INDEPENDENT MULTIDISCIPLINARY SCIENCE TEAM (IMST)

State of Oregon

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August 16, 2000

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Enclosed is the IMST report of a scientific workshop that we conducted on conservation hatcheries and supplementation. Supplementation is a strategy by which hatcheries are used to produce fish from wild stocks that are reintroduced into the natural environment to become naturally spawning "wild fish". It is a specialized aspect of a hatchery strategy for Oregon. Supplementation is a relatively recent development and one about which there is both controversy and uncertainty. It is the focus of the Conservation Hatchery Improvement Proposal (CHIP) in which the State of Oregon would engage in an enlarged program of experimental supplementation projects.

We organized this workshop to help the Team with its work on our broader hatchery project, but also to provide a better base of information as the State considers the Conservation Hatchery Improvement Proposal. Active participation in the workshop was limited to a relatively small number (32 invitees, plus 6 members of the IMST) of invited technical specialists. We limited participation to ensure a manageable size and to facilitate the productive work of the group. Inevitably when this is done some qualified individuals or the organizations they represent are left out, and that was the case for this workshop as well. However, IMST selected invitees to ensure that a good cross-section of disciplinary expertise, experience, perspective and organizational representation were included.

A draft of this report was offered to workshop participants for review and comment. IMST revised the report to reflect comments and suggestions, as we felt appropriate. Participants did not review the revised report. This final report is a report by the IMST of the workshop and it should not be considered as a consensus document of the workshop participants.

In addition to this report, IMST has established a public record of the workshop. The Record is maintained by the Oregon Watershed Enhancement Board and includes

- The audio tapes of plenary sessions and public comment periods
- Written comments by Dr. James Lannan, a workshop participant, on "quality of science", reflecting an area of discussion he felt received inadequate attention
- Written comments submitted by John Platt, an attorney, of the Columbia River Intertribal Fish Commission, reflecting his remarks during a public comment period
- Comments on the review draft of this report submitted by workshop participants

The IMST is finding that scientific workshops of this type are very valuable for identifying and clarifying the technical and scientific aspects of issues relevant to the mission of the Oregon Plan for Salmon and Watersheds. The reports of these workshops are solely the responsibility of the IMST and are simply our summary of them.

I hope this information will be helpful as work on the Oregon Plan for Salmon and Watersheds continues.

Sincerely yours,

Logan A. Norris
Chair, IMST

Enclosure

cc: IMST
Joint Legislative Committee on Stream Restoration and Species Recovery
Workshop Participants

Conservation Hatcheries and Supplementation Strategies for Recovery of Wild Stocks of Salmonids: Report of a Workshop

Independent Multidisciplinary Science Team
Portland, OR
June 19-21, 2000

Technical Report 2000-1

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

July 18, 2000

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Executive Summary

The Independent Multidisciplinary Science Team (IMST) convened regional leaders in hatchery management and salmon recovery on June 19-21, 2000 for a scientific workshop on Conservation Hatcheries and Supplementation Strategies for the Recovery of Wild Stocks of Salmonids. The purpose was to provide better information (a) to help the IMST with its work on hatchery reports, and (b) to help policy makers as they consider proposals for the State of Oregon to engage in a program of supplementation. The goal of the workshop was to identify, clarify and compile the scientific basis on which conservation hatcheries and supplementation strategies may help accomplish the mission of the Oregon Plan for Salmon and Watersheds (Oregon Plan).

This report is prepared by the IMST. It was reviewed by workshop participants and revised by IMST accordingly. It does not necessarily reflect consensus on all points by workshop participants. IMST alone is responsible for the report. The report includes abstracts of plenary scientific presentations and case histories of supplementation projects, a brief description of the Oregon Conservation Hatchery Improvement Proposal (CHIP), and the results of three concurrent work group discussions. These work group discussions focused on:

- Conditions under which supplementation could be used in wild salmonid recovery
- Appropriate methods for supplementation
- Approaches for the evaluation of supplementation over time

A series of major points emerged during the plenary sessions and during the concurrent work group sessions. These points, organized by topic, summarize the most important factors to address when planning or implementing a supplementation program.

Overview and Conceptual Framework

- Supplementation is part of a suite of strategies (e.g., habitat enhancement and restoration, changes in land use, changes in fish harvest activities, removing impediments to fish passage) that may be used together for recovery of wild salmonid populations.
- When possible, limiting factors (e.g., ecological or habitat conditions, impediments to fish passage) should be addressed before implementing a supplementation program.
- Supplementation may help to maintain a gene pool but is not likely to lead to recovery of salmonid populations unless the root causes of decline are addressed.
- Supplementation is still in experimental stages; alternative strategies for meeting the goals of a particular project should be considered before supplementation is used.
- During the design, implementation, and monitoring of supplementation, programs should, as much as possible, utilize what is known about wild salmonid life cycles while developing and testing supplementation strategies and tactics.
- Clearly defined goals and monitoring of their attainment are important to the success of supplementation programs.

Assessment and Design of Supplementation Programs

- The population status of the target population is a prime factor in considering supplementation. Supplementation efforts of greater risk can be tolerated in areas where the current probability of existing population/stock survival is very low.

- Risks and benefits should be evaluated before implementing a supplementation program.
- Supplementation might be implemented to provide “genetic conservation” while other measures (e.g., habitat improvement) that will greatly improve the chances of success of a supplementation program over the long term are also being implemented.
- Ideally, supplementation should end when recovery goals are met.

Methods

- It is extremely important to identify areas with suitable habitat and underutilized carrying capacity when choosing supplementation as a tool to aid recovery of salmonid populations.
- Supplementation should be placed in an ecosystem context. Important considerations include carrying capacity, the connectivity of the population, the impacts on existing populations/stocks and on other species, levels of adult returns, as well as additional ecological factors.
- Preservation of genotypic and phenotypic diversity is extremely important when stocks are selected or developed for supplementation. Domestication selection should be minimized. Use “local broodstocks” or an appropriate alternative to minimize divergence from the wild population. When possible, allow for a natural range in the diversity of life history patterns.

Evaluation

- Monitoring and evaluation are essential to assessing whether supplementation was successful and goals of a particular program were met. This requires adequate experimental design and “references or controls” for comparisons.
- Abundance, stock productivity, ecological and genetic diversity, and fish distribution data are all important when evaluating the results and/or success of supplementation.
- Due to the inherent cost and limitations of monitoring programs, monitoring efforts will be most efficient, and will provide the most comprehensive information, when coordinated among agencies.

Based on this workshop the IMST reaches the following interim conclusion pending completion of our phase III hatchery project report: Supplementation may be a useful strategy as part of a comprehensive program of species recovery. We note that it has not been extensively tested, therefore needs to be used cautiously and with a strong component of monitoring and adaptive management to ensure it is not harmful to recovery of wild stocks, and that it is achieving the intended goals.

Introduction

The IMST convened regional leaders in hatchery management and salmon recovery in Portland, Oregon on June 19-21, 2000, for a scientific workshop on Conservation Hatcheries and Supplementation Strategies for the Recovery of Wild Stocks of Salmonids (Agenda, Appendix 1). The purpose was to provide a better base of information (a) to help the IMST with its work on the broader hatchery report, and (b) to help policy makers as they consider proposals for the State of Oregon to engage in an enlarged program of experimental supplementation projects. The goal of the workshop was to identify, clarify and compile the scientific basis on which conservation hatcheries and supplementation strategies may help accomplish the mission of the Oregon Plan.

This report includes abstracts (provided by the speakers) of plenary scientific presentations and case histories of supplementation, a brief description of the Conservation Hatchery Improvement Proposal (CHIP), and the results of three concurrent work group discussions. These work group discussions focused on:

- Conditions under which supplementation could be used in wild salmonid recovery
- Appropriate methods for supplementation
- Approaches for the evaluation of supplementation over time

The IMST conducted the workshop and active participation was limited to invited participants (Appendix 2). They were selected on the basis of their scientific expertise and experience with management of hatchery programs and to include a variety of scientific perspectives on supplementation and to draw technical experts from a variety of organizations in the Pacific Northwest. Our goal was also to keep the group small enough to ensure productive discussion, but this also resulted in some other individuals who have appropriate expertise not being included. Invited speakers for the plenary sessions provided abstracts of their presentations and relevant references for the scientific and technical basis for their comments. Many of these are included the bibliography of the report.

This is a report prepared by the IMST summarizing the workshop. It is not intended as the position of the IMST on this topic, but is simply intended to capture the outputs of the workshop process. A draft was reviewed by workshop participants and revised as judged appropriate by the IMST. It is not a consensus document of the participants, and does not necessarily reflect the views of all participants.

This report includes the speakers' abstracts of their presentations, a summary of work group discussions, and a list of references. It does not include a summary of the discussions that followed individual presentations by speakers during the plenary sessions. These discussions were intended to clarify issues for the workshop participants as they prepared for their individual participation in one of the three workgroups. These discussions were recorded on audiotapes made during plenary and public comments sessions.

The workshop was open to the public and consistent with Oregon Public Meetings law. The Record of this workshop includes this report and the following available through the Oregon Watershed Enhancement Board office (contact Bev Goodreau (503) 986-0187):

- The audio tapes of plenary sessions and public comment periods.
- The agenda and list of workshop participants.

- Written comments by Dr. James Lannan, a workshop participant, on “quality of science”, reflecting an area of discussion he felt received inadequate attention.
- Written comments submitted by John Platt, an attorney, of the Columbia River Intertribal Fish Commission, reflecting his remarks during a public comment period
- Comments on the review draft of this report submitted by workshop participants.
- Public observers, and those making comments.

Science Base

The initial plenary session featured a series of presentations on the science relevant to the issues of conservation hatchery management and salmonid fisheries supplementation. The presentations were intended to provide a common starting point for subsequent discussions.

Salmon Supplementation: Empirical Assessment and ESA Context

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Abstract

Artificial propagation of Pacific salmon has been used for over a century to provide increased harvest opportunities and mitigate reductions in natural populations due to factors such as habitat destruction and blockage of migratory routes. More recently, attention has focused on the potential of hatchery propagation to reduce risks to and speed recovery of depleted natural populations--a process often called supplementation. Both types of hatchery programs can be consistent with the federal Endangered Species Act (and, more generally, with long-term conservation of natural salmon populations), but in somewhat different ways: 1) If production hatcheries are isolated enough, their direct and indirect effects on natural populations may not rise above a threshold for concern; and 2) If supplementation programs can potentially provide a net long-term benefit to wild populations by helping them become naturally self-sustaining.

A large number of supplementation programs have already been initiated in the Pacific Northwest and many more are planned. To improve the information base for evaluating salmon supplementation, we undertook a review of information for existing programs. Rather than using a single measure of "success," we evaluated programs according to how well they have accomplished a series of specific objectives. Major conclusions that emerge from a preliminary results of data for 19 salmon supplementation programs in northwestern North America: 1) Many supplementation programs have achieved a measure of success in the aspects of fish culture traditionally associated with salmon hatcheries (e.g., high egg-smolt survival; adult : adult replacement rates in excess of 1.0). 2) To date, however, little information is available about the performance of hatchery fish and their progeny in the natural environment. Therefore, the premise that hatchery supplementation can provide a net long-term benefit to a natural population is an hypothesis that has not yet been tested. This fact should be kept in mind in evaluating the appropriate use of supplementation programs.

Towards A Risk-Benefit Analysis For Salmon Supplementation[1]

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Abstract

Discussion and implementation of salmon supplementation in the Pacific Northwest has focused primarily on its potential benefits, which include reduction of short-term extinction risk, speeding recovery, reseeding vacant habitat, and increasing harvest opportunities. Some risks of supplementation to natural populations have also been recognized; however, risk analysis is seldom comprehensive, and managers are often in the position of attempting to find the least disagreeable way of dealing with deleterious effects that were not anticipated when a supplementation program began. Ideally, a comprehensive risk/benefit analysis for salmon supplementation should be conducted before a supplementation program is initiated. Key points to consider in such an analysis include the following:

- It is important to clearly articulate the nature and goals of the proposed program, because many of the risks and potential benefits depend heavily on these factors. Key questions to consider include, Is the primary focus of the program conservation of natural populations, increased production, or a combination of the two? What is the anticipated scale and duration of the program, and what will be the source of broodstock?
- Supplementation is most clearly appropriate in two situations: 1) when short-term extinction risk for the population is high, and 2) in reseeding vacant habitat that is unlikely to be colonized naturally within a reasonable time frame.
- In other cases, the question whether to use supplementation should be evaluated carefully after an objective assessment of the risks as well as potential benefits. It should be recognized that the risks of using supplementation may outweigh its potential benefits, even for populations that face some degree of demographic and/or genetic risk.
- Genetic risks of supplementation include loss of genetic diversity (both within and between populations) and loss of fitness.
- A variety of strategies can be used to minimize risks of supplementation, but most risks cannot be eliminated entirely. Furthermore, some risks are inversely correlated, such that efforts to reduce one risk simultaneously increase others.
- In some years, successful supplementation programs may create more adults or juveniles than can be utilized in a biologically sound manner. Nevertheless, there may be strong pressure on program managers to spawn or release the excess individuals, resulting in elevated risks to the natural populations. The possibility that this situation will develop should be considered and incorporated into the analysis of risks and benefits before deciding whether to implement a program.

[1] This title was originally scheduled as a presentation by Don Campton, who was unable to attend. The presentation was prepared and presented by Robin Waples.

