OCTOBER 31, 2000, TESTIMONY OF DR. STANLEY GREGORY, IMST, TO THE PACIFIC FISHERIES MANAGEMENT COUNCIL

Stanley Gregory, Ph.D.
Independent Multidisciplinary Team
Oregon Plan for Salmon and Watersheds

To
Pacific Fishery Management Council

October 31, 2000

I am Dr. Stanley Gregory, a member of the Independent Multidisciplinary Science Team (IMST), part of the Oregon Plan for Salmon and Watershed. The mission of the Oregon Plan is the recovery of depressed stocks of wild salmonids, and the role of the IMST is to provide scientific oversight for this effort. I am here today representing the IMST.

The IMST has examined the management of salmon harvest under the Oregon Plan for Salmon and Watersheds. Previously, we identified specific issues that we feel need to be included in the PFMC process and reported these to the Oregon Department of Fish and Wildlife. The OCN Working Group invited IMST members to observe the 2000 Review of Amendment 13 to the Pacific Coast Salmon Plan.

The purpose of my testimony today is to reinforce with PFMC some key aspects of the 2000 Review of Amendment 13. These are the same points we made with ODFW earlier.

We previously concluded that:

> **Reductions of harvest impacts under Amendment 13 have been substantial and have been essential to prevent extinction of coho salmon stocks along the Oregon Coast and lower Columbia River.**
>
> **The life-cycle model and spawner monitoring surveys have strengthened salmon management in Oregon.**
>
> **The state of Oregon and PFMC have not explicitly defined recovery of depressed salmon stocks and criteria for evaluating recovery.**
>
> **Because OCN coho salmon stocks have declined to such low numbers and spawners have not replaced themselves in recent years, we continue to recommend adjusting fisheries impacts to the lowest levels possible.**
>
> **The IMST strongly endorses the development of critical conservation measures to be added to the harvest impact matrix of Amendment 13. In addition, indicators of extreme conditions may be needed as practical limits when severe conditions are observed.**
>
> **The Year 2000 Review of Amendment 13 of the Pacific Fisheries Management Council is an important opportunity for the State of Oregon to evaluate management directions and future directions for salmon harvest management.**

Specific Recommendations

The following recommendations were made by IMST to ODFW as they represent the State of Oregon in this matter to PFMC. I reiterate these today to reinforce their importance directly with PFMC.

1. The IMST recommends that ODFW advocate that new criteria be incorporated into the matrix of Amendment 13 to include "very low" OCN coho salmon parent spawner abundance and "very low" marine survival.

   This will strengthen the criteria designed for protection or recovery of populations under extreme conditions. Under these conditions, no directed coho fisheries should be allowed and fishery related impacts should be reduced to the lowest levels possible.

2. The IMST recommends that ODFW advocate the applicability of (a) the Minimum Sustainable Escapement (MSE) concept to augment the use of (b) the number of OCN ocean recruits in setting harvest impacts.

   This could provide a safeguard against loss of stocks during periods of low freshwater or ocean survival. The National Research Council (1996) recommends this methodology to minimize extinction risks of a population or metapopulation and to enhance recovery. Because spawner abundances have been extremely low and recruitment for all three recent brood years (1995, 1996, 1997) has been below replacement, fishery impacts should be as close to zero as possible until established signs of recovery are observed.

3. The IMST recommends that ODFW advocate that decisions to change harvest levels incorporate elements of stock abundance over longer periods of time and include consideration of the spatial distribution of stocks.

   The timeframe and spatial distribution of OCN coho salmon stocks is a critical aspect of measuring recovery. Harvest policies should be revised to require responses over sufficient time to indicate real population trends. We offer the following criteria as possible examples to be incorporated into the decision process whereby harvest levels are changed.

Criterion 1. Stock Abundance. Stock abundance has achieved a defined minimum sustainable escapement before harvest impacts can exceed 10-13%.

Criterion 2. Duration of Recovery. Stocks have achieved greater than 1:1 spawner-to-spawner replacement for each brood year over at least three brood cycles.

Criterion 3. Spatial Distribution. Stocks have achieved two consecutive generations of recovery (spawning recruits/parental adult of >1.5) with seeding above level 2 (75% seeding of available habitat).

4. The IMST recommends that ODFW advocate initiation of a scientific review of the Fisheries Regulation Assessment Model (FRAM) used to estimate harvest levels on OCN stocks components.

   Such a review might be incorporated into the Year 2000 review of Amendment 13.

5. The IMST recommends that ODFW advocate adherence to the policy that links decisions on ocean harvest to the status of the weakest stock component.

Oregon currently adheres to this requirement, but pressures to allow fishing by sport or commercial fishermen create challenges for following this policy.

