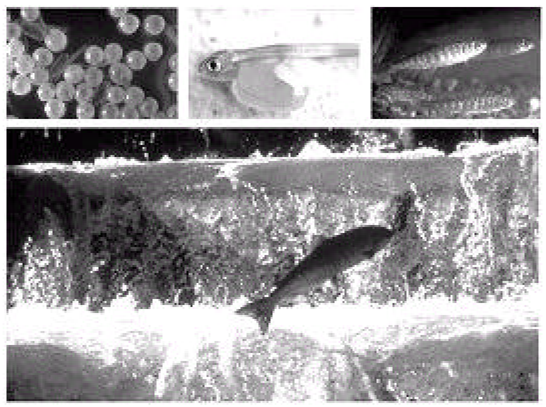
Artificial Production Review



Report and Recommendations of the
Northwest Power Planning Council

Council document 99-15

October 13, 1999

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Executive Summary

I. Introduction

In July 1997, Congress directed the Northwest Power Planning Council (Council), with the assistance of the Independent Scientific Advisory Board (a panel of 11 scientists who advise both the Council and the National Marine Fisheries Service on scientific issues related to fish and wildlife), to conduct a thorough review of all federally funded artificial production programs in the Columbia River Basin. Congress directed the Council to recommend a coordinated policy for future operation of artificial production programs and to provide recommendations for how to obtain such a policy.

II. The Council's recommendations

A. Implementing artificial production reform policies

The region needs action and leadership to implement new artificial production policies, to decide whether and where to use artificial production, and to ensure that future artificial production funding is contingent on reforms being made. These decisions need to be made for each subbasin and implemented as part of a broader strategy to meet regional fish recovery goals.

The Council is prepared to do its part by amending its Columbia River Basin Fish and Wildlife Program beginning this winter. The Council also will set in motion the needed subbasin planning effort. To that end, the Council makes six recommendations for implementing new artificial production policies:

1. Tribal, state and federal agencies should evaluate the purposes for each artificial production facility and program in the basin within three years.
2. Program managers should evaluate and improve the operation of artificial production programs that have agreed-upon purposes, consistent with the proposed policies in this report.
3. Program managers should use existing processes to implement artificial production reforms. Examples of existing processes include the annual federal agency and Northwest Power Planning Council funding processes, Endangered Species Act implementation and the Council’s periodic revisions of its Columbia River Basin Fish and Wildlife Program.
4. Congress and the Bonneville Power Administration need to ensure that money to implement the reforms is available.
5. The Council should assist in the formation of an interagency team to oversee and evaluate the reforms.
6. The Council, other regional decision-makers and Congress should assess the success of the recommended reforms after five years.

B. Elements of a coordinated policy for the future role of artificial production in the Columbia River Basin

Artificial production is one of many tools for meeting fish recovery objectives. The need for it, and its effectiveness, must be evaluated as objectives evolve. Artificial production must be used in a manner consistent with an ecologically based scientific foundation for fish recovery so that fish can be raised for harvest while minimizing the impact on, or benefiting, fish that spawn naturally.

Based on a scientific foundation for ecologically sound fish and wildlife management developed as a part of the Multi-Species Framework process, and on a scientific assessment by the Scientific Review Team of how artificial production might fit within that ecological framework, the Council recommends 10 policies to guide use of artificial production:

1. The purpose and use of artificial production must be considered in the context of the environment in which it is used.
2. Artificial production remains experimental. Adaptive management practices that evaluate benefits and address scientific uncertainties are critical.
3. Artificial production programs must recognize the regional and global environmental factors that constrain fish survival.
4. Species diversity must be maintained to sustain populations in the face of environmental variation.
5. Naturally spawning populations should be the model for artificially reared populations.
6. Fish managers must specify the purpose of each artificial production program in the basin.
7. Decisions about artificial production must be based on fish and wildlife goals, objectives and strategies at the subbasin and basin levels.
8. Because artificial production poses risks, risk management strategies must be implemented.
9. Production for harvest is a legitimate management objective of artificial production. But to minimize adverse impacts on naturally spawning populations, harvest rates and practices must be dictated by the need to sustain naturally spawning populations.
10. Federal and other legal mandates and obligations for fish protection, mitigation, and enhancement must be fully addressed.

III. Purpose of the Review

A. Brief history of Columbia River Basin fish hatcheries

Artificial production of fish has been used in the Columbia River Basin for many purposes during this century. Hatchery programs have produced both resident fish (those that do not migrate to the ocean, such as bull trout and rainbow trout) and anadromous (ocean-going) fish, especially chinook and coho salmon and steelhead. These species have also been the focus of tribal, sport and commercial fisheries management in the basin.

There are more than 150 hatcheries and associated facilities for anadromous and resident fish in the basin. Federal and state agencies, Indian tribes and private interests operate them. Many are intended to mitigate the impact of dams, which have blocked access to about one-third of the salmon and steelhead habitat that existed historically in the Columbia basin. Dams also affect resident fish by blocking historic freshwater migration routes, inundating spawning areas and altering the "natural" ecosystem.

Resident fish hatcheries, like salmon and steelhead hatcheries, mitigate losses caused by the hydropower system. In some cases, such as in areas blocked by dams, losses of anadromous species are mitigated through the production of resident species, which may include native and nonnative species adapted to the altered environment. Because resident and anadromous fish co-exist in the Columbia River ecosystem, it makes sense to review resident fish artificial production programs together with salmon and steelhead artificial production programs as components of an integrated artificial production program for the future.