- Two factors argue strongly for a cautious approach to initiating new supplementation programs. 1) Long-term effects of fish culture on natural populations are largely unknown, and it remains to be determined whether supplementation can lead to permanent increases in abundance of natural populations. 2) Once started, supplementation programs may be difficult or impossible to terminate even if it would benefit the natural populations to do so.
- When supplementation is used, it should be regarded as experimental and carried out within an adaptive management framework. Adequate monitoring and evaluation are essential to tracking the success of individual programs as well as in providing insight into the general usefulness of supplementation.
- Considerable uncertainty exists regarding both the risks and potential benefits of supplementation. This uncertainty should be acknowledged at the outset and factored into the risk/benefit analysis. It should be recognized that even aggressive, well-designed monitoring programs may have limited power to resolve all the complex uncertainties regarding supplementation.
- Although a comprehensive risk/benefit analysis should be conducted for each proposed supplementation program, an informed decision about the appropriate scale and nature of supplementation can only be made by considering a broader (basin-wide or region-wide) perspective. Within a region, it may be reasonable to try a variety of different approaches under an adaptive management approach, taking care to leave a substantial fraction of natural populations unaffected by direct or indirect effects of supplementation.
- Supplementation should also be evaluated in the broader context of other recovery efforts for the population(s). In general, methods that are less invasive than artificial propagation should be used whenever possible. If supplementation is used, it should be integrated with other recovery measures to provide maximum benefit.

Interspecies Interactions and Supplementation

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Abstract

Interspecies interactions will occur as a result of supplementation programs, but whether those interactions are biologically significant, socially acceptable and whether the impacts of the interactions are statistically detectable depends upon the supplementation program. Interactions from different programs will never be exactly alike. Two kinds of interactions are particularly important 1) those that influence target species production goals and 2) those that influence non-target species conservation goals. This talk will focus on the latter of these interactions.

Interactions will occur concurrently with supplementation dynamics and these interactions may take a long time to express themselves because supplementation takes a long time. Four stages of supplementation dynamics can be identified 1) baseline, 2) broodstock, 3) building, and 4) boundary. Various permutations of interactions including ecological release (reduction in negative interactions), ecological restriction (reduction in positive interactions),

type I (interactions between hatchery and wild fish), and type II (interactions between progeny of hatchery fish and wild fish) interactions will occur depending upon which stage of supplementation is occurring.

Many ecological interaction mechanisms have been observed, but few, if any, studies have demonstrated population level impacts conclusively. Interaction mechanisms include predation, competition, disease, behavioral anomalies, food availability, harvest, and broodstock collection. Most of these interactions can have both direct and indirect effects. Tools to manage ecological interactions include risk assessment, risk minimization strategies, risk containment monitoring, and risk containment actions. Risk assessment can be used to identify the probabilities of unacceptable impacts occurring, but frequently there will be high scientific uncertainties about the risks. Risk containment requires that impacts less than a specified objective be detectable. Impacts to abundance are rarely detectable below 20% of baseline abundance because of high inter-annual variation. We have the ability to manage risks much better than we have in the past, but they will cost more and take more planning and commitment than previously thought. The Regional Assessment of Supplementation Project definition of supplementation has never been tested with respect to interspecies interactions [RASP 1992]. It remains to be seen whether supplementing one species can be done without harming other valued non-target species beyond specified biological limits.

Supplementation Research

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Abstract

Various studies have shown genetic differences between hatchery and wild anadromous Pacific salmon (*Oncorhynchus* spp.) for traits including development rate, habitat utilization, predator avoidance, spawning time, territoriality, aggression, growth, and survival. No single study, however, has provided conclusive evidence that artificial propagation poses a genetic threat to conservation of naturally spawning populations. When the published studies and three studies in progress are considered collectively, however, they provide compelling evidence that the fitness for natural spawning and rearing can be rapidly and substantially reduced by artificial propagation. This issue takes on great importance in the Pacific Northwest where supplementation of wild salmon populations with hatchery fish has been identified as an important tool for restoring these populations. Recognition of negative aspects may lead to restricted use of supplementation, and better conservation, better evaluation, and greater benefits when supplementation is used.

Reproductive Behavioral Interactions and Relative Breeding Success Of Captively Reared And Wild Coho Salmon

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Abstract

In the Pacific Northwest, releasing captively reared adult salmon (*Oncorhynchus* spp.) for natural spawning is an evolving strategy for the recovery of imperiled populations. The ability of captively reared fish to spawn naturally may be compromised by their artificial rearing environments, which differ markedly from those experienced by wild fish. Berejikian et al. (1997) conducted a breeding behavior and success experiment, comparing captively reared and wild coho salmon (*O. kisutch*) in a manipulated natural stream channel. They found that wild males dominated captively reared males of similar size in 86% of spawning events. Both wild and captively reared females attacked captively reared males more frequently than wild males indicating a preference for wild males. Wild females established nesting territories earlier and constructed more nests per individual than captively reared females of similar size, suggesting an intrasexual competitive advantage. Nevertheless, captively reared coho salmon demonstrated the full range of behaviors shown by wild coho salmon of both sexes, and the ability to successfully reproduce. In a follow-up study (Berejikian et al. In Review), wild coho salmon males outcompeted captively reared males and controlled access to spawning females in 11 of 14 independent trials in artificial stream channels. In two cases where satellite males were observed participating in spawning, DNA genotyping results determined that they did not sire any of the progeny. When spawning occurred at night and was not observed, DNA results confirmed behavior-based determinations of dominance made before dark. Aggression data collected during the first hour of competition indicated that dominance was established soon after the males were introduced into a common arena containing a sexually active female. We hypothesize that decisions by subordinate males to avoid direct competition may have minimized conflict. The competitive inferiority of captively reared coho salmon in this and Berejikian et al. (1997) probably reflects deficiencies in rearing environments, which fail to produce appropriate body coloration and body shape, and perhaps alter natural behavioral development.

The following three papers were part of an evening discussion session. They address the question "When is the use of supplementation appropriate in the recovery of depleted salmon and steelhead populations?"

When Is Supplementation Appropriate?

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Abstract

Experience with population modeling, evaluation of stream habitat restoration, and evaluation of a hatchery supplementation program have provided insights into the potential for supplementation of wild populations with hatchery fish. Research has shown that wild populations can be slow to respond to increases in survival if the beginning population is too small. Habitat restoration has the potential to create situations where habitat capacity is much greater than seeding level. These situations may be appropriate for supplementation. Supplementation must use fish that are as similar to the wild fish as possible and should be limited to 3-4 brood cycles, depending on the species.

Conclusions:

- Supplementation may be appropriate following habitat restoration that has documented an increase in smolt capacity and low seeding level.
- Fish used in supplementation programs should be as similar to the wild fish as possible.
- Out-planting of adults may work best.
- Limit releases to 3 cycles for coho, 4 cycles for chinook.
- Supplementation programs must be evaluated.

Estuarine and Ocean Environments: What Do We Need To Know Before Using Supplementation?

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Few studies have been conducted to understand factors influencing the capacity of Oregon estuaries and near-shore ocean environments to support juvenile salmon. Yet the fact that all salmon must travel through an estuary en route to the ocean suggests that estuarine conditions must be carefully evaluated before deciding whether it is appropriate to supplement depleted wild salmon populations with hatchery fish. Three categories of information are important to any such evaluation:

Habitat availability

Habitat inventories have been completed for few Oregon estuaries since the late 1970s. Information is needed about the quantities and distribution of estuarine habitats and historical changes that may affect the salmon rearing potential of Oregon watersheds. In many Northwest estuaries, major proportions of wetland habitats have been removed through diking, draining, and filling. Extent of estuarine habitat loss may be a major factor affecting the potential benefits of supplementation.

Habitat capacity

Few studies in Oregon have evaluated the specific structural qualities of estuarine habitats or the ecological interactions that affect their productive capacities for salmon. Most fish surveys in Oregon estuaries involve general inventories of a narrow range of habitat types, particularly clean, sandy beaches that can be readily sampled with beach seines. Few studies have targeted complex shallow-water habitats, including muddy sloughs, backwater areas, and salt marsh channels, which may provide refugia and productive feeding areas for small subyearling salmon. Several studies indicate that the growth potential of salmon in some estuaries may be a function of population density and prey availability. Ongoing research at Salmon River estuary (Oregon) illustrates that the location of habitat within the larger estuarine system may be an important determinant of its productive capacity for salmon.

Population structure/life-history diversity

Salmon have devised a wide variety of life-history strategies for using estuarine habitats, including different times and sizes of estuarine and ocean migration, duration of estuarine residence, etc. This diversity of behaviors affords resilience to salmon species in a fluctuating environment. It also maximizes the productive capacity of estuaries by dispersing fish throughout all available habitats and insuring continued "turnover" of habitat by different life-history types that are staged to move through the system at different times. Thus, loss of life-history diversity could affect the salmon rearing capacity of an estuary independent of the total

amount or quality of habitat available. In particular, hatchery programs that concentrate the periods and areas of estuarine use by salmon may create artificial "bottlenecks" to production through density dependent mechanisms.

Ultimately, estimates of salmon survival in estuaries will be needed to evaluate the potential benefits and risks of supplementation. There are few data on the survival of salmon in estuaries or the relative importance of estuarine conditions to adult salmon returns. Deciding whether supplementation would likely benefit depleted populations implies an understanding of major factors that contribute to variations in freshwater, estuarine, and marine salmon survival.

Population Dynamics

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Abstract

Artificial selection in the hatchery environment

The genetic diversity of hatchery stocks can be maintained, and their genetic impact on wild stocks minimized, by breeding programs that deliberately generate genetic diversity. This employs the genotype-environment interaction for production of traits that is affected by artificial selection in hatchery environments that differ in their designs, such that different genotypes are favored in different supplementation hatcheries (see also Doyle et al. 1991).

Population regulation and habitat use

A central question in population ecology is: how does the distribution of animals change when the overall population size changes? Expansions of local populations can be categorized in three distinct patterns in time and space: 1) habitat use increases proportionately in all habitats independently of density or quality; 2) habitat use increases proportionately more in marginal secondary habitats than in primary habitats; 3) habitat use increases proportionately more in primary habitats than in secondary habitats. It is often assumed that a successful model of supplementation will result in Type 3. To detect the patterns that occur requires time-series data on local population abundances over the entire distribution range of a population, and few datasets of this nature exist. However, review of the literature and analysis using Atlantic salmon as a study animal indicates that Type 2 habitat expansion is probably more common. Use of secondary habitat is thought to lead to greater straying and gene flow among populations (Talbot and Myers, in review).

Age-specific mortality rates and restoration alternatives

I show a contour plot of egg-smolt with smolt-adult mortality rates resulting from a Chinook cohort model developed by CRITFC (Figure 1). The cohort model uses the actual age-specific sex ratios, age-specific ocean maturation rate, age composition and age-specific life history parameters. I plotted the egg-smolt survival rate against return rate under a series of variable environmental conditions. The figure indicates that with maximum expected egg-smolt

survival in nature (perhaps as high as 20%), smolt-adult survival must be higher than 0.8-0.9% to reach replacement. Many areas in the Columbia River Basin have smolt-adult survival substantially lower than that, so that even under the best river conditions, recovery is not possible. Simple habitat improvements will also not be sufficient, and migration corridor, estuary and ocean mortalities are likely to remain high for the foreseeable future. Under normal habitat conditions (2-5% egg-smolt survival), smolt-adult survival has to reach 3% for replacement. Typically, fall Chinook in the Snake R. have a 0.2-0.3% smolt-adult survival rate, substantially below replacement. With typical survival values observed, it is thought that supplementation is the primary options for areas such as the Mid-Columbia and the Snake R., whereas aggressive habitat and passage solutions may be more effective in the lower Columbia River Basin.

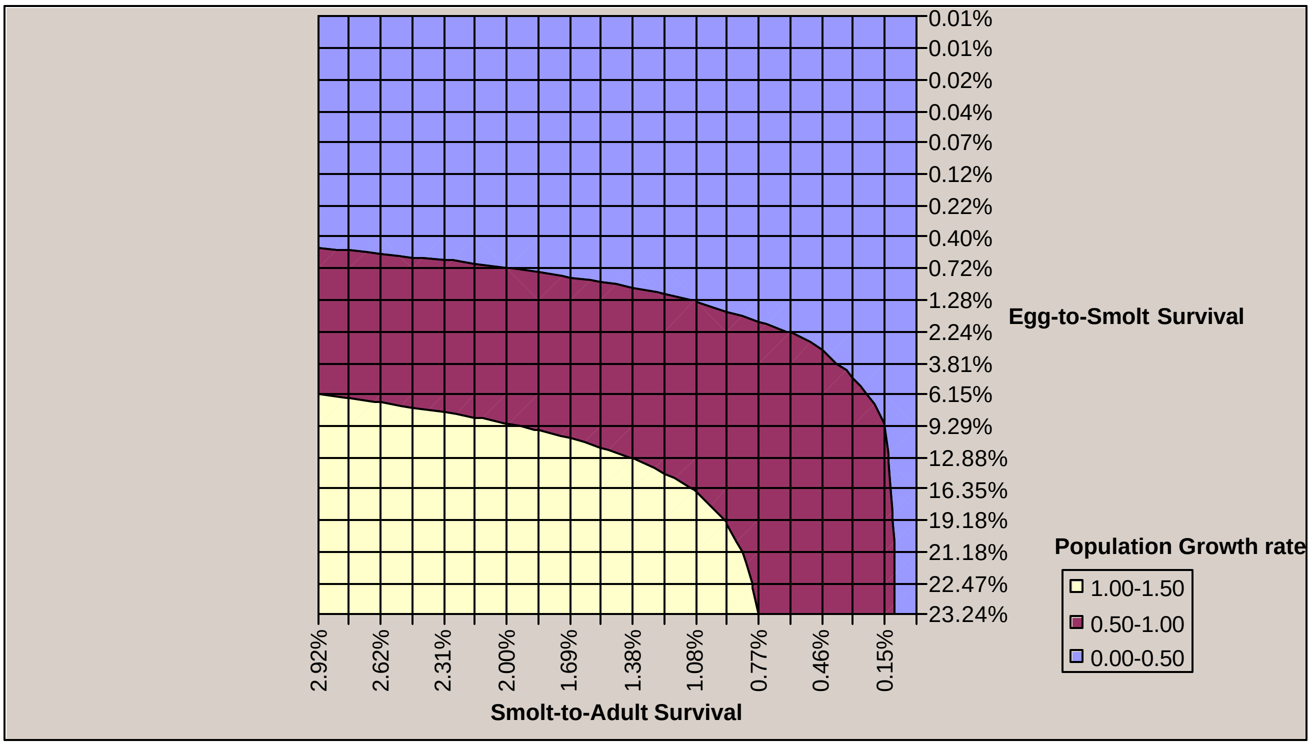

Figure 1. Age-specific survival rates.