6. The IMST recommends that ODFW advocate determining the relationship between the response of salmon juveniles and their food webs to carcass abundance.

    Criteria should be developed that consider the impacts of harvest management on carcass abundance and distribution. Strategies for stock recovery need to recognize the role of food resources and carcasses in production of smolts in freshwater habitats. As an example, management criteria could identify minimum numbers of spawners per mile of stream to provide the food base necessary to support young salmon.

7. The IMST recommends that ODFW support PFMC review of hook & release.

    This is a key factor for impact analysis of indirect fisheries (e.g., impacts of chinook fisheries, impacts of sport fisheries for marked hatchery coho salmon). Analysis of hook & release mortality should continue after 2000 because uncertainty is high and ocean conditions are highly variable. Hook-and-release mortality rates may vary with ocean temperatures and productivity, therefore setting fixed rates may lead to additional problems in the future.

8. The IMST recommends that ODFW advocate determination of the degree to which plausible extremes in mortality and in spatial and temporal variation can influence the risk of extinction.

    Hooking mortality and encounter rates are variable, and sensitivity analysis can help evaluate their impact on probability of extinction. Current reviews have discarded upper and lower quartiles of research results. These extreme values may not represent average conditions, but they could have undesirable consequences under specific sets of conditions. The model could be used to test the effects of extreme rates to determine the consequences of the plausible boundaries around the average rates determined in the review process. Extreme rates can also be incorporated into a randomized version of the Monte Carlo runs as a form of sensitivity analysis. Highly sensitive parameters should be strengthened by monitoring, especially by double-index tagging.

9. The IMST recommends that ODFW advocate that PFMC use an explicit analytical process that incorporates monitoring results, harvest records, and the life-history model as part of the decision process for harvest levels.

    This analysis should link spawner surveys, habitat surveys, marine survival or impacts and model projections. It should also be spatially explicit to the greatest degree allowed by the data and model structure.

10. The IMST recommends that ODFW advocate that PFMC incorporate dynamic and changing landscape conditions in the analytical process to reflect potential habitat restoration, human-related degradation, and natural disturbances.

    Use of dynamic conditions for both ocean and freshwater environments will provide more realistic projections of future population trends and risks of extinction. Such integration also recognizes regional goals to protect and restore watershed conditions along the Pacific Coast.

2000 Review of Amendment 13 to the Pacific Coast Salmon Plan

The 2000 Review has directly addressed several of the IMST's recommendations to the State of Oregon for issues related to PFMC management decisions. Following are brief comments on the important recommendations of the 2000 Review Report and their relation to our recommendations to ODFW and via this testimony today to PFMC.

In particular, the IMST strongly endorses the development of precautionary criteria for conditions of extremely low spawner abundance. Addition of the "Very Low" and "Critical" parental spawner categories to the matrix greatly strengthen the management of impacts on coastal coho salmon. These additions are consistent with the original framework of the Salmon Management Plan and incorporate aspects of the concept of "minimum sustainable escapement" that was recommended in a recent review of salmon management by the National Research Council.

The IMST has consistently supported the application of management decisions based on the status of the weakest subaggregate, which the 2000 Review has continued to endorse. A significant change is the elimination of the provision for limits on moving to higher harvest impacts when a basin exhibits less than 10% full seeding. IMST recognizes the arguments provided for the elimination of basin criteria, and the lack of precision in basin estimates of spawners is a valid concern. This change in Amendment 13 may be justifiable at this point and the additional levels of protection within the matrix may minimize undesirable impacts, but the IMST recommends continued development of methods and information to effectively manage salmon at the scale of basins or river networks. The IMST encourages the PFMC to consider future actions that would strengthen basin-level estimates of spawners and additional local data that would permit protection of smaller basins and their stocks in the future.

The IMST has found the Nickelson/Lawson model to be scientifically rigorous and strengthens the PFMC process. We strongly encourage state and federal agencies to integrate current and future habitat condition with the modeling of fishing impacts, ocean survival, and salmon populations. At present, the model incorporate dynamic ocean conditions and changing fisheries, which is a strength. Unfortunately, the future projections do not incorporate dynamic changes in habitat, either as a result of watershed restoration or future habitat degradation. A more dynamic view of habitat could be incorporated based on readily available land use/land cover information and projections of land use policies.

The 2000 Review addresses the most critical recommendations of IMST. We would be negligent if we did not point out that several IMST recommendations were not addressed in this review—longer timeframes required before major changes in harvest impacts, incorporation of ecosystem functions of carcasses in management targets, review of the Fishery Regulation Assessment Model (FRAM) model, use of dynamic landscape information in model projections. The IMST recommends that the OCN Working Group could provide an updated assessment in the near future and possibly incorporate issues that emerge from the regional response to their report.