Most of the artificial production programs in the Columbia River Basin are financed with federal money in some way. For example, many are financed through annual appropriations by Congress under the Mitchell Act, a 1938 law that provides money to mitigate the impact of federal Columbia River dams and other activities. Others, like the Lower Snake River Compensation Program artificial production programs, which were built to mitigate the impact of federal dams on the lower Snake River, are paid for with annual congressional appropriations that are repaid by the Bonneville Power Administration. Additionally, the Northwest Power Planning Council, through its Columbia River Basin Fish and Wildlife Program, provides money from Bonneville Power Administration ratepayers to finance artificial production programs that mitigate the losses for Indian tribes and others in the basin.

B. Why a review of artificial production was needed

Many species of fish in the Columbia River Basin have declined significantly, particularly ocean-going fish such as salmon and steelhead and certain freshwater species including bull trout and sturgeon. It is a crisis characterized by depleted fish populations, degraded and blocked spawning habitat and protection under the Endangered Species Act for 12 separate salmon and steelhead. Resident fish, including bull trout and sturgeon, are also listed in some areas.

Fish hatcheries play a unique role in the Columbia River Basin. They have been identified as one of the causes of the current declines, particularly for salmon. At the same time they also are considered part of the solution. The purpose of many artificial production programs in the basin is currently unclear. While many artificial production programs were built to mitigate the impact of dams or to produce fish for harvest, their role today is less certain. There also is concern about adverse impacts of artificially produced fish on fish that spawn naturally.

Salmon and steelhead artificial production programs historically produced fish for harvest by tribal, commercial and sport fishers. Artificial production programs are capable of producing literally millions of fish, vastly beyond the production capability of fish that spawn naturally. Yet both types of fish — artificially and naturally spawning — are caught in Columbia River fisheries. The cumulative effect contributed to overfishing the naturally spawning populations, and ultimately speeded their decline.

As declines continued, fisheries scientists increasingly recognized that traditional fish hatchery practices needed to be changed. Producing fish for harvest remains a legitimate use for artificial production programs, but scientists are identifying and articulating a role for artificially produced fish as functioning components of ecosystems.

Artificial production programs might be used to rebuild populations of fish that spawn naturally and also provide fish for tribal, sport and commercial harvest. In doing so, they should minimize the adverse impacts from interactions between artificially produced fish and those that spawn naturally. Interactions can adversely impact the unique genetics of fish that spawn naturally and, over time, dilute or weaken the unique genetic makeup of those populations.

IV. How the Council conducted the review

The Council, in coordination with the Independent Scientific Advisory Board, appointed a Scientific Review Team of experts in artificial production to provide an independent assessment of the basin's artificial production programs. In April 1999, the Team submitted its report (see Appendix 1), a review of science, to the Council (Council Document 99-4, April 1999).

The Council also conducted an extensive public process that received input and comment from hatchery managers, tribes, environmental groups, recreational fishers and others. The Council appointed a Production Review Committee to coordinate the artificial production review and assist the Council in developing artificial production policies. The committee was composed of approximately 25 individuals with expertise and interest in fish production, who met once a month beginning in January 1998. The Council also conducted two public workshops and numerous public meetings to discuss artificial production, explain progress on the review and to receive public comment.

Artificial Production Review

Report and Recommendations of the Northwest Power Planning Council

October 13, 1999

I. Background

Congress asked the Northwest Power Planning Council, with the assistance of the Independent Scientific Advisory Board, to review all federally funded artificial fish production programs in the Columbia River Basin and report to Congress with "a formal recommendation for a coordinated policy for the future operation of federally funded hatcheries." The Congress also asked for a recommendation for "how to obtain such a coordinated policy." This is the Council's report.

The report has three parts:

- This Part I describes the background for the Artificial Production Review.
- Part II contains the Council's recommendations for the policies that should guide the future operation of hatcheries in the basin. Attached to the end of this report is a draft set of performance standards to implement these policies.
- Part III contains the Council's recommendations for how to implement reform in artificial production programs consistent with the policies.

The report is followed by a number of appendices that are described in the report.

A. Artificial Production Programs in the Columbia River Basin

Critical Issues and Policy Developments

Artificial production programs produce the majority of salmon and steelhead that annually return to the Columbia River. Development in the Pacific Northwest has degraded the ability of natural river habitat to sustain naturally spawning fish populations. The region has tried to mitigate for that loss through hatchery production.

According to the National Marine Fisheries Service's recent Biological Opinion on artificial propagation, [1] adult hatchery produced fish comprise approximately 50 percent of the fall chinook, 70 to 80 percent of the spring/summer chinook, 70 percent of the steelhead, and 95 percent of the coho salmon. Annual releases of hatchery-reared salmon and steelhead from all federal and non-federal programs grew at one time to more than 200 million juveniles. Production was reduced in the mid-1990s by funding reductions and Endangered Species Act considerations. Projected hatchery releases in 1999 total 142.5 million juveniles, with more than 100 million from the federally funded hatcheries. The scale and proportion of artificially produced resident trout and other resident fish to naturally spawning resident fish may be of a similar magnitude.

Appendix 2 to this report contains a description of the major artificial production programs in the Columbia basin, federally funded programs as well as hatchery programs associated with FERC-licensed dams and the state fish and wildlife agencies. That appendix also contains a description of

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[1] National Marine Fisheries Service, *Biological Opinion on Artificial Propagation in the Columbia River*, Endangered Species Act Section 7 Consultations with Bonneville Power Administration, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service, and Authorization of Section 10 Incidental Take Permits with Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife (March 29, 1999).

how the policies concerning artificial production have been in transition for more than a decade, as the region has learned more about hatcheries.