Case Histories

In the second plenary session, biologists presented a series of supplementation case histories. Each of these case histories was intended to answer the following questions: 1) What was/is the objective of the supplementation? 2) How was performance of the supplementation measured? and 3) What was the actual outcome of the supplementation?

Oregon/Washington Experiences With Some Older Studies.

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Abstract

In the 123 years that salmon and steelhead have been produced at hatcheries, the effectiveness of hatchery fish in rebuilding depressed wild populations and the reproductive differences between hatchery and wild fish have rarely been examined. Three older examples (pre-1990) that represent an exception to this pattern were discussed. In the first two examples, the supplementation objective was experimental. Specifically, these studies were designed to determine if wild and hatchery fish transferred characteristics to their offspring that effected their subsequent survival and growth. In the third example, the supplementation objective was to rebuild depressed populations of wild fish.

The first study was conducted on hatchery and wild steelhead from the Deschutes River in Oregon (Reisenbichler and McIntyre, 1977). These authors found that offspring of hatchery fish survived poorer in the wild environment and offspring from wild fish survived poorer in the hatchery environment. The comparisons were made for the first year of life. The hatchery stock had been initiated from the wild population only 2 generations previously.

The second study discussed was a project carried out on the Kalama River in Washington for both summer and winter steelhead. A genetic mark, selectively bred into all hatchery fish was used to estimate the proportion of naturally produced offspring that had hatchery parents. In all cases the proportion of naturally produced steelhead having hatchery parents was considerably less than the proportion of hatchery fish in the parental spawning population. Therefore, hatchery fish spawning in the wild had less reproductive success than did wild fish. This difference was substantial. For summer steelhead, naturally produced fish having hatchery parents survived only 16% of the survival rate for naturally produced fish having wild parents. For winter steelhead, fish with hatchery parents survived only 8% of what was observed for those with wild parents. The differences in relative survival developed in both the freshwater and marine environments. Therefore, smolt to adult survival of naturally produced hatchery offspring was considerably less than for wild offspring. One implication of this observation is that assessing the success of supplementation programs only within the freshwater portion of the life history is not adequate. The potential for considerable differential survival between offspring of hatchery and wild fish occurs in the marine environment.

The third case history was a less rigorous, postmortem evaluation of a supplementation program implemented for lower Columbia coho. Beginning in the early 1970's, depressed populations of coho in tributaries of the Columbia downstream of the Willamette River were stocked with a total of 17 million presmolts and 10,000 adults. Evaluation of spawner density data did not demonstrate any positive effect of these releases. Most of these populations appeared to go extinct in the late 1980's. The hatchery supplementation program may have had a neutral effect on this outcome or it may have contributed to the extirpation of these populations.

These studies demonstrate that: 1) reproductive differences between naturally spawning hatchery and wild fish can exist, 2) these differences can be very large, and 3) supplementation programs that ignore the potential for such differences will likely fail.

Umatilla River and Lookingglass Creek Programs

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IMST Note: Mr. James introduced this topic, then the following two papers were presented as part of this topic.

Umatilla Basin Steelhead Enhancement and Spring Chinook Reintroduction

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Abstract

Once abundant Umatilla spring chinook were extirpated in the early 1900s through the development of irrigation diversions that blocked passage and degraded and/or dewatered the river. Endemic steelhead populations were also reduced from historic levels. A comprehensive salmonid restoration program was planned in the 1980s with most of the actions beginning in the 1990s. The restoration and supplementation program included habitat restoration, fish passage facility improvement, flow augmentation, monitoring and evaluation, genetic conservation, artificial production and harvest management. Artificial production programs included the supplementation of endemic steelhead and the restoration of spring chinook, fall chinook and coho salmon.

Steelhead supplementation goals were to 1. Fully seed the existing and expanded habitat (created by habitat restoration projects), 2. Provide sustainable Tribal and non-Tribal harvest opportunities, 3. Return 4000 natural and 5,670 hatchery adult steelhead to the Umatilla River, and 4. Maintain the genetic character of the endemic stock. Initial adult return goals were developed in the 1980s but are being modified to reflect knowledge acquired from hatchery and natural production Monitoring & Evaluation

(M&E) projects. Steelhead supplementation methods include producing and releasing 150,000 steelhead smolts of endemic stock from naturally produced adults, acclimating smolts in natural production areas, and implementing intensive disease monitoring and prevention programs. Genetic conservation methods include: 1) using naturally produced endemic steelhead for broodstock, 2) using hatchery reared adults of endemic stock only for backup, 3) using matrix spawning techniques, and 4) monitoring genetic characteristics of the population (microsatellite and mitochondrial DNA). Harvest management methods include monitoring and regulating Indian and non-Indian fisheries as well as restricting the harvest of naturally produced adults and juveniles.

Steelhead supplementation performance measures include adult counts at Three Mile Falls Dam (TMD), spawning ground surveys (redds/mile), natural parr surveys (index site trend data) and harvest monitoring. The ladder and fish handling facilities at TMD were improved for adult passage, broodstock collection and for monitoring juvenile outmigration, adult returns, sex composition, age composition and run timing. Steelhead hatchery smolt to adult returns (SAR) averaged 0.48%. Original SAR return goals (2.7%) for steelhead were based on observations during the 1980s.

The results of the steelhead supplementation efforts include an average return of 716 hatchery and 1255 natural adult steelhead (1991-2000). Parent progeny ratios averaged 1:6.07 for hatchery adults and 1:0.73 for natural adults with a combined ratio of 1:1.08 (spawners 1988-1997 and returning adults 1991-2000). Natural adult steelhead returns in the Umatilla River were no worse than John Day and Walla Walla trends which also showed a decline in the mid 1990s with increases in 1999 and 2000. The Umatilla total run with both hatchery and natural steelhead combined was uniquely positive in comparison to steelhead returns in adjacent basins (1988-2000).

The redds/mile per adult female spawner in index areas ranged from 0.0022 to 0.0093 (1988 – 1999) with a general increase from 0.0037 in 1994 to 0.0093 in 1999. The ratio of hatchery to naturally reared endemic stock female spawners in natural habitat increased from 0.079 in 1988 to 0.53 in 1999 with a high of 0.93 in 1997. There were more redds/mile per adult female spawner when the ratio of hatchery to natural female spawners was higher. Hatchery reared adults were observed on redds in the natural spawning areas. The percent males of natural adults averaged 28% and ranged from 26 to 30%. The percent males of hatchery reared adults averaged 41% and ranged from 27 to 50%. The percentage of fish spending one year in the ocean was similar between natural adults (36 to 65%, mean of 47%) and hatchery reared adults (32 to 78%, mean 52%; 1993-1999). Return timing was highly influenced by flows and somewhat variable from year to year, but return timing was very similar between hatchery and naturally reared adult steelhead.

Juvenile abundance trends observed in index areas followed adult escapement trends. Natural smolts were smaller in size (mean of 180 mm) than hatchery smolts (210 mm). Hatchery and natural smolts had similar outmigration timing. The protocols for collecting and spawning natural adult steelhead were followed to conserve the genetic character of the endemic stock. Genetic samples were collected in 1992 and 1994 to provide baseline data for future comparisons and monitoring of genetic characteristics. The steelhead supplementation program has allowed harvest opportunities for Indian and non-Indian fisheries each year.

In conclusion, hatchery supplementation of endemic Umatilla Basin steelhead has been successful in terms of maintaining adult returns, spawning escapement and harvest.

CTUIR recommends maintaining the program, continuing monitoring and evaluation and adjusting the goals to more realistic return rates based on observations during the last two decades (not on several good return years observed in the 1980s).

Spring Chinook reintroduction goals were to 1. Restore spring chinook to the Umatilla Basin and fully utilize the available chinook habitat. 2. Provide sustainable Tribal and non-Tribal harvest opportunities, 3. Return 1000 natural and 10,000 hatchery adult spring chinook to the Umatilla River, and 4. Maintain the genetic character of the reestablished stock. The return goals are being revised to 2,000 natural and 6,000 hatchery adults.

Spring chinook reintroduction methods included producing and releasing 1.23 million subyearling (age 0+) smolts and 520K yearling (age 1+) smolts, acclimating smolts in natural production areas, and implementing intensive disease monitoring and prevention programs. Smolt production was changed to 810K yearling and will be further modified to 1.2 million yearling smolts as monitoring determined that subyearling releases were unsuccessful. Genetic conservation methods include collecting broodstock from Umatilla River returns, selecting broodstock from a representative cross section of the run, and using matrix spawning techniques. Harvest management methods include monitoring and regulating Indian and non-Indian fisheries.

Spring chinook reintroduction performance measures include adult counts and TMD, spawning observations, redds/mile, egg deposition, parr abundance, and smolt outmigration timing and survival.

The results from the spring chinook reintroduction effort include an average hatchery SAR rate of 0.5% for chinook reared at Bonneville with an average of 1496 hatchery adult returns (1990-2000) and an average of 111 natural adult returns (1996-2000). The natural component of the run ranged from 3.7 to 16% (1996-2000) and is near the original goal of 10% natural adults even though the total number of adults is well below the goal.

Natural spawning of hatchery adults has ranged from 59 to 347 redds (1990-1999) and was directly related to the number of returning adults. Annual egg deposition estimates ranged from 0.2 to 1.3 million (mean of 3900 eggs per female observed in spring chinook returning to the Umatilla River). Survival to spawning averaged 95% in the quality habitat of the North Fork of the Umatilla River (above RM 90) and dropped to 10% in the lower reaches (RM 70) where water temperatures were higher.

Juvenile chinook were observed annually in spawning areas but observed densities have been highly variable because of flooding and variable spawning escapement. Smolt outmigration timing is similar for both hatchery and natural smolts. Hatchery smolts (145 mm) average 45 mm longer than natural smolts (100 mm). The reintroduction program has allowed an Indian and non-Indian harvest opportunity during 7 of the last 11 years with 100 to 1200 adults harvested per year.

In conclusion, the reintroduction of spring chinook salmon in the Umatilla Basin has been successful in terms of adult returns, spawning escapement and harvest. CTUIR recommends increasing the yearling program to 1.2 million yearling smolts, continuing monitoring and evaluation, and adjusting return goals to match observed SAR's and expected fisheries.

Evaluation Of Reestablishing Spring Chinook Salmon Natural Production in Lookingglass Creek, Using A Non-Endemic Hatchery Stock

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Abstract

Hatchery-produced adult Rapid River stock spring chinook salmon that returned to Lookingglass Hatchery was used to evaluate the restoration of natural production in Lookingglass Creek above the hatchery weir. To quantify the success of the restoration effort, we compared life history characteristics of the hatchery adults and their naturally produced progeny with those of the extinct Lookingglass Creek population and other extant natural populations in Columbia River basin tributaries. We released between 99 and 133 adult Rapid River stock spring chinook salmon each year above the Lookingglass Hatchery weir from 1992 to 1994. After completing weekly spawning ground surveys above the weir each year, we estimated the total adult escapement, which included released fish and other fish that escaped above the weir, to be 220 with 49 redds produced in 1992, 297 with 132 redds in 1993, and 121 with 40 redds in 1994. There was no significant difference in mean adult-per-redd estimates among the Rapid River hatchery stock, the extinct Lookingglass Creek natural population, or other natural populations in the Columbia and Snake River basins. The estimated mean juvenile production-per-redd for the 1992 to 1994 cohorts was similar to what was seen for the extinct Lookingglass Creek stock for the 1967 to 1969 cohorts and higher than the mean observed for the Grande Ronde River and Catherine Creek populations for the 1992 to 1994 cohorts. We PIT-tagged about 1,000 juvenile spring chinook salmon within the Lookingglass Creek production areas from the 1992 to 1994 cohorts to determine arrival timing and minimum survival rates to Lower Granite Dam. The Oregon Department of Fish and Wildlife also PIT-tagged juveniles from production areas of several Grande Ronde River basin tributary populations during the same time period. The arrival timing at Lower Granite Dam of juvenile spring chinook salmon from Lookingglass Creek was within the range seen for the other Grande Ronde River spring chinook salmon populations. The arrival timing for Lookingglass Creek was most similar to the Wenaha, Minam, and Lostine River populations. These populations, including Lookingglass Creek, have production areas that are closer to Lower Granite Dam than the upper Grande Ronde River and Catherine Creek populations. The naturally produced progeny from Lookingglass Creek had a similar mean minimum survival rate to Lower Granite Dam compared to that of other Grande Ronde Basin natural populations. The mean parent-per-progeny ratio for the Rapid River stock spring chinook salmon released from 1992 to 1994 above the weir on Lookingglass Creek, was similar to the ratios seen for other Grande Ronde River tributaries for the same years.

Canadian Supplementation & Captive Broodstock Programs

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B.C.'s living gene bank (LGB) steelhead trout (*Oncorhynchus mykiss*) re-building initiative may be successful in re-juvenating or maintaining steelhead populations if ocean conditions for steelhead improve or get no worse. It may fail if conditions worsen and few LGB releases survive, or if the returns seriously disrupt population genetic structure and further decrease fitness in an otherwise seriously compromised population. Steelhead populations have declined to dangerously low levels below recruitment replacement over the past decade in the index river, the Keogh River, and in their southern B.C. distribution (East Coast Vancouver Island and Lower Mainland streams) based on relative indices of abundance over the Province. A plan is proposed to assess LGB using an experimental approach with replication to assess the numerical, biological, and genetic response in treated (3) and control (3) streams. This initiative and assessment, part of several methods of rehabilitation in recovery plans for the Georgia Basin, will be a major undertaking involving a decade of research. An adaptive approach is required, including several probing investigations early in the project, development of a steelhead supplementation model, and statistical procedures for testing for differences in response. Smolts (100 per LGB stream) were collected beginning 1998, and survivals in the hatchery have averaged 70%. Wild smolt collection will continue for one generation (5 years) only. Genetic representation of Keogh River LGB smolts collected in 1998 was not statistically different from wild in allelic frequency comparisons of archived samples from scales. The DNA fingerprints were also used to guide the matings to avoid sibling or half-sibling crosses. Pedigrees will be followed as the project unfolds through smolt release, adult return, and as the LGB returns subsequently integrate into the wild population. The first LGB smolts will be released in 2001.

Chinook Salmon Supplementation in the Imnaha River Basin

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Abstract

The Imnaha River Basin historically supported a healthy run of chinook salmon that contributed to commercial, recreational, and tribal fisheries. The Imnaha chinook population declined precipitously from escapement levels of over 5,000 in the late 1950s to less than 500 fish in the late 1970s. Much of the decline was attributed to construction and operation of four Lower Snake River dams. The Lower Snake River Compensation Plan was implemented to

mitigate for annual losses of 3,210 adults. The Imnaha chinook hatchery program was initiated in 1982 to restore and maintain natural spawning populations with an objective to operate the hatchery program so that genetic and life history characteristics of hatchery fish mimic those of wild fish. A temporary adult collection and juvenile acclimation facility was operated from 1982-1988 and a permanent facility was constructed in 1989.

Broodstock collection began in 1982 and wild fish comprised a majority of the broodstock until 1989 when a significant number of hatchery fish began to return to the basin. The percentage of wild fish captured that were retained for broodstock varied considerably from a low of 17% in 1993 to 100% during the first three years of collection. During the early years of trapping, the weir was installed late in the migration and only late returning fish were retained for broodstock. Smolt production levels have varied from approximately 25,000-450,000 annually. Smolt-to-adult survival rates have generally been poor ranging from 0.05 to 0.58%.

In our evaluation of the program we have found that:

1. High prespawning mortality and egg loss influenced effectiveness significantly during early years of operation.
2. Poor smolt-to-adult survival for most broodyears has limited success.
3. We have observed differences in run-timing and age structure between hatchery and natural fish. Hatchery fish return a higher proportion of age 3 males and fewer age 5 fish. The run timing of hatchery fish has been later than natural fish in some years.
4. We have not seen significant differences in genetic characteristics between natural and hatchery fish.
5. Progeny-to-parent ratios for natural spawning fish have been consistently below replacement since the 1983 broodyear, while hatchery fish ratios have been well above replacement for most years.
6. We have not seen a consistent increase in the number of naturally produced fish that return to the basin. Modeling results indicate that the combined total population of natural and hatchery fish and the number of natural spawners (combined natural and hatchery) is greater than the natural population would be had we not initiated the hatchery program.

The hatchery program has undergone a number of changes as a result of utilizing an adaptive management framework. Changes that have reduced the risk to the natural population and shifted program emphasis from mitigation to conservation have been made in the production levels, management objective priorities, broodstock management, natural escapement management, and rearing and release strategies. We have developed a sliding scale broodstock management framework that attempts to balance demographic risks associated with low numbers of natural spawners with genetic risks associated with the hatchery program. The percentage of fish retained for broodstock, percentage of hatchery fish released above the weir to spawn naturally, and the minimum percentage of broodstock that are natural origin is adjusted based on the escapement level (Table 1). This sliding scale management plan will serve as the guiding framework for Imnaha chinook salmon hatchery management. If hydro system survival improvements are not achieved, natural productivity will remain low and we will be unable to meet any long-term conservation management objectives.

Table 1. Sliding scale management framework for use of the hatchery program in the management and recovery of Imnaha River spring chinook salmon.

Escapement Level	Maximum % retained for broodstock Natural	Hatchery	% Hatchery above weir	Minimum % broodstock of natural origin
<50	0	0	*a*	NA
51 – 700	50	50	*a*	*a*
701 – 1000	40	*a*	70	20
1001 - 1400	40	*a*	60	25
> 1,400	30	*a*	50	30

a   A result of implementing other criteria

Adapting From Mitigation to Conservation: A Case History of the Grande Ronde Spring Chinook Hatchery Program

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Abstract

Grande Ronde basin spring chinook salmon populations declined precipitously following closure of Lower Granite Dam, the fourth Lower Snake River dam. Recreational and commercial fisheries targeting these Snake River stocks have been closed for many years. The Lower Snake River Compensation Plan (LSRCP) was initiated in Oregon in the late 1970s, and annual smolt and adult mitigation goals were established. Management objectives to restore fisheries, to restore and maintain natural populations, and to maintain endemic wild populations of spring chinook salmon in the Minam and Wenaha rivers were adopted to guide program implementation. These objectives provided primary direction for the first ten years of program operation. Lookingglass Hatchery serves as the primary production facility for the Grande Ronde chinook program.

When initial broodstock development programs were considered in the late 1970s, it was thought that there were too few wild fish available to develop adequate broodstock in a short enough timeframe. Therefore, hatchery stocks (Rapid River and Carson) were imported from outside the basin. Rapid River was used predominately since the mid-1980s. Annual smolt releases up to 900,000 occurred throughout the 1980s and 1990s. In addition, adults, smolts, and pre-smolts were outplanted into Catherine Creek and the upper Grande Ronde River to supplement natural production. Smolt-to-adult survival rates have been highly variable and the

only release strategy that has proven successful is yearling smolts. We monitored the proportion of natural spawners that were hatchery strays in the Wenaha, Minam, and Lostine rivers. Based on origin of carcasses recovered on spawning ground surveys, we determined that a high proportion (90% in some years) of natural spawners in the unsupplemented rivers were hatchery strays.

In the early 1990s two major policy rulings influenced the direction of this hatchery program. Oregon Department of Fish and Wildlife (ODFW) adopted a Wild Fish Management Policy and the National Marine Fisheries Service (NMFS) listed Grande Ronde spring chinook as threatened. It was clear that we could no longer continue the program as in the past. The program was operating well outside Wild Fish Management Policy guidelines and was inconsistent with sound conservation principles. Three genetic and biological questions needed resolution to decide the future role of hatcheries in Grande Ronde basin chinook management:

- What is the demographic status and near-term risk of extinction of chinook populations in the basin?
- What genetic effects had resulted from prior outplanting and straying of non-endemic hatchery stocks?
- Did there remain any genetic differentiation between natural and hatchery populations and between natural populations?

Escapement levels had declined rapidly throughout the Grande Ronde basin, reaching all-time lows from 1994-1996. Spawning escapement was below 50 in Catherine Creek, Lostine River and upper Grande Ronde River populations in 1994 or 1995. Genetic analysis conducted by NMFS indicated that there remained significant genetic differentiation between natural populations and between the hatchery population and natural populations. However, there were years when some natural populations were similar to the hatchery population. Given the demographic status and genetic information, we reached the following conclusions regarding the management and science questions:

- Prior supplementation efforts with non-local hatchery stocks had failed as indicated by the continued decline of supplemented populations, poor progeny-to-parent ratios in years when hatchery fish comprised a high proportion of natural spawners in supplemented streams, and low natural escapements in supplemental streams.
- Risk of extinction is high based on escapement trends, abundance of spawners, and low progeny-to-parent ratios of natural populations.
- Significant genetic differentiation remained in the basin.
- Hatchery programs using endemic broodstock should be initiated immediately in Catherine Creek, upper Grande Ronde and Lostine rivers.
- Given the uncertainties associated with use of artificial propagation to enhance natural production, we should use a diversified approach and maintain the Minam and Wenaha river basins as wild fish management areas.

We have implemented a number of management actions in direct response to our conclusions. First, in 1995, we initiated a captive broodstock program with collection of parr from Catherine Creek, upper Grande Ronde and Lostine rivers. Smolts produced from captively reared adults were released in parent streams in 2000. In 1997, we began collection of adults in these same rivers. We have had limited success with this adult collection approach due to low abundance of adults. Co-managers completed construction of adult collection and juvenile acclimation facilities on Catherine Creek, upper Grande Ronde and Lostine rivers. The conventional supplementation programs will be implemented using a sliding scale framework. This management framework is premised on the theory that at low population levels the greatest risk to population persistence is demographic. Therefore, at low population levels we place fewer genetic risk constraints on the hatchery program in an attempt to boost population levels quickly, using the survival advantage provided by the hatchery. As population levels increase above threshold, the demographic risks are of less concern and more constraints are placed on the hatchery program to control genetic risks associated with artificial propagation (domestication selection, non-intentional directional selection, Ryman and Laikre effect). The sliding scale guides the allocation of natural and hatchery fish to broodstock, natural production, and harvest.

If we cannot improve mainstem passage survival and increase natural productivity so that progeny-to-parent ratios consistently equal or exceed 1.0, recovery will never occur.

Anadromous Salmonid Supplementation and Conservation Programs in Idaho

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Abstract

The Idaho Department of Fish and Game's (IDFG) long-term objective for salmon and steelhead management is to maintain Snake River populations at levels that will provide sustainable harvest while meeting natural spawning escapement objectives, preserving genetic resources of natural populations, and utilizing available natural habitat. (IDFG 1992 and 1996). Attainment of this objective has been impacted by the severe decline in abundance of naturally produced fish over the past forty years. The decline has been so great that, pursuant to the Endangered Species Act, Snake River sockeye salmon were listed as endangered in 1991, Snake River spring/summer and fall chinook salmon were listed as threatened in 1992, and Snake River steelhead were listed as threatened in 1997.

The IDFG initiated restoration and conservation programs in response to the status of natural salmon and steelhead populations. These programs include chinook salmon and steelhead supplementation, sockeye salmon captive brood stock, and chinook salmon captive rearing. The sockeye salmon captive brood stock program was initiated as an emergency conservation program to prevent extinction of the population. The other programs were initiated primarily as research programs, to resolve critical uncertainties surrounding the use of supplementation and conservation hatchery strategies to meet specific management objectives. In addition to the strong research component in each of these programs, they concurrently address population restoration and conservation objectives.

Idaho Supplementation Studies (ISS) is a large-scale chinook salmon supplementation evaluation being conducted in Idaho. The study is based on the RASP (1992) definition of supplementation: "…the attempt to use artificial propagation to maintain or increase natural production while maintaining the long-term fitness of the target population, and while keeping the ecological and genetic impacts on nontarget populations within specified biological limits." It

is a cooperative study that incorporates most of the anadromous chinook salmon production habitat in the state. The IDFG is the lead cooperator; other cooperators in the evaluation include the Nez Perce Tribe, Shoshone-Bannock Tribes, U.S. Fish and Wildlife Service, and Idaho Cooperative Fish and Wildlife Research Unit. The ISS was initiated in 1992 following completion of the study design (Bowles and Leitzinger 1991). The study design identified 20 treatment and 11 control streams in the Salmon River and Clearwater River basins.

The objectives and hypotheses of ISS can be condensed into two questions; "Can supplementation work?" and "What supplementation strategies work best?" The study focuses on measuring population responses to supplementation, identifying critical life history intervals where supplementation effects are evident, and determining the mechanisms and specific impacts of supplementation on these critical life history intervals. Important components of this study are the development of a supplementation brood stock (for certain treatment sites) that includes natural origin fish, application of treatments for at least one generation, followed by at least one generation of post-treatment monitoring.

Brood years 1991-1995 releases (treatments) were approximately 3.2 million juvenile chinook salmon (Walters et al. in process). Adult returns from these releases were (and will be) used to supplement the natural spawning populations and a portion is used to maintain the supplementation brood stock. It is too early in the study to determine if supplementation has increased natural production and what effects it may have had on natural productivity. Preliminary analyses indicate that prior supplementation activities (not performed under ISS or not utilizing a specific supplementation brood stock) likely did not increase the number of natural origin recruits returning to spawn. However, it is possible that these earlier supplementation efforts may have prevented further declines of some populations. The real test of supplementation (under ISS) will occur over the next five to seven years as the number of natural origin recruits is measured in supplemented and control streams.

Increasing natural production through supplementation can only be realized if natural production is limited by low adult escapement and the mortality factor that caused the population to decline is removed. Without improvement in smolt to adult survival, salmon and steelhead populations in Idaho are expected to further decline. For populations facing an imminent risk of extinction, the IDFG initiated a captive rearing program to maintain metapopulation structure (Hassemer et al. 1999). Captive rearing is a short-term approach to species or population preservation. The strategy of captive rearing is to prevent cohort collapse of the target population by providing captive-reared adult spawners to the natural environment and maintain the continuum of generation to generation natural smolt production. This strategy differs from more conventional captive brood stock programs in that sexually mature adults are not spawned in captivity to produce progeny for release. Although this program targets stocks at high risk of extinction, its primary motivation was to develop the technology for captive culture of chinook salmon and to monitor and evaluate captive-reared fish during both the rearing and post-release/spawning phase. Results from this program are intended to facilitate the development of future conservation programs.

The captive rearing program was started with the collection of brood year 1994 progeny from three river systems in Idaho; approximately 200 juveniles were collected from each system. After fish pass through the smolt phase, some are reared to sexual maturity in freshwater and the remainder is reared in saltwater. Maturation of the brood year 1994 cohort was completed in 1999; and the brood year 1995 cohort will complete maturation in 2000. Sexually mature male and female adults were outplanted in 1998 and 1999 to evaluate spawning behaviors and spawning success. Preliminary results have been both encouraging and discouraging. While we have successfully reared the fish to sexual maturity in captivity, the fish have not achieved age-specific size targets. Gamete quality evaluations conducted using in-hatchery spawning revealed substantial among female variation in survival to the eyed egg stage. The mature adults released to spawn naturally exhibit a range of normal spawning behaviors. However, time of spawning appears to be later than that of their cohorts that matured through a 'natural' life cycle.