Providing harvest opportunities in the ocean and in the river has traditionally been the primary objective of artificial production in the basin. Success at meeting that objective is an open question, especially the long-term productivity and sustainability of artificial production for these fisheries. Nevertheless, the critical issues of the last decade have gone beyond the basic question of how to produce fish for harvest to four concerns:

- **Broaden harvest opportunities**

  Can and should artificial production programs be revised to spread harvest opportunities and success to greater areas of the basin? For many decades the production policy directed by Congress and the federal and state agencies largely replaced upriver fish lost to development with hatchery-produced fish in the lower river. The trend has reversed somewhat — for example, the number of smolts from lower river artificial production programs that are released upriver has been increasing since 1980, and resident fish production in the areas blocked by dams has received increased financial support since 1995. The magnitude and significance of the shift is in debate.

- **Improve survival of artificially produced fish**

  Is it possible, and economically feasible, to boost the survival of artificially produced fish by using spawning, rearing and release techniques that more closely mimic natural spawning, rearing and migration patterns?

- **Avoid harming natural populations**

  Do artificial production activities adversely affect naturally spawning fish to a significant degree and thus undermine efforts to protect and rebuild naturally spawning populations? If so, can artificial production be altered to avoid or minimize the harm? Will attempts to improve survival of artificially produced fish by mimicking natural rearing and release patterns help or hinder the effort to protect natural populations? The concern for impacts on naturally spawning fish has cut across the basin and programs since the 1980s, but in the last few years the issue has been highlighted by Endangered Species Act considerations.[2]

[2] Eleven species (or "evolutionarily significant units" of species) of salmon and steelhead that spawn in the Columbia River or its tributaries have now been listed as threatened or endangered under the Endangered Species Act — Snake River fall chinook, Snake River spring/summer chinook, Snake River sockeye, Snake River steelhead, upper Columbia River spring chinook, upper Columbia River steelhead, middle Columbia River steelhead, lower Columbia River spring chinook, lower Columbia River steelhead, upper Willamette River spring chinook, and upper Willamette River steelhead. (A note on terminology — what the Power Council and most everyone else calls the "mid-Columbia" region — above the confluence of the Snake River and below Chief Joseph and Grand Coulee dams — the National Marine Fisheries Service calls the "upper Columbia," as this part of the Columbia is now the farthest extent of anadromous fish migration, which defines the extent of the Fisheries Service's jurisdiction under the Endangered Species Act.) With regard to resident fish in the basin, bull trout and the Kootenai River white sturgeon have been listed by the U.S. Fish and Wildlife Service, and it is likely that others types of trout will be listed in the near future.

- **Protect and rebuild naturally spawning populations**

  Can artificial production programs be designed to avoid harm and assist in preserving and rebuilding naturally spawning populations? The basin has seen a proliferation of "supplementation" and "conservation" initiatives, which encourage many and worry others.

Thus the critical issues that the region faces on artificial production revolve around whether and how production activities can play a role in providing significant harvest opportunities throughout the basin while also acting to protect and even rebuild naturally spawning populations.

Congress and the region should be aware that artificial production policies and activities in the basin are in a state of transition, a rather dramatic transition in some cases. The stereotype of the hatchery and the production manager pumping out fish for possible harvest opportunities without awareness of the environmental context of that production or concern for the potential ecological effects no longer exists. The efficacy of traditional artificial production techniques and the possibility of adverse effects from artificial production on naturally spawning fish have been center-stage issues in the debates on artificial production in the basin for more than a decade.

Out of that debate has come a myriad of scientific and policy studies urging reform in artificial production, a series of efforts at policy reformulation, and continuing research into and theorizing about the many uncertainties in the interaction of artificially produced fish and their environment. Out of that debate has also come a number of actions and orders that constitute a partial step toward implementation of reforms in artificial production activities. The most recent event is the March 1999 Biological Opinion issued by the National Marine Fisheries Service under the Endangered Species Act. That opinion concluded that federally funded artificial production programs with non-endemic stocks are jeopardizing the continued existence of lower Columbia and Snake River steelhead listed under the ESA and prescribed changes in operations, in the form of Biological Opinion's Reasonable and Prudent Alternatives, to remedy that situation.

The Council concludes the region is less in need of policy development and more in need of focused actions and leadership to implement production policy reforms. The basin needs decisions and agreements at the basin, province[3] and subbasin levels on what it wants to accomplish in fish and wildlife recovery[4] as a whole and in each subbasin. The region also needs to determine what strategies seem most promising for reaching these objectives, and whether and how to use the artificial production tool in each subbasin as part of these strategies.

Decisions about the future of artificial production need to be based on the best available scientific knowledge of how river ecosystems function and how fish and wildlife populations survive and interact. And as these decisions are being made, the region also needs the will and the financial wherewithal to change artificial production operations to meet the identified needs. We will cooperate with production managers to meet a rigorous set of performance standards for modern

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[3] The term "Province" is applied to a group of subbasins that have similar ecological characteristics based on geology, climate and topography. The framework defines 10 Ecological Provinces in the Columbia River Basin.

[4] The term "Recovery," as used throughout this document, means to rebuild populations to sustainable and/or harvestable levels through protection, enhancement, and mitigation as expressed in the Northwest Power Act and the Council's Fish and Wildlife Program adopted thereunder.

artificial production operations. It will be necessary to provide sufficient resources to help managers meet those standards to bring about the necessary changes desired.