The supplementation and captive rearing programs conducted by the IDFG are considered experimental at this time. They were designed to address specific and different management objectives, either population rebuilding or population conservation. The desired management outcome for any intervention strategy should be clearly defined prior to implementing the strategy; allowing for the selection of the appropriate strategy to achieve the outcome.

CHIP Presentation

The third plenary session focused on the Conservation Hatchery Improvement Proposal (CHIP). It was in the evening and was organized and conducted by ODFW and the Coastal Salmon Restoration and Production Task Force.

Conservation Hatchery Improvement Program

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Abstract

This proposal calls for ODFW to research, develop, and implement conservation strategies for the recovery and supplementation of wild salmon populations using innovative hatchery programs on a pilot project/research scale. A variety of capabilities would be tested developed at a limited number of locations and/or facilities to serve conservation and research purposes for populations along the Oregon coast and in the lower Columbia Basin. Programs would involve expanding existing facilities with additional rearing and acclimation structures to increase capacity to accommodate a diversity of stocks and life history types. Features would include new and existing structures that would be designed to more closely emulate natural rearing conditions. Weirs or traps would be constructed to collect broodstock , separate returning hatchery and wild adults, and allow for evaluation of supplementation projects. Staff would be dedicated to conduct research, and monitor and evaluate programs, including activities such as disease screening, genetics profiling, spawning ground surveys, creel census, juvenile/outmigrant sampling, and broodstock collection/adult sorting.

Developing these facilities and conducting the research, monitoring and evaluation, will provide ODFW with the needed information to better protect, recover and enhance wild fish populations which is critical to achieving the goals of the Oregon Plan and the ESA. If the pilot projects are successful, these types of programs will greatly enhance the capability to supplement critically depressed fish populations in a scientifically defensible manner. The programs will also allow ODFW to assess the potential impacts of hatchery fish on wild populations, develop techniques to minimize undesirable interactions, and provide the information necessary to improve the fitness and survival of hatchery fish, which will in turn increase the benefits of hatchery programs.

One example of a CHIP project proposal includes reintroduction of lower Columbia chum derived from Grays River (Washington) wild stock and incubated at Klaskanine Hatchery. Appropriate locations in Oregon tributaries would be identified using habitat surveys. Fry releases or chum egg boxes would then be located where returning adults would likely spawn successfully. All hatchery origin fish would be otolith marked for subsequent identification. Control or reference streams would be identified for comparison with supplemented streams. Outplants would be continued through one brood cycle. Monitoring elements would include

juvenile seining to assess initial survival and spawner surveys to identify relative production of hatchery and natural origin recruits.

Another example is installation of an adult trap for Nonpareil Dam on Calapooya Creek , which would allow collection of genetic samples for monitoring hatchery-wild interaction of an existing program that is releasing hatchery coho fry above the dam site. Microsatellite DNA samples would be collected from each returning adult for 3-4 generations to establish a genetic pedigree of the spawning population. The relative contribution of hatchery and wild spawners to subsequent recruits could then be evaluated. The results of the evaluation would provide an assessment of the effectiveness of supplementation strategies and risk of genetic introgression in wild populations. A juvenile trap at the dam site would provide life-cycle information and the relative contribution of hatchery and wild spawners to the smolt production.

A final example is for Fall Creek Hatchery to be modified to allow experimental rearing strategies including "Natures Way" conditions. The purpose of the project would be to evaluate the potential benefits of rearing under conventional, low density, and Natures Way conditions. There are 10 raceways available which would allow a variety of treatment and control scenarios to be evaluated.

Concurrent Work Groups

Workshop participants were assigned to one of three groups and each work group had a specific question to address. The questions were:

1. Under what conditions should supplementation be used in the recovery of depleted stocks of wild salmonids? (Group 1)
2. What are the appropriate methods/strategies? (Group 2)
3. How should the effect of supplementation be evaluated over time? (Group 3)

In addressing the assigned question, each work group was also asked to consider the following two additional questions: 1) Are hatchery and wild salmonids different in ways that are important to the design and implementation of supplementation projects? 2) What are the effects of hatchery management and hatchery fish on wild salmonids? However, these two questions did not get significant attention, as reflected in the workshop response to additional questions.

Each group discussed the questions in depth, compiled a set of scientific evidence for that position, and prioritized the elements of their answer before presenting a report in the final plenary session described below.

Under what conditions should supplementation be used in the recovery of wild salmonids? (Work Group 1)

Work Group Participants: Tom Nickelson (group leader), John Buckhouse, André Talbot, Bruce Ward, Rich Carmichael, Kay Brown, Jim Hall, Robin Waples, Jim Lannan, Logan Norris, Gary James

Introduction

The work group first defined the terms "recovery" and "supplementation." They developed a decision tree for identifying situations when supplementation could be considered. Several key questions in the decision tree lead a user through important factors to address before supplementation is considered. A number of important conditions and information needs were identified to address each of the key questions. Once a decision has been made to consider supplementation, a risk/benefit analysis of the specific proposal must be done before implementing a supplementation program. Each of these components is discussed in more detail in the following sections.

Definitions of Recovery and Supplementation

Work Group 1 developed working definitions of recovery and supplementation for use in their discussion[2]. Recovery was defined as "the process of moving a population of salmonids from a depressed condition to a condition where the population is self-sustaining, has a low probability of extinction, and is capable of providing desired social and cultural benefits." The work group adopted the definition of supplementation developed by the Regional Assessment of

[2] The Independent Multidisciplinary Science Team conducted a workshop where the definition of recovery was a key point of focus, IMST Technical Report 1999-2.

Supplementation Project: “Supplementation is the attempt to use artificial propagation to maintain or increase natural production while maintaining the long-term fitness of the target population, and while keeping the ecological and genetic impacts on target populations within specified biological limits.” (RASP 1992).

The work group acknowledged that one goal of the Oregon Plan is harvestable numbers of fish, and therefore they included a goal of providing social and cultural benefits in their working definition of recovery. However, specific social and cultural benefits were not defined.

Other terminology related to supplementation of salmonid populations was briefly discussed (rebuilding, reintroduction, persistence and maintenance). Work group members suggested that reintroduction into habitats where there are presently no fish may be part of a recovery strategy (Withler 1982), especially when considering recovery over larger spatial scales where metapopulation connectivity is important and desired. Rebuilding populations, and persistence and maintenance of populations, were not discussed further.

The Decision Tree

The work group quickly adopted a decision tree approach for identifying the conditions under which supplementation could be considered as a recovery strategy. Work group participants recognized that while the decision tree approach suggested here is in a “yes-no” framework, some questions and concerns may not have clear-cut, yes or no answers or fit neatly into a decision tree approach. Therefore, it is important to evaluate supplementation proposals on a case-by-case basis in order to take specific circumstances and conditions into account. Once a decision has been made to consider supplementation, a risk benefit analysis should be done before implementing a supplementation program.

The work group decided that the status of the population was the most important factor when considering supplementation, and was the first item considered in the decision tree (Figure 2). Five population statuses were identified.

Population Status

1. No existing population. There are no fish present and a population has not been present for at least one generation.
2. Existing population is depressed, has low probability of becoming self-sustaining, and has unacceptable probability of extinction under present conditions.
3. Existing metapopulation is depressed and lacks genetic and demographic connectivity (dynamic processes that lead to healthy metapopulations are lacking).
4. Existing population (or metapopulation) is not meeting goals or is not capable of providing desired social and cultural benefits, but habitat conditions suggest that the population should be capable of meeting goals or providing benefits.
5. Existing population is not depressed and is meeting goals or providing identified social and cultural benefits.

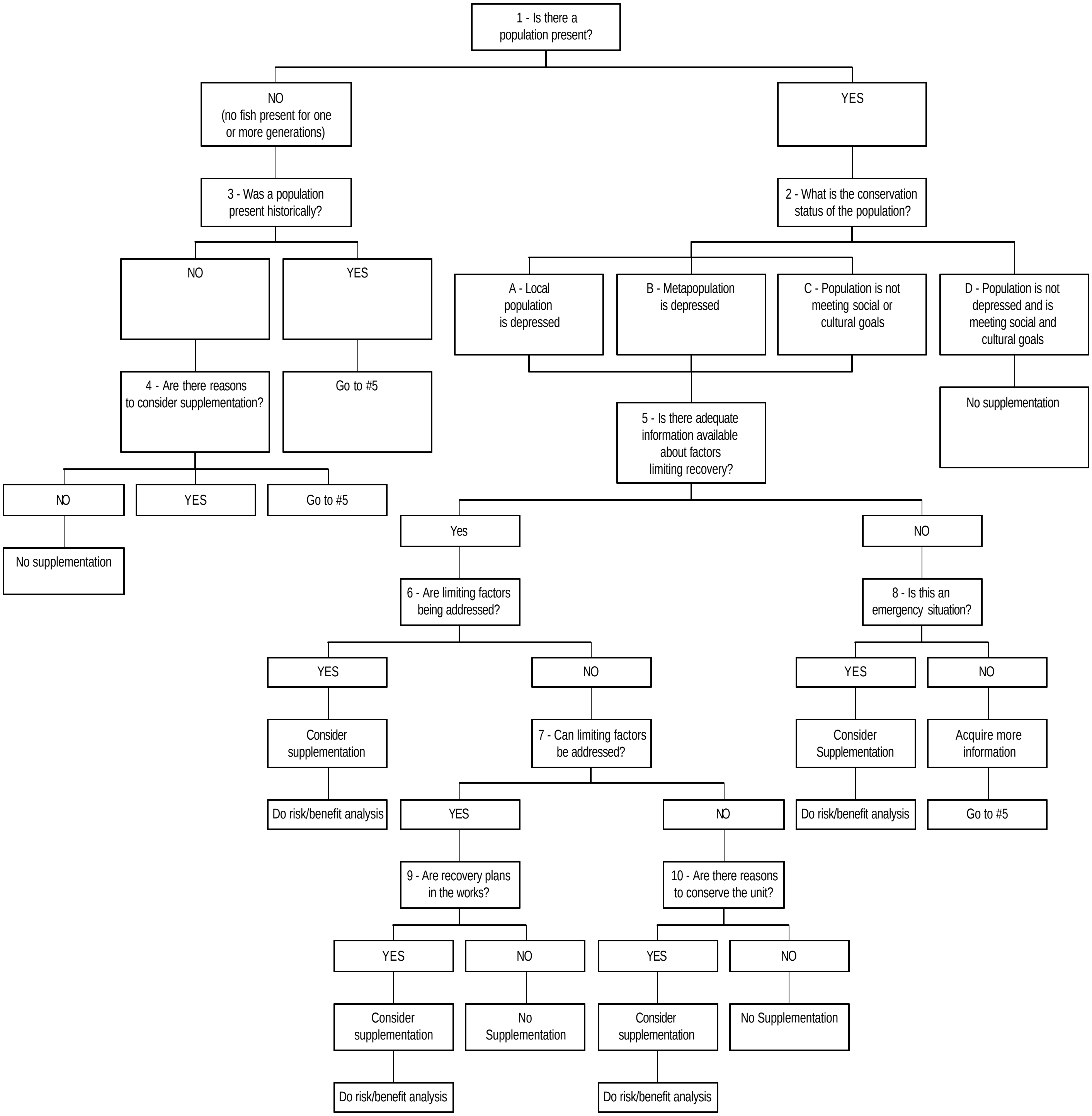

Figure 2. Decision tree to use to identity the conditions under which supplementation could be considered. André Talbot shared a decision tree (Appendix 3) that stimulated the development of Figure 2.

Decision Points: Key Questions and Information Needed

Key questions were developed for use in the decision tree. Each of these key questions is a decision point in the decision tree. At each decision point, specific information is needed (listed below) about habitat or population conditions to address the key question. The information needed is divided into four major categories: habitat, demographics, biodiversity, and integration of information. The key questions and the information needed to answer each question are in the box below.

Key Questions	Information Needed
1. Is there a population present?	Demographics 1a
2. What is the conservation status of the population? (see population status section above).	All
3. Was a population present historically?	Demographics 1a
4. Are there reasons to consider supplementation?	Habitat 2; Demographics 3, 4; Biodiversity 3; Integration 1, 2
5. Is there adequate information available about factors limiting recovery?	All
6. Are limiting factors being addressed?	Integration 2
7. Can limiting factors be addressed?	Integration 2
8. Is this an emergency situation?	Demographics 1a, 1b, 1c, 2a, 2b; Biodiversity 1, 2, 3
9. Are recovery plans in the works?	Habitat 2, 3, 4; Demographics 1a, 1b, 1c
10. Are there reasons to conserve the unit?	Habitat 2; Demographics 3, 4; Biodiversity 1, 2, 3; Integration 1, 2

Information Needed

Habitat

1. Ocean productivity.
2. Quality and quantity of habitat by life-stage (capacity).
3. Temporal and spatial scale of variability.
4. Biogeographic distribution.

Demographics

1. Abundance.
    a. Life-stage specific abundance; consider both temporal and spatial dimensions.
    b. Rate of population decline and trends in population numbers.
    c. Status relative to habitat capacity.
2. Productivity.
    a. Recruits per spawner relationship (adult-to-adult, temporal scale, and trends) (Johnson et al. 2000).
    b. Life-stage specific productivity rates (e.g., adult-to-smolt, smolt-to-adult, and others). There is a need to partition productivity by life-stage in order to identify where the productivity problem resides.