B. The Council's Artificial Production Review

A Coordinated Response to Regional and Congressional Concerns

The report of the Senate Committee on Appropriations on the FY 1998 Energy and Water Development Appropriations Act, Senate Report 105-44 (July 10, 1997), included the following directive to the Council:

> *Hatchery review report*—Due to budgetary constraints it is critical that federally funded programs, such as the hatchery programs for the Columbia River basin, spend limited Federal dollars wisely and in a cost-effective manner that maximizes the benefits to the fish resource. The Committee directs the Northwest Power Planning Council with assistance from its Independent Scientific Advisory Board to conduct a thorough review of all federally funded hatchery programs operating in the Columbia River basin, including an assessment of the hatchery operation goals and principles of State, tribal, and Federal hatcheries, and produce a formal recommendation for a coordinated policy for the future operation of federally funded hatcheries in the basin and how to obtain such a coordinated policy. National Marine Fisheries Service, U.S. Fish and Wildlife Service and the States of Oregon, Washington, and Idaho and Indian tribes in the basin should assist the Council in its review by providing information necessary to conduct a thorough review of federally funded hatchery programs. An independent, comprehensive review that examines all federally funded hatcheries and their roles in fishery restoration is long overdue.

Science Review Team -- Independent Scientific Review Supplies Framework for Reforms

Following Congress' request, the Council initiated what it has called the Artificial Production Review (APR). Part of the review involved the Independent Scientific Advisory Board (ISAB), as requested by the Senate Committee. With the help of the ISAB, the Council formed a Science Review Team (SRT), consisting of four ISAB members, two outside experts in artificial production and one scientist from the Council staff. The Council then asked the Science Review Team to review the state of the science of artificial production. The SRT produced an initial report in December 1998 and then revised that into a final report for the Council in April 1999.[5] A copy of the Science Review Team's report is included as Appendix 1 to this report. The recommendations of the Science Review Team have been incorporated in the policies and standards discussed in Part II of this report.

Production Review Committee -- Using Regional Experts and Stakeholders to Propose and Consider Reforms

Representatives of state and federal fish and wildlife agencies, the basin's Indian tribes, and non-governmental entities interested in artificial production worked on this report through an

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[5] Science Review Team/Independent Scientific Advisory Board, *Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin, A Scientific Basis for Columbia River Production Programs*, Northwest Power Planning Council, Document 99-4 (April 1999).

advisory committee formed by the Council — the Production Review Committee. The purpose of this work through 1998 and into 1999 was to collect information on production programs in the basin and to develop and debate various approaches to production policy. The committee is also helping develop performance standards that can be used to evaluate artificial production programs over time, as described in Part II.

Workshops and Draft Reports

Following the Science Review Team's initial report, the Council held a two-day workshop on January 19-20, 1999, to discuss production policy. Approximately 75 participants attended, including policy and technical representatives from tribal, state and federal agencies, members of the Science Review Team, Council members and staff, hatchery owners and operators, private fishing interests, conservation group representatives, utility representatives, and others. For purposes of discussion at the workshop, the Council staff developed a "Strawfish" proposal, a possible statement of production policy derived largely from the Science Review Team's initial report and recommendations, other scientific studies conducted over recent years, and a set of general scientific principles developed as part of what is known as the Multi-Species Framework process now underway in the region. Jim Waldo from the Gordon Thomas Honeywell law firm in Tacoma, Washington, facilitated the workshop. The facilitators produced a report to the Council discussing what happened at the workshop, recommending certain steps for the further development of the production policy statement, and recommending a set of actions for implementing reforms in artificial production policy.[6]

One lesson learned from the workshop was that the Science Review Team's initial science report and the Council staff's production policy "Strawfish" did not sufficiently consider the evolution in production policy and the emergence of ESA and consultation requirements during the last decade or adequately address resident fish. For this reason, the Council asked the SRT to reorient and supplement its initial report. While the SRT undertook that task, Council staff, with the aid of workshop facilitator Jim Waldo and further input from participants in the Production Review Committee, revised the production policy statement to capture a set of hypotheses, principles and policies based on developments in artificial production theory and practice embodied in a number of scientific and policy reports in the 1990s. The Council released the revised policy statement and the workshop facilitators' report to the public for review and comment, including a series of public meetings around the basin in March and April of 1999.

Just before the completion of the final SRT report, the National Marine Fisheries Service released the hatchery Biological Opinion described above (*see* footnote 1), including findings of jeopardy with regard to the effect of some production activities on listed steelhead. The Biological Opinion further changed, in significant ways, the dynamics of production policy and implementation, with the promise of even greater changes to come in the year 2000 with a further revised Biological Opinion to address new ESA listings (also in March 1999) in the basin. The final SRT report followed soon after. As revised, the SRT report is a scientific document that can be the basis for further considerations of production policy.

[6] *Facilitator's Report on the Columbia River Basin Artificial Production Workshop, January 19 and 20, 1999*, prepared by Gordon, Thomas, Honeywell, Malanca, Peterson & Daheim, P.L.L.C., for the Northwest Power Planning Council (February 23, 1999). Copies of this report are available upon request from the Council.

Following these events, the Council staff produced a draft report to Congress containing a proposed statement of production policy and recommendations for implementing policy reform. At its May 1999 meeting in Montana, the Council approved the release of the draft report for public review and comment. Based on the comments received during the public comment period, on further work by the Production Review Committee and the facilitation team (especially on performance standards and implementation recommendations), and on further reflection by staff and Council members, the Council revised its draft into this report to Congress.

II. Recommended Policies for the Future Role of Artificial Production in the Columbia River Basin

Congress asked the Council for "a formal recommendation for a coordinated policy for the future operation of federally funded hatcheries in the basin." Part II of the report provides that recommendation — a set of policies and performance standards to guide decisions on the use of artificial production for specifically defined purposes, based on scientific and management principles described below. In developing its policies for artificial production, the Council relied in part on the written recommendations of the independent Science Review Team, in response to Congress' legitimate concern that hatchery operations and decisions use the best available science.

A. Scientific Principles Provide Basis For Policy Changes
Best Available Science will Improve Chances of Success

Recent reviews of Columbia basin fish and wildlife activities highlighted the need to base fish and wildlife restoration efforts on fundamental ecological principles, with the river (and relevant parts of the Pacific Ocean) understood as a system of interacting biological and physical components (the ecosystem). These studies[7] also point to the elements of an ecologically based scientific foundation for fish and wildlife recovery. On that basis, the Multi-Species Framework Process developed an explicit scientific foundation to guide the development of an ecological framework. The foundation has eight principles:

1. The abundance and productivity of fish and wildlife reflect the conditions they experience in their ecosystem over the course of their life cycle.
2. Natural ecosystems are dynamic, evolutionary, and resilient.
3. Ecosystems are structured hierarchically.
4. Ecosystems are defined relative to specific communities of plant and animal species.
5. Biological diversity accommodates environmental variation.
6. Ecosystem conditions develop primarily through natural processes.
7. Ecological management is adaptive and experimental.
8. Human actions can be key factors structuring ecosystems.

These fundamental principles will be the basis, in the Framework process, for the measures used to characterize the Columbia basin ecosystem and its interrelated parts and to evaluate ecosystem changes that may result from various strategies and actions. These principles could later form the scientific foundation for an overarching fish and wildlife plan integrated across all elements of human interaction with the Columbia basin environment and the fish and wildlife in it, including evaluating and understanding the role of artificial production.[8]

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[7] The Independent Scientific Group's *Return to the River*, the National Research Council's *Upstream,* and *Wy-Kan-Ush-Mi Wa-Kish Wit*, the fish recovery plan of the Warm Springs, Yakama, Umatilla and Nez Perce tribes.

[8] For more details on the Multi-Species Framework Process, on the ecological analytical basis for that process, and on the scientific foundation principles and their scientific basis, see in particular two documents from the Framework process, available on the Framework web site (www.nwframework.org) and from the Northwest Power Planning Council: *An Ecological Framework for the Multi-Species Planning Process* (November 3, 1998), and *Development of a*

The Council considers the Artificial Production Review to be consistent with the scientific foundation of the Multi-Species Framework. The Council's focus in the production review has been to explore what these general scientific principles mean for artificial production and to recommend policies for artificial production consistent with the scientific framework.

To understand how the principles from the Framework specifically relate to artificial production, the Council, as directed by Congress, turned for advice to its Independent Scientific Advisory Board. The report of the Scientific Review Team is the result, attached to this report as Appendix 1. The Council developed the policies that follow in this Part, and its understanding of the "purposes" of artificial production, consistent with the scientific principles stated in the SRT's report.

B. Management Principles and Legal Mandates

Artificial production policies and decisions must be consistent with the array of legal mandates that relate to fish and wildlife management in the Columbia River Basin. These include, for example:

- Treaty fishing rights and other rights of Indian tribes such as those in the *U.S. v Oregon* litigation
- The obligation in the Northwest Power Act to protect, mitigate and enhance the basin's fish and wildlife affected by hydropower development
- The requirements of the Endangered Species Act
- Various mitigation obligations in law and agreement, such as the Mitchell Act, or John Day Dam mitigation, or the Lower Snake River Compensation Plan
- Wild fish policies of the states

Management objectives associated with these mandates — such as for harvest opportunities, or for in-kind, in-place mitigation, or for protection of specific natural populations — are equally important. Acting in a manner consistent with all these mandates is not easy — some are regional in scope and some are local, some objectives overlap, others conflict unless managed carefully. But they cannot be ignored even when inconvenient.

On this basis, all of the purposes for artificial production described below are considered legitimate and plausible management choices in the future. The Council understands its task as did the Scientific Review Team — to describe scientific ecological principles and associated policies that need to be considered when decisions are made on the use of artificial production. These principles and policies must be addressed for there to be a reasonable chance of achieving multiple management objectives that managers will identify out of their legal mandates, such as producing fish for harvest while protecting naturally spawning populations.

Regional Framework for Fish and Wildlife Restoration in the Columbia River Basin: A Proposed Scientific Foundation for the Restoration of Fish and Wildlife in the Columbia River Basin (July 7, 1998; Council Document No. 98-16).

C. The Five Purposes of Artificial Production

Artificial production is a tool used to address specific biological and management problems. To be able to evaluate whether to use the tool, and how effectively any particular use of the tool is, it is important to describe clearly the purpose of using artificial production, including the biological and management goals that it is intended to solve. The purpose of artificial production also guides the selection and application of production policies and the choice of performance standards. Thus it is necessary to describe the purposes first, and how the Council understands the purposes in the context of the broader ecosystem and management principles noted above, before describing the production policies.

Table 1 defines five purposes for artificial production, which are described further below. The purposes are based on scientific information summarized by the Scientific Review Team, the scientific focus of the Framework process, the experience and insights of the fishery managers, legislative and legal mandates, and the needs of the Council's Fish and Wildlife Program.

These purposes are described with respect to the *rationale* for using artificial production, a combination of the overarching social and legal *motivation* to do something about fish and wildlife, and the *biological problems* in the way of achieving the objective and that the use of artificial production will help surmount. The purposes are further described with respect to the *implications* of the decision to use artificial production to address the rationale, including a set of *assumptions* or conditions and a *duration* for the use of the tool.