3. Relationship to other populations. Examine environmental factors, abundance and productivity relationships among conservation units. Consider population distribution (geographic, environmental and demographic) and utilize a core population concept.
4. Connectivity of populations and the amount of demographic exchange.

Biodiversity (within and between conservation units).

1. Life history (e.g., run timing, juvenile pathways, age structure, repeat spawners). Life histories can be genetically based, but it is important to understand the relative importance of both genetics and environment in shaping life history traits.
2. Genetic structure and uniqueness. Consider how genetic variation and diversity is organized within and between populations, the effective population size, and gene flow (connectivity).
3. Ecological role or unique environments.

Integration of Information

1. Extinction risk analysis (e.g., minimum viable population analysis and others). This was identified as the most important information to evaluate.
2. Limiting factors analysis.

Risk/Potential Benefit Analysis

Once a decision is made to consider supplementation in a specific situation, a risk/benefit analysis should be conducted. The risk/benefit analysis is the final step taken before supplementation is implemented. It was suggested by work group members that there are several approaches to risk/benefit analysis that can be used (Waples unpublished, Pearsons and Hopley 1999, Ford and Currens 1999, Beasley et al. 1999, Beasley et al. 2000), so specific methods were not discussed. Rather, the work group identified general considerations to be included in a risk/benefit analysis.

The risk/benefit of a supplementation action should be compared with the risk/benefit of no-action or other non-supplementation actions (e.g., habitat enhancement or improvement). All risk/benefit analyses (for supplementation, no-action or other non-supplementation action) should consider current, short-term and long-term risks and benefits. In addition, risks and benefits should be considered for specific life-stages. A supplementation program should then address the specific "at risk" life-stage, while minimizing the risks this may impose on other life-stages.

The work group generally agreed that if there is a high probability that a population might become extinct if no action is taken, then an approach to recovery that included supplementation could be considered, even when the risks are high. In many cases, other recovery actions that do not involve supplementation should be strongly considered before considering supplementation.

Conclusions

Work Group 1 attempted to define the conditions under which supplementation should be used in recovery of depleted salmonid populations. Although the decision tree framework, combined with risk/benefit analysis, is a reasonable approach to decision-making, some questions or situations do not fit neatly into this framework, so specific proposals and situations need to be assessed on a case-by-case basis. In addition, some issues related to risk/benefit analysis need to be addressed such as the specific method to use, how and whether to evaluate risk quantitatively or qualitatively, and how to evaluate risks and benefits objectively. In addition, many methods currently used rely on the creation of lengthy lists of risks and benefits that are used with the idea that if you get more risks on the list than benefits, it will negate any benefits. This is not necessarily the best approach, since an evaluation of risks and benefits involves more than just a sum of each, but rather involves an evaluation of the level of risk that is acceptable, in light of the potential benefits.

The work group emphasized that because of the uncertainty in the outcome of recovery actions a diversity of recovery strategies, in addition to supplementation, should be used in order to "spread the risk" of relying only on supplementation or on only one or two methods. Attempts should be made to minimize uncertainties. A modeling approach can be used to evaluate risks and benefits, the possible effects of uncertainty, and the probabilities of specific outcomes. Finally, monitoring and evaluation are very important in assessing the outcome of any implemented recovery or supplementation strategies.

What are the appropriate methods and strategies? (Work Group 2)

Work Group Participants: Fred Allendorf (group leader), Barry Berejikian, Doug DeHart, Kathryn Kostow, Jim Lichatowich, Mike McLean, Loren Miller, Jennifer Neilsen, Todd Pearsons, Bill Smoker

Introduction

Work Group 2 agreed that there were no specific strategies that would be common to the implementation of any or all supplementation programs, but that methods/strategies would depend on case-specific goals. Strategies are dependent on program goals, and universal strategies are difficult to establish. The group compiled a set of seven basic guiding principles that should be considered when designing a supplementation program. When applying these principles, the context of the program and the circumstances of the other principles should be considered, and specific supplementation strategies should be developed on a case-by-case basis. The members of the work group felt that all of these principles were important and needed to be considered. They did not prioritize the listed principles, but noted that the first two principles should be addressed before the others were considered.

Principle 1: Goals and Context

Many of the strategies that are used for supplementation are context-specific and should be evaluated on a case-by-case basis. Depending on the objectives of the supplementation program and the current population's status, different goals may be established. Supplementation means different things to different people, and hatcheries could have goals that range from supplying fish for harvest to establishing a gene bank. Therefore, before beginning the program, goals must be clearly and unambiguously stated, with examples where possible. Measurable objectives and endpoints for success or lack of success of the program should be established. When possible, these endpoints should be quantitative (or easily measured qualitative goals) so that there is a clear measure of success and a termination point for the program. The termination of the supplementation program must be clearly defined along with the goals. Endpoints could range from recovery under the Endangered Species Act (ESA) to recovery under the Oregon Plan to providing full harvest opportunities.

Principle 2: Define and Understand the Problem

There were several factors that work group members felt should be addressed when defining a problem for supplementation. These factors include identifying limiting factors (including carrying capacity of the system), identifying the critical life stage (where is the current bottleneck?), determining which method of supplementation is likely to achieve the goals (may need to reconsider goals), and considering the big picture to integrate supplementation work with other recovery actions. The design of supplementation programs must include provisions for the correction of the problem (i.e., the production bottleneck). In a system where much of the available habitat is above many dams, supplementation strategies might include the maintenance of the population until the effects of the dams can be mitigated. However, even in that case, recovery programs could integrate supplementation and habitat restoration. Depending on the situation, the effects of dams can be removed, partially removed, or not removed at all.

Principle 3: Minimize Harmful Genetic Effects

Context should be considered when addressing genetic concerns, and a strategy should be clearly defined. Actions may differ if the goal is to create a harvestable population than if the goal is to rebuild numbers of fish in a depleted population. To minimize harmful genetic effects, there are three processes that should be addressed during supplementation. First, genetic drift and loss of genetic variability should be considered, including consideration of the effective population size (N_e) when planning supplementation strategies. Second, the effects of natural selection, including domestication selection and loss of fitness in the wild, should be considered. Finally, gene flow or lack of gene flow within and among populations and its effects should be addressed. Local broodstocks should be used when possible, and efforts should be made to minimize straying in most cases. There are various methods for achieving these genetic goals, some of which are discussed under Principle 4 – Mimic Wild Fish.

Principle 4: Mimic Wild Fish

Members of the work group acknowledged limitations in the ability of hatcheries to produce a truly "wild" fish, and suggested that to create a truly "wild fish", the hatchery would need to be a river. In producing a hatchery fish, we are attempting the difficult task of creating a fish that is "fit" in two different environments (hatchery and natural environment). In the absence of a better model, the group agreed that a model for the production of hatchery fish for supplementation should be wild fish in the basin. The fish that survive, return to the river, and reproduce successfully in the wild are the fish that have attributes that should be mimicked in hatchery fish. Mimicking wild fish is a vehicle to get through life history bottlenecks. Wild attributes may also be important for spawning and mate selection. Although desirable attributes may differ depending on the context (target population), certain attributes such as predator-avoidance, natural coloration, natural-like feeding behavior, size at time of release that is similar to wild fish, wild-like pre-smolt growth rate, and run-timing that coincides with wild fish are desirable. These attributes can best equip fish to survive or spawn in the wild and have minimum impacts on any remaining wild population.

Deciding which wild-fish attributes are desirable to duplicate, how to mimic those attributes, and the consequences of this need to be considered on a case-by-case basis. There are limits to knowing, measuring, and understanding which attributes are important. There is no specific "wild-type" fish but a range of "wild types" that let fish respond to a variable natural environment. Maintaining variability in "wild-type" fish is a key to success. However, it is important to understand that mimicking the desirable attributes that best equip fish to survive and spawn in the wild may not necessarily result in mimicking the genetic variability of wild fish.

The point of any hatchery is to increase fish survival (per capita survival for supplementation); this necessarily changes the selective pressures on the hatchery fish and makes them different than the wild population. Another consideration is that for supplementation to be successful, supplemented fish must reproduce successfully in the wild and their offspring must come back to reproduce. There are trade-offs between mimicking a natural environment in the hatchery and survival. For example, the best survival occurs when steelhead smolts are released from hatcheries as yearlings, however, wild steelhead can exhibit a wide range of natural histories, spending two or more years in fresh water. Mimicking the natural life-history variation in steelhead populations, which produce smolts up to seven years old, would reduce the benefit of the hatchery program. A supplementation hatchery should try to maintain post-release survival and provide the highest pre-release survival possible.

One example, using Oregon Department of Fish and Wildlife data from the Hood River Monitoring Program, showed that one-year-old hatchery steelhead smolts were larger than wild steelhead at the time of smolting and outmigrated through a smaller time window than did wild fish (Kostow et al. In Prep). It is difficult to produce hatchery fish that mimic the complex life histories of steelhead, smolting over three or more years and having larger outmigration windows.

Principle 5: Ecosystem Perspective

The work group felt that all supplementation plans should begin with an ecosystem perspective, including a baseline description of the ecosystem and the determination of whether the ecosystem and the population are appropriate targets for supplementation. The status of the target population may be a result of habitat degradation due to human activity. Carrying capacity and conditions of freshwater, estuarine, and ocean environments should be considered over short and long (e.g., decadal oscillations) temporal scales. Operational designs should consider ecological/ecosystem dynamics whenever possible.

The ecological impacts of supplementation to target populations and other populations of the target species also need to be considered. The ecological impacts of supplementation to non-target populations must also be considered, and these impacts should not exceed limits specified in program goals (these limits are advisable, but rare). These impacts include the effects of competition and predation both within and among species, pathogen transfers to non-target species, and the creation of large predator populations. Supplementation needs to do more than just replace wild fish with hatchery fish, and single-species management approaches often are not successful because they fail to consider how non-target species can affect target species and how target species can affect non-target species of concern. If there are multiple species within a basin for which supplementation is being considered, a decision must be made to supplement all species or restore the habitat (fix the underlying problem).

In taking an entire ecosystem perspective, the benefits to one target species must outweigh the costs (risks) to non-target species and the ecosystem as a whole. Costs can often be measured as deviations from a baseline condition in both population numbers of all species and in environmental conditions, and may or may not be the historic condition. The determination of the baseline condition includes a social/value decision. Examples of supplementation strategies that use an ecosystem perspective are: releasing fish in areas and at times when risks to non-target taxa are acceptable; releasing few, if any, fish when carrying capacity is being approached; and releasing fish when ecological feedback indicators suggest that predation and pathogen conditions are desirable. Hatchery releases may need to be adjusted to the ecosystem yearly, perhaps with some indicators of ecosystem condition.

Principle 6: Learn, Monitor, and Evaluate – Portfolio of Approaches

The work group decided that, at a minimum, the consequences of the actions taken to accomplish a supplementation goal need to be understood. Uncertainty and the risk of failure must be managed. Several alternative approaches to any supplementation plan need to be considered. These alternative approaches to supplementation could range from small, experimental pilot projects using simple research objectives and monitoring plans to more complex research projects with more involved research objectives. The availability or ease of collecting data should also be considered because it may be easier to gather data at some sites than others because the study sites are more accessible to researchers or because data are easy to obtain from fish counts at existing fish ladders. Regional research facilities may be useful in endeavors to implement and monitor supplementation. A few high-intensity monitoring stations could produce results that carry over elsewhere. In the early stages of supplementation research, areas/basins with good learning and research opportunities should be prioritized for supplementation activities. Monitoring and evaluation were discussed in more detail in Work Group 3.

The work group discussed the advantages of using a portfolio approach to supplementation. Using this approach, different types of strategies would be attempted, creating a research portfolio for each supplementation program. Given lag times in results of newly implemented supplementation processes, attempting several alternative strategies (having a backup) may be useful and reduce the likelihood of failure of the supplementation effort.

Another method suggested was phased implementation of conservation/supplementation hatcheries, phasing hatchery objectives from research into implementation of conservation goals as the program progressed. The hatchery would continue to operate under different sets of goals as the phased implementation proceeded, later moving from conservation goals to harvest goals. The function of the hatchery could change over time with checkpoints or decision points along the way. In this way, full supplementation should not begin until the answers to research questions are clear.

Principle 7: Costs

As a final principle, the work group decided that the financial costs of correctly implementing an entire supplementation program (including monitoring and evaluation) should be evaluated before a program begins. A program could be set up with decision points for re-evaluation of costs along the way. The cost of the supplementation activity should be compared to the cost of fixing the underlying problem (e.g., restoring habitat) before the project begins.

Conclusions

A few underlying themes emerged from the discussions of the work group. First, all supplementation activities are context specific. Goals, objectives, and implementation strategies must be set on a case-by-case basis. Identifying the limiting life history stage in the target population is key to understanding the current problem and producing a successful supplementation effort. Another key to planning a successful supplementation program is to ensure a balance of costs and benefits for the target populations, for the ecosystem, and for other factors. Current research programs and published literature may provide a starting point for how (or how not to) meet supplementation objectives. When beginning a program, specific strategies can be developed only after program goals and desired endpoints are established.

How should the effects of supplementation be evaluated? (Work Group 3)

Work Group Participants: Dave Fast (group leader), Tom Backman, Daniel Goodman, Eric Loudenslager, Chuck Tracy, Mark Chilcote, Reg Reisenbichler, Peter Hassemer, Dan Bottom, Craig Contor, Bill Pearcy, Katy Kavanagh, Ken Currens

Introduction

While the discussion of evaluating supplementation ranged across many topics, it was agreed that there were several focal points related to the subject. These topics were developed with the assumption that supplementation has been determined to be necessary and will be conducted. The first of these foci was that successful evaluation can only be conducted for a supplementation program with established goals. After specifying goals, evaluation criteria can then be developed that reflect the type and quality of data to be collected. Within the criteria, protocols and methods must be established to collect the required data. Since project goals may vary, generalized indicators of success common to all supplementation projects were discussed. This report on the evaluation of supplementation is divided into five sections: goals, evaluation criteria, methods and protocols, indices, and conclusion.