The *assumptions* and *duration* are a function of the biological problem. For example, a motivation for using artificial production might be to hasten rebuilding of a depleted fish population. For this decision to make sense biologically, it has to include the *assumption* that the natural habitat is largely intact or is being restored, and that the main biological problem is that natural productivity cannot rebuild the population fast enough to satisfy the social or legal motivation. In this case, the *duration* of the action should be temporary—the natural system should take over once production numbers increase and artificial production is no longer needed.

This logic implies a certain type of facility and an investment of limited duration, as well as certain policies and performance criteria. At the time artificial production is planned and initiated, and at periodic times after development, the managing entity should explicitly identify the proposed purpose of the facility, and then be able, based on evaluation data, to make the corresponding determinations of problem, assumptions or conditions, and duration.

Table 1. Purposes of Artificial Production

	Rationale		Implications	
Purpose	**Biological Problem**	**Motivation**	**Duration**	**Assumption or Condition**
Augmentation	Limited natural production capacity in freshwater; capacity of other habitat areas supports increased production	Increase harvestable numbers of fish	Permanent, but flexible if changes in harvest become desirable because of social, legal, or biological reasons	• Freshwater habitat is operating at capacity • Harvest, ocean capacity, mainstem habitat does not limit production, therefore, there is excess capacity in other life stages • Artificially produced population can coexist with and not jeopardize fitness of natural populations

Table 1. Purposes of Artificial Production (cont.)

	Rationale		Implications	
Purpose	**Biological Problem**	**Motivation**	**Duration**	**Assumption or Condition**
Mitigation	Habitat has been permanently blocked or altered by human activities resulting in a decline in survival and/or capacity, or elimination of the fish population	Replace or compensate lost habitat capacity of naturally produced fish with artificially produced fish (anadromous or resident) for harvest or some other reason. This includes: • Artificial propagation to increase production of the affected resident or anadromous fish population • 2) Introduce or increase production of another anadromous fish species for the loss of anadromous fish or resident fish species for the loss of resident fish; and, • 3) Substitution of a resident fish species for the loss of anadromous fish in irrevocably blocked areas.	Permanent for the foreseeable future, but changes in the environment may make mitigation unnecessary	• No prospect for restoration of habitat that is being replaced by artificial production, at least not in other than long-term • Harvest, ocean capacity, mainstem habitat does not limit production, therefore, there is excess capacity in other life stages • Artificially produced population can coexist with and not jeopardize fitness of natural populations

Table 1. Purposes of Artificial Production

	Rationale		Implications	
Purpose	**Biological Problem**	**Motivation**	**Duration**	**Assumption or Condition**
Restoration	Low or no natural production, but potential for increase or reintroduction exists because habitat capability is sufficient as it exists or due to restoration activities	Hasten rebuilding or reintroduction of a population to harvestable levels	Temporary (recognizes that duration may be long-term, but habitat will be or is adequate to support fish populations without artificial propagation.)	• Habitat is good or in the process of being restored as artificial production program is being implemented • Harvest, ocean capacity, mainstem habitat does not limit production, therefore, there is excess capacity in other life stages • Artificially produced population can coexist with and does not jeopardize fitness of target and other natural populations.

Table 1. Purposes of Artificial Production (cont.)

	Rationale		Implications	
Purpose	**Biological Problem**	**Motivation**	**Duration**	**Assumption or Condition**
Preservation/ Conservation	• Extremely low population abundance causes potential for extinction or losses of genetic diversity • Correctable habitat deterioration	Conserve genetic resources of fish populations impacted by habitat loss or degradation, including preservation of populations faced with imminent demise using methods such as captive propagation and cryopreservation.	Temporary (until causes of natural population decline are rectified)	• Genetic characteristics can be maintained via artificial propagation • Habitat problems will be corrected in the immediate or distant future
Research	Critical uncertainties from the other purposes, plus specific critical uncertainties with application of artificial propagation	How to effectively use artificial production to address the other motivations	Dependent on study design, objectives, and results	An explicit experimental design capable of providing usable answers to specific problems.

Augmentation

An augmentation artificial production program provides fish for a specific reason, such as harvest, in numbers beyond the capability of the natural system. It operates within an intact natural system that is functioning at or near its natural capacity in the freshwater juvenile life stage, with excess capacity available at other life stages. It augments natural productivity to address a social motivation, such as the desire for harvest greater than the existing natural system can sustain.

Because the Columbia River Basin is heavily altered from its natural state, there are few examples of augmentation facilities in the basin. Examples can be found, however, in southeast Alaska, where artificial production programs augment the production from largely intact natural systems for harvest. Possible examples of augmentation programs in the Columbia River might include some resident fish hatcheries that are used to provide “put and take” fisheries in otherwise intact natural lake systems.

Mitigation

Artificial production programs are frequently used to mitigate for the loss or reduction of specific fish populations because of destruction or significant degradation of freshwater habitat by human activities. The artificial production is provided as compensation for the fish capacity lost to allow development of the habitat for other human uses. The loss of habitat to be mitigated is essentially permanent. Most artificial production programs in the Columbia River Basin fall into this category. (Mitigation production programs are sometimes referred to as compensation programs. This is usually done to avoid the term "mitigation," which is used in a confusing number of ways.)

For example, several salmon production programs in Idaho are intended as mitigation for blockage of the Snake River by Hells Canyon Dam. Similarly, the artificial production programs of the Lower Snake River Compensation Plan were constructed to compensate for the fish passage loss and reduction in quality of salmon habitat associated with construction and operation of Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams. Some artificial production programs above blocked areas, such as Hells Canyon and Chief Joseph dams, mitigate for salmon losses with resident fish species. Production of resident native, and in some instances non-native, species that are adapted to the existing altered environment may be preferable to species that inhabited the basin before development.