Goals of supplementation

Initially, the work group debated whether to monitor results, or judge the success of supplementation programs. They concluded that both were equally important. In order to evaluate success, goals must be clearly stated. Therefore, the work group developed a list of general goals for supplementation based on four supplementation applications.

Supplementation applications were identified as reintroduction, recovery, rebuilding, and persistence using the RASP (1992) definition (see Work Group 1) of supplementation. Reintroduction supplementation would be used where a population had been extirpated and the goal is to reestablish a viable fish stock to the area. Recovery supplementation would be used in the recovery of a depleted stock with the objective of increasing the number of fish spawning to produce progeny that would return to spawn in the wild. Rebuilding supplementation would be used to increase the number of adult fish returning in a run but not necessarily the number reproducing. Persistence supplementation would be used to maintain an existing population in the face of limiting factors, such as a migration barrier or loss of habitat, that can not be readily resolved. The common goals for reintroduction, recovery and rehabilitation supplementations are that the introduced population must successfully interbreed with the existing wild population, and that supplementation programs should end at some point to allow the blended population to develop naturally. Persistence supplementation has the goal to keep a population from becoming locally extinct and may not be a temporary measure.

Evaluation Criteria

Four general criteria for evaluating supplementation were established: *abundance, productivity, distribution,* and *diversity.* Information related to each of these criteria must be collected for hatchery and naturally produced fish utilizing the wild environment and for hatchery and naturally produced fish used within the hatchery program. *Abundance* is a numerical assessment of the population by life history stage (e.g., smolt or adult). Stock *productivity* in the natural environment can be measured from ratios between different life history stages, for example spawners to smolt recruits or spawners to adult recruits and is indicative of the survival probability of a life history type. Population *distribution* is also potentially important given that thriving populations expand into additional habitat, some of which may be marginal. Distribution in all life history stages, assessed under the abundance criterion, should be considered to avoid overlooking an important stage. *Diversity* was divided into ecological and genetic components. Ecological diversity relates to the condition of the environment and non-target taxa. It includes community structure and habitat-driven life history paths. Genetic diversity, on the other hand, reflects the genetic component of the target taxa life history pathways and is important to consider at both the population and metapopulation levels.

Within each evaluation criterion, four monitoring types, each of which answers different questions about the project goal, were identified: compliance, status and trends, effectiveness, and validation. Compliance indicates whether the project is achieving its intent of producing more fish and is the least intense type of monitoring. Status and trends monitoring is potentially a more useful assessment of how a population changes during the project and allows an assessment of the impact of eliminating supplementation. Effectiveness monitoring is a determination of whether the supplementation stabilizes the population, permits the cessation of the project, and is more rigorous than the previous two types of monitoring. Validation monitoring is considered the most rigorous type, and would assess the effects of supplementation on the fitness[3] of the wild population to ensure no detrimental changes were occurring.

Priority of evaluation criteria

Given limited management resources, it is necessary to establish priorities for evaluating supplementation programs. This ranking of priorities was done at the evaluation criteria level. Abundance determination was identified as a top priority because it is critical for assessing the number of returning adults and spawners in order to evaluate the health of the population, and these data can be used to assess the other evaluation criteria. Population productivity assessment was also identified as a top priority in order to project future population trends. Diversity assessment was also considered important because a diverse gene pool has potential benefits for the population. In addition, diversity assessment could detect the potential for habitat constraints and unexpected ecological effects of supplementation. Determining population distribution was ranked slightly lower in priority than the other criteria. Nevertheless, it was felt that assessing distribution provided important information on habitat quality, habitat utilization, and population viability. In the final analysis, all of the evaluation criteria were considered very high priority by the group although the ultimate priorities of the criteria will depend on the project objectives.

Scope of evaluation

Evaluation scale and design

Evaluation of supplementation programs will be difficult and expensive, but it is critical for determining whether the project goals are being met. Evaluation is of such importance that the work group recommended that supplementation should not be done in any basin where the effects cannot be monitored. There are two potential clients who would use evaluation information: the hatchery operators that are conducting the supplementation, and the stakeholders that want to evaluate the general success of the hatchery supplementation program. These clientele create the need for a hierarchical arrangement of evaluation that will require the integration of individual supplementation evaluation projects into a systematic region-wide program. Where applicable, integrating multiple supplementation projects into a single

[3] Fitness is defined as the genetic contribution by an individual's descendants to future generations of a population. R.E. Ricklefs. 1979. Ecology. Chiron Press, Inc. New York

evaluation program, such as straying analysis or freshwater mortality, can reduce costs and increase the utility of the data recovered. Moreover, such coordinated efforts allow assessment of local effects on the population and regional effects on the species.

Evaluation procedures for supplementation projects need to be constructed with the same rigor as the protocols used in scientific research. The sampling design should be robust enough to discern wide-scale variation, and the data collected must be precise enough to provide sufficient statistical power to make assessments of the program on a regional scale. It was also suggested that the power of evaluation projects be determined *a priori* to address the scope of sampling required and potential uncertainty from the data obtained.

Genotypic determination

The effects of supplementation on genetic diversity were an underlying concern throughout the work group's discussions of evaluation. They concluded that in order to determine the true impacts of supplementation, data that allow the comparison of hatchery-influenced fish with wild fish are critical. The work group clarified the distinctions between wild and hatchery fish to facilitate a discussion of how such data could be collected. They defined *wild fish* as fish with no ascertainable hatchery influence. Fish raised in a hatchery were defined as *hatchery fish*. However, problems arose when the work group tried to classify the progeny of hatchery fish. *Natural origin recruits* (NOR) was selected as the general term for naturally spawning fish that arise after a hatchery supplementation program has begun. These fish can have wild ancestry, be derived from the hatchery stocks, or be hybrids of the two. In reality, the difficulties of determining the extent of hatchery ancestry beyond the parent generation are substantial, so classifying NORs may be impractical.

Change in fitness was considered to be the ultimate assessment of the effect of supplementation on a naturally spawning population, and the hatchery ancestry of individuals must be assessed to fully understand the effects of supplementation on fitness. While the risks that supplementation may put on fitness at risk by reducing genetic diversity and creating a founder population are very clear, the biological risks and potential benefits from expanding diversity through supplementation are far less certain. Statistical variation among sites can be reduced by evaluating changes in fitness, and combining evaluation at many facilities can eliminate additional noise. This is important because fitness tests have little statistical power and will require the most effort and resources to conduct.

Methods of assessing fitness of the three different types of fish (hatchery, wild, and NOR) were discussed extensively. There was concern within the work group that the expense of determining hatchery ancestry genetically would be prohibitive. Genetic markers are available for developing hatchery pedigrees, but the cost of these studies and the uncertainty in parentage are serious limitations to be considered. If differences among the fish types could be related to reproductive ecology, fish types could be used to assess fitness. Then, for example, observational spawning channels could be incorporated into hatcheries to evaluate fitness based on reproductive behavior or success.

Methods and Protocols of Supplementation Monitoring

For each of the four criteria presented earlier, a set of methods will be needed to obtain the desired data. For all data collected, the work group considered reference streams (or other controls) to be critical in order to compare supplementation effects. A control stream is as similar as possible to the treated stream, except that the hatchery fish are not introduced into it. The work group also suggested that baseline data on the supplemented population would be useful for making comparisons.

Abundance

The purpose of collecting abundance data is to distinguish between wild and hatchery fish and to assess the total number of fish in the population. Sufficient data for a population viability analysis (PVA) is needed to adequately measure abundance. If the fish are divided into different life history stages (adults, smolts, and juveniles), the data collection methods can be categorized within them. Adult assessments need to be conducted annually and should include data on age structure and sex ratio. Marking hatchery fish is critical to assessing abundance, and complete marking reduces variance, which is important for evaluations with inherently low statistical power.

Data collection methods for adults were divided into three categories: direct counts, indirect methods, and stream surveys. Direct counts require a dam, weir, trap, ladder, or other collection facility. Some of these tools can be very practical to install in any location, but they may miss a portion of the population. These structures could also affect adult migration and spawning location, causing a direct impact on the population. Indirect methods of assessing adult populations include counts of fish per stream mile in a random section of stream, mark-recapture analysis, redd counts, and tributary trapping of adults. These methods were considered inferior to the direct counts but could be utilized in areas where direct counts were not practical. Stream surveys are also important for estimating abundance if direct counts are unavailable.

Sampling juvenile and smolt abundances is far less involved than sampling adult abundance. Methods for counting juveniles include fry and pre-smolt density estimates, which can be obtained by electrofishing or snorkeling. Smolt counts should differentiate between hatchery and wild fish and create an age structure profile to detect any differences in outmigration characteristics between hatchery and wild fish. Determining the ancestry of NORs is difficult, and it is unlikely that they can be separated from other juveniles in smolt counts.

Productivity

With the collection of quality abundance data, assessing productivity is accomplished by computing indices and ratios from these data. Although it is not likely to be a factor in populations receiving supplementation, productivity is density dependent and indices of productivity must account for the reproducing population. Evaluation of reproductive ecology becomes important if productivity declines. Assessments could include behavioral factors (e.g., mate selection and competition) and physiological conditions (e.g., gametic viability and reproductive success). Reproductive success is best evaluated by comparing reference or control to supplemented streams and should include controlled studies and population level observations such as DNA pedigree analysis.

Distribution

Spatial and temporal trends in distribution can provide measures of population performance. Distribution data should be collected on all life history stages but should focus on spawning and rearing stages. Stream surveys are also useful in determining distribution changes. As long as abundance data are collected in a spatially explicit manner, they can be used to assess population distribution. For example, total counts of redds can provide a distributional assessment when combined with Global Position System (GPS) location mapping. Through a coordinated interaction among management groups intra- and inter-basin straying can be assessed on a metapopulation level. Although the incidence of straying is presumed to be less than 10% in most cases, straying can have a potentially important effect on genetic diversity.

Diversity

While ecological diversity was recognized as an important concern, the methods for assessing it are unclear and/or complex. Habitat characteristics, such as temperature and nutrient status are easily monitored but potentially difficult to relate to population success. Habitat-driven life history paths are also hard to assess. Describing the methods for monitoring the effects on non-target taxa were even more challenging. It was difficult to determine the level of detail needed to assess community diversity indicators, such as species richness. The work group concluded that the best way to evaluate ecological diversity was to monitor selected non-target taxa both before and after supplementation (where possible) and in relation to a reference area.

Genetic diversity must be addressed on both the population and metapopulation level. Conservation of genetic life history paths is important. In adults, migration times, spawn times, fecundity, size, age structure, sex ratio, and egg retention should be preserved. In juveniles, age, size, migration times, and unique life history patterns (e.g., residual fish and precocial males) should be preserved. Genotypic structure and diversity should also be assessed through molecular biology monitoring. Baseline genetic data are desirable for supplementation programs before they are established.

Indices of Supplementation Success

The work group created indices for success of supplementation programs that are related to the evaluation criteria. These success measures are testable questions/hypotheses that can be addressed by evaluating the supplementation project. Therefore, they are not definitive criteria but rather speculative in nature. Successful reintroduction, recovery, and rebuilding supplementations would be indicated by an increase in abundance of NORs, while for persistence the expectation would be a stable NOR abundance. Variability in abundance should also be accounted. If, for example, the coefficient of variance for abundance does not increase, this may suggest a stock is resilient to perturbation. Similarly a reduction in density specific production for NORs may not be associated with a successful supplementation program, nor would a reduction in genetic (genotypic or phenotypic) diversity of target taxa or in natural ecological diversity (i.e., no non-target taxa effects) be anticipated.

Conclusion

The evaluation of hatchery supplementation programs is a biologically, statistically, and logistically complex problem. Given the difficulty of determining fish ancestry once supplementation has begun, assessing the genetic effects of combining hatchery and wild populations (*e.g.* selection or drift) will be challenging. Moreover, the effects of supplementation on salmonid populations will be extremely difficult to separate from those of habitat manipulation, climate variation, and various management practices, such as harvest. These other factors can potentially overwhelm an otherwise successful supplementation program rendering it ineffective. Distinguishing natural random variation from actual management effects is made more difficult by the complexity of the system. Furthermore, the spatial and temporal scale at which supplementation operates increases the potential variation and complexity of assessment and analysis. Therefore, this work group assembled an ideal scenario for evaluating supplementation. It is recognized that only the initial phases of such a project can be conducted as a management activity. The later stages are actually in the realm of potential scientific experiments with the associated risk and uncertainty. As supplementation becomes a standard practice, evaluation protocols and priorities will become clearer.

"Additional Questions" Addressed by the Work Groups

Two additional questions were included on the agenda of the workshop. These questions were discussed by participants in the three work groups and during the plenary sessions. Some very general answers to these questions were given. The workshop participants considered these questions to address important issues to consider when using supplementation to conserve salmonids, but they were not able to assemble the necessary information to adequately answer the questions in the time available.

Question 1. "Are hatchery and wild salmonids different in ways that are important to the design and implementation of supplementation projects?"

The initial answer to this question is, yes, there are differences between salmonids reared in the wild, and salmonids reared in hatcheries, but similarities remain. Differences and similarities may appear in physical attributes, genetic structure and gene expression, behavior, and or life strategies. However, the implications of these differences to the design and implementation of supplementation projects depends on the individual combinations of circumstances. Little information is known, requiring further research and/or monitoring of supplementation efforts.

Question 2. "What are the effects of hatchery management and hatchery fish on wild salmonids?"