In theory, a mitigation production program compresses the production potential of the lost habitat, for one or more life-stages of the population to be propagated, into the artificial habitat of one or more hatcheries. In anadromous and resident fish mitigation programs, the production from this habitat still must exist within the remainder of the natural ecosystem. For resident fish substitution programs[9], the habitat available must meet the needs of the substituted species of resident fish. The degree the artificial production program can compensate for lost habitat will depend in part on the quality of the habitat outside the hatchery in which the fish will spend the remainder of its lifecycle, and on the overall biological fitness of the propagated species in the habitat outside the hatchery.

Restoration

Artificial production has been proposed as a means to speed or "jump-start" recovery of natural populations, especially in order to achieve a harvestable population size. A restoration program assumes a population is reduced or eliminated by habitat degradation or other effects (e.g. overharvest), but that the problem has or is being corrected and the existing biological system is now or will soon be capable of sustaining natural production. The motivation for the facility is that society does not wish to wait for natural productivity to rebuild the population. An extreme case of a restoration production program is where the natural population has been eliminated, and fish are reintroduced by artificial production when the problem causing the extirpation is removed. A restoration program is a temporary measure that will be withdrawn once the natural population is rebuilt or a determination is made that restoration is not possible.

[9] Policies and measures for resident fish substitution are in Sections 10.1 and 10.2 of the Council's Fish and Wildlife Program. The intent of this policy is to replace losses of anadromous fish in areas now permanently blocked to salmon and steelhead with resident fish species.

For example, suppose chinook were eliminated from a watershed because irrigation withdrawals effectively dried up parts of the river in late summer. Action was then taken to reduce withdrawals and re-open the river to passage. With the native population eliminated, a restoration facility could be used to rear and release a compatible population that would be encouraged to return and spawn in the habitat. Over time the artificial production program would be phased out as the natural population rebuilt.

Preservation/Conservation

In recent years, as numerous salmon and resident fish populations declined alarmingly, artificial production programs have been proposed to preserve the genetic resources of very small populations pending future rebuilding. This is recognized as an undesirable result of not identifying and addressing a situation with a population that should have been addressed at an earlier point in its decline with a less extreme approach for recovery. Populations that require preservation/ conservation face imminent demise or extirpation and, in most cases, are listed under the federal Endangered Species Act. In these situations, without immediate protection, the population will be extirpated, and the genetic resource lost. In certain situations, intervention in emergency situations may be desirable in the absence of a plan. In these situations, a plan for recovery must be developed and implemented immediately. Appendix 3 contains interim standards for captive propagation that should provide guidance for certain types of preservation and conservation activities.

A preservation production program, involving the use of techniques such as captive propagation and cryopreservation, is an emergency, temporary measure. A reasonable assumption is that the longer a population is reared in the captive environment, the less it will resemble the original naturally producing population in regard to genetics and behavior. Hence, the duration of the preservation/conservation purpose should be minimized. Therefore, it requires an explicit recovery plan with a compressed timeframe for return of the fish to the wild and an effective plan for dealing with the underlying habitat or management problem. Without such a plan, a preservation hatchery could become simply a museum to preserve fish with uncertain connections to the natural population structure, rather than a program of protective custody.

Research[10]

What initially seemed like a rather straightforward application of engineering and animal husbandry has proven to be a thorny problem of melding technology with the natural biological system. The Scientific Review Team and other scientific observers continue to point to a wide range of biological uncertainties and problems associated with artificial production. This indicates the need for a concerted research program to investigate specific problems and an aggressive evaluation program to track progress and identify success and failure.

Because artificial production is an evolving technology, *all* artificial production programs have a research and evaluation function. Within an overall plan to evaluate and develop the technology, individual programs could be used experimentally. But it is not cost-effective or necessary to undertake research into the difficult and critical uncertainties at every facility. Instead, some facilities are designed specifically to carefully examine specific questions. The distinguishing feature of a research program is its operation within a strict experimental design. It likely has

[10] Among other things, the research purpose addresses SRT guideline number 3 (see Appendix 1).

facilities to allow replication and testing. Importantly, a research facility should have an explicit mechanism to convey its results to the larger community so its techniques can be refined and replicated where effective.

Combinations of purposes/shifts in purpose

A hatchery facility or program may serve more than one purpose. A particular facility may contain more than one population and operate for a different purpose for the different populations. For example, the Bonneville hatchery now serves as a mitigation and a preservation facility for different populations.

A second situation is where a facility serves dual purposes for one population. For example, the Umatilla hatchery has a *restoration* function, intended to help re-seed the natural productive capacity of the Umatilla River, and a *mitigation* function, as mitigation for permanent habitat degradation in the Umatilla and mainstem Columbia. If so, the permanent *mitigation* aspect of the hatchery might continue, even as the temporary *restoration* aspect comes to an end, but with an appropriate shift in operations. In another example, the production program in the Grande Ronde River is combining aspects of restoration and preservation. It is legitimate for a hatchery to have a combination of purposes, but the multiple purposes need to be clearly identified and the implications addressed.

Because motivations and problems change over time, the purposes for artificial production will also change. The purpose of some existing hatcheries is now quite different from the purpose for which they were originally constructed. Production programs that were originally intended as mitigation for loss of habitat due to dam construction or other development, for example, are now being evaluated for their use as preservation/conservation facilities. As problems and motivations change during time, it is important to refine the purpose because policies and performance criteria for the facility will change accordingly. In a later section of this report, the Council recommends the re-evaluation of the purposes of each artificial production facility and program over the next three years.