The initial answer to the second question addressed by all of the groups was that it depends on the circumstances. Some effects of traditional production hatchery management on hatchery fish, and the success of these fish in the wild, are known but many are not. Interactions with and influences on wild fish are generally not well known, and observations vary with each case documented and at different geographic scales. Again, caution is recommended when general statements or answers are given. There are many aspects of genetic and ecological interactions between hatchery and wild salmonids about which there are little or no data. Implementation of supplementation should not be carried out until a sound scientific basis for procedures has been established. Areas of potential interactions or interactions of concern need to be identified and monitored as part of a supplementation project to prevent unintentional or unwanted effects within the supplemented population and to other populations, and to develop better knowledge and understanding of the effects which occur.

Conclusions

In both cases, there was agreement that the answers to these two questions depend on the circumstances. The answers would involve a rather detailed analysis of how hatchery and wild salmonids differ, how they affect one another, and when these factors might be important. This analysis could be conducted through research on supplementation at different scales.

Workshop Summary

A series of major points emerged during the plenary sessions and during the concurrent work group sessions. These points, organized by topic, summarize the most important factors to address when planning or implementing a supplementation program.

Overview and Conceptual Framework

- Supplementation is part of a suite of strategies (e.g., habitat enhancement and restoration, changes in land use, changes in fish harvest activities, removing impediments to fish passage) that may be used together for recovery of wild salmonid populations.
- When possible, limiting factors (e.g., ecological or habitat conditions, impediments to fish passage) should be addressed before implementing a supplementation program.
- Supplementation may help to maintain a gene pool but is not likely to lead to recovery of salmonid populations unless the root causes of decline are addressed.
- Supplementation is still in experimental stages; alternative strategies for meeting the goals of a particular project should be considered before supplementation is used.
- During the design, implementation, and monitoring of supplementation, programs should, as much as possible, utilize what is known about wild salmonid life cycles while developing and testing supplementation strategies and tactics.
- Clearly defined goals and monitoring of their attainment are important to the success of supplementation programs.

Assessment and Design of Supplementation Programs

- The population status of the target population is a prime factor in considering supplementation. Supplementation efforts of greater risk can be tolerated in areas where the current probability of existing population/stock survival is very low.
- Risks and benefits should be evaluated before implementing a supplementation program.
- Supplementation might be implemented to provide "genetic conservation" while other measures (e.g., habitat improvement) that will greatly improve the chances of success of a supplementation program over the long term are also being implemented.
- Ideally, supplementation should end when recovery goals are met.

Methods

- It is extremely important to identify areas with suitable habitat and underutilized carrying capacity when choosing supplementation as a tool to aid recovery of salmonid populations.
- Supplementation should be placed in an ecosystem context. Important considerations include carrying capacity, the connectivity of the population, the impacts on existing populations/stocks and on other species, levels of adult returns, as well as additional ecological factors.
- Preservation of genotypic and phenotypic diversity is extremely important when stocks are selected or developed for supplementation. Domestication selection should be minimized. Use "local broodstocks" or an appropriate alternative to minimize divergence from the wild population. When possible, allow for a natural range in the diversity of life history patterns.

Evaluation

- Monitoring and evaluation are essential to assessing whether supplementation was successful and goals of a particular program were met. This requires adequate experimental design and "references or controls" for comparisons.
- Abundance, stock productivity, ecological and genetic diversity, and fish distribution data are all important when evaluating the results and/or success of supplementation.
- Due to the inherent cost and limitations of monitoring programs, monitoring efforts will be most efficient, and will provide the most comprehensive information, when coordinated among agencies.

Based on this workshop the IMST reaches the following interim conclusion pending completion of our phase III hatchery project report: Supplementation may be a useful strategy as part of a comprehensive program of species recovery. We note that it has not been extensively tested, therefore needs to be used cautiously and with a strong component of monitoring and adaptive management to ensure it is not harmful to recovery of wild stocks, and that it is achieving the intended goals.

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Appendix 1

Workshop Agenda

Appendix 1. Agenda

Conservation Hatchery and Supplementation Workshop
June 19-21, 2000
Double Tree, Jantzen Beach Hotel
909 North Hayden Island Drive
Portland, Oregon 97217

<u>Day 1 (June 19)</u>

1:15 PM Introduction (Welcome, Background, Purpose, Goals)

<u>Science Base</u>

(20 minute presentation, 10 min. discussion)

1:30 Dr. Robin Waples, NMFS – Supplementation from the NMFS perspective
2:00 Dr. Robin Waples, NMFS – Supplementation -- genetic considerations
2:30 Break
3:00 Dr. Todd Pearsons WDFW– Interspecies interactions
3:30 Dr. Reg Reisenbichler, USGS – Supplementation research
4:00 Dr. Barry Berejikian, NMFS – Mating behavior studies
4:30 Open discussion
5:15 Public Comments
6:00 Adjourn

7:00 What do we need to know before using supplementation to recover depleted salmon populations? Three speakers will give 15 minute presentations addressing this question from different perspectives followed by at least an hour of open discussion.
Mr. Tom Nickelson, ODFW -- Fresh water habitat
Mr. Dan Bottom, NMFS – Marine and estuarine habitat
Dr. André Talbot, CRITFC – Population dynamics

<u>Day 2 (June 20)</u>

Case Histories
A series of supplementation case histories,
each of which is to answer the following questions:
What was/is the intended result?
How was performance measured?
What was the outcome?

8:00 Mark Chilcote, ODFW -- Oregon/Washington experiences with some older programs
8:30 Mr. Gary James, CTUIR -- Umatilla River and Lookingglass Creek programs
Craig Contor, CTUIR – Umatilla Basin Steelhead Enhancement and Spring Chinook Reintroduction
Mike McLean, CTUIR – Evaluation of Reestablishing Spring Chinook Salmon Natural Production in Lookingglass Creek, Using a Non-Endemic Hatchery Stock
9:10 Dr. Bruce Ward, UBC Canadian Supplementation & Captive Broodstock Programs
9:40 Mr. Rich Carmichael, ODFW -- Imnaha and Grande Ronde programs
10:30 Break
11:00 Mr. Pete Hassemer, IDFG – Salmon River program

11:30 Open discussion -
11:55 Public Comments
1:00 Policy forum: Senator Ted Ferrioli, Paul McCracken, Roy Hemmingway
1:30 Orientation to work group assignments
We will divide the workshop participants (speakers and invited scientists) into three groups. Each group will be assigned one of the following questions to answer:

1. Under what conditions should supplementation be used in the recovery of depleted salmon populations?
2. What are the appropriate methods and strategies?
3. How should the effect of supplementation be evaluated?

Each work group in addressing its assigned question should also consider these two additional questions:

1. Are hatchery and wild salmonids different in ways that are important to the design and implementation of supplementation projects?
2. What are the effects of hatchery management and hatchery fish on wild salmonids?

1:35 Work Groups convene
Each group will have a group discussion leader and a recorder.
During this first work session, each group should draft the answer their question and begin compiling the scientific basis for the answer.
4:30 Return to Plenary Session
Each group leader will summarize progress, answer questions.
5:00 Public comments
5:30 Adjourn

7:00-9:00 PM CHIP Proposal Presentation and Discussion – Organized by ODFW and the Coastal Salmon Restoration and Production Task Force

<u>Day 3 (June 21)</u>
8:00 Working groups reconvene in individual sessions.
During this session the groups should finish the work of the previous day then prioritize the elements of their answer. For example, The group addressing question 1 would rank in priority order the conditions that should trigger the use of supplementation for salmonid recovery. The group addressing question 2 would prioritize the various elements of supplementation strategies. The group addressing question 3 would prioritize the elements of a monitoring and evaluation program.

1:00 Reconvene in plenary session
Each group leader will report findings
Discussion and questions
3:00 Break
3:30 Develop Conclusions of workshop
5:00 Public comment period
5:30 Adjourn

Appendix 2

Workshop Participants

Appendix 2. Workshop Participants

A Scientific Workshop on
Conservation Hatcheries and Supplementation Strategies
for Recovery of Wild Stocks of Salmonids
June 19-21, 2000
Portland, Oregon

Workshop Participants

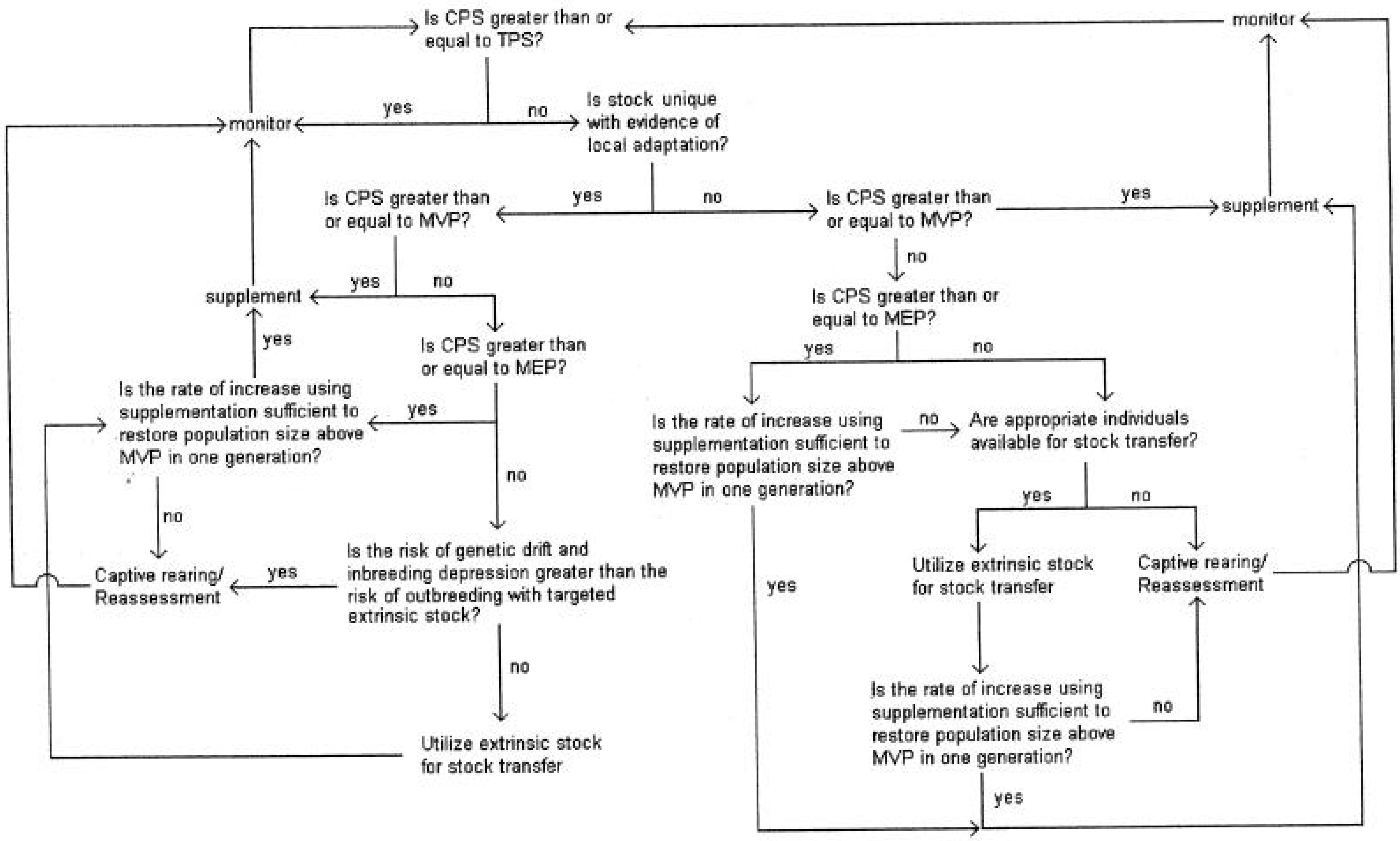
Hassemer, Pete	Idaho Department of Fish & Game
James, Gary	Confederated Tribes of the Umatilla Indian Reservation
Pearsons, Todd	Washington Department of Fish & Wildlife
Reisenbichler, Reg	USGS/BRD - NW Bio Science Center
Talbot, André	Columbia River Inter-Tribal Fish Commission
Berejikian, Barry	National Marine Fisheries Service
Waples, Robin	National Marine Fisheries Service
Ward, Bruce	University of British Columbia
Carmichael, Rich	Oregon Department of Fish & Wildlife - LaGrande
Chilcote, Mark	Oregon Department of Fish & Wildlife - Portland
Nickelson, Tom	Oregon Department of Fish & Wildlife - Corvallis
Bottom, Dan	National Marine Fisheries Service
Kostow, Kathryn	Oregon Department of Fish & Wildlife - Portland
Tracy, Chuck	Oregon Department of Fish & Wildlife - Portland
Allendorf, Fred	University of Montana
Currens, Ken	Northwest Indian Fish Commission
Smoker, Bill	University of Alaska
Lannan, Jim	
Neilsen, Jennifer	USGS/BRD - Alaska Bio Sciences Center
Brown, Kay	Oregon Department of Fish & Wildlife
Miller, Loren	University of Minnesota
Fast, Dave	Yakama Indian Nation
Loudenslager, Eric	Humboldt State University
Goodman, Daniel	University of Montana
Backman, Tom	Columbia River Inter-Tribal Fish Commission
Hulett, Patrick	Washington Department of Fish & Wildlife
Smith, Steven	National Marine Fisheries Service
DeHart, Douglas	US Fish & Wildlife Service
Hall, Jim	Oregon State University
Contor, Craig	Confederated Tribes of the Umatilla Indian Reservation
McLean, Mike	Confederated Tribes of the Umatilla Indian Reservation
Thomas Flagg	National Marine Fisheries Service
Norris, Logan	IMST
Buckhouse, John	IMST
Kavanagh, Katy	IMST
Pearcy, Bill	IMST
Elmore, Wayne	IMST
Lichatowich, Jim	IMST

Appendix 3

André Talbot Decision Tree

Appendix 3

Decision tree for Determination of Restoration Strategy



Source: André Talbot