D. Policies to Guide the Use of Artificial Production

The scientific principles, legal mandates, and purposes provide the backdrop for policies on the use of artificial production. Decisions to use the tool of artificial production, and how to use it, need to be made in a scientifically sound manner to achieve management objectives by addressing specific biological problems. The following policies are intended for that purpose — to be applied to allow for a detailed understanding and evaluation of artificial production in the basin.

These policies need to be considered in the context of the natural conditions of the Columbia River Basin as it now exists. In most places, this ecosystem is significantly altered from the time when Europeans began inhabiting the basin more than 150 years ago. This means that fish populations adapted to the original "natural" conditions of the Columbia basin may not be the same as those that are now or could be naturally produced. This does not mean that habitat will not be improved to be more productive for native fish populations and species, but only that the original habitat conditions are not achievable in the foreseeable future. Therefore, when these policies speak of natural conditions, they are referring to current or foreseeable improvements in the existing, altered ecosystem. Production for harvest is a legitimate management objective of artificial production. However, to minimize the particular adverse impacts on natural populations associated with harvest management of artificially produced populations, harvest rates and practices must reflect or be dictated by the requirements to sustain naturally spawning populations.

1. **The manner of use and the value of artificial production must be considered in the context of the environment in which it will be used.**[11]

Artificial production must be used consistent with an ecologically based scientific foundation for fish and wildlife recovery. A number of considerations are embedded in this policy, including:

- The success of artificial production depends on the quality of the environment in which the fish are released, reared, migrate and return.
- Artificial production provides protection for a limited portion of the life cycle of fish that exist for the rest of their lives in a larger ecological system, albeit altered, that may include riverine, reservoir, lake, estuarine and marine systems that are subject to environmental factors and variation that we can only partially understand.
- The success of artificial production must be evaluated with regard to sustained benefits over the entire life cycle of the produced species in the face of natural environmental conditions, and not evaluated by the number of juveniles produced.
- Domestication selection is the process whereby an artificially propagated population diverges in survival traits from the natural population. This divergence is not avoidable entirely, but it can be limited by careful hatchery protocols such as those required by policies in this report.
- For actions that mitigate for losses in severely altered areas, such as irrevocably blocked areas where salmon once existed, the production of non-native species may be appropriate in situations where the altered habitat or species assemblages are inconsistent with feasible attainment of management objectives using endemic species.

2. **Artificial production must be implemented within an experimental, adaptive management design that includes an aggressive program to evaluate benefits and address scientific uncertainties.**[12]

The ability of artificial production to provide sustained management and biological benefits over the entire life cycle and throughout the ecosystem, and to minimize adverse effects to naturally spawning populations, remains a topic of debate.

3. **Hatcheries must be operated in a manner that recognizes that they exist within ecological systems whose behavior is constrained by larger-scale basin, regional and global factors.**[13]

The performance of artificial production programs should mirror the dynamics and behavior of the larger system. Expectations of constancy in either returns or management are unrealistic.

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[11] This policy should be implemented in a manner that addresses SRT guidelines 1-2 and 4-13 (see Appendix 1).
[12] This policy should be implemented in a manner that addresses SRT guidelines 16-19 (see Appendix 1).
[13] This policy should be implemented in a manner that addresses SRT guidelines 1-2 and 4-13 (see Appendix 1).

- Management of artificial production, and the expectations of that management, should be flexible to reflect the dynamics of the natural environment. Production and harvest managers should anticipate large variation in artificial production returns similar to that in natural production.
- The management and performance of individual facilities cannot be considered in isolation but must be coordinated at watershed, subbasin, basin and regional levels, and must be integrated with efforts to improve habitat characteristics and natural production where appropriate.

4. A diversity of life history types and species needs to be maintained in order to sustain a system of populations in the face of environmental variation.[14]

Recent scientific reviews have indicated that effective restoration of fish populations to the Columbia River may depend far more on protecting and restoring biological diversity and habitat than simply increasing abundance. A central management consideration in all artificial production should be to minimize adverse effects on biological diversity and, to the extent possible, to use the artificial production tool to help reverse declines in biological diversity.

5. Naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, mating protocol, behavior, growth, morphology, nutrient cycling, and other biological characteristics.[15]

Natural selection hones the characteristics of fish populations against the template of the natural environment. These dynamics shape natural populations so that they collectively have the characteristics necessary to sustain the species in the face of environmental variation. These naturally selected populations thus provide a model that should at least guide the efforts to sustain successful artificially reared populations, even if replicating all natural conditions is not feasible. The use of locally adapted or compatible broodstocks, and a corresponding reduction in the use of population transfers and non-endemic populations, is a significant part of this policy.

The implications of this policy may differ somewhat depending on whether the focus is to improve survival of artificially produced fish, avoid adverse impacts on natural populations, or use artificial production to try to restore naturally spawning populations. How this policy applies in any particular situation should be tested using the following three working hypotheses:

- With regard to increasing the survival of the hatchery population itself, the working hypothesis is that mimicking the incubation, rearing and release conditions of naturally spawning populations will increase survival rates after release into the natural environment. Some efforts to mimic natural rearing processes, such as the use of shading, are generally accepted as appropriate practices. Uncertainty lies in how far managers should go in mimicking natural rearing conditions in an effort to improve survival, especially considering the increasing cost, the difficulty of some measures, and the possibility of declining benefits. In addition, there are certain situations in which the survival of artificially produced fish appears to be enhanced by *not* mimicking natural

[14] This policy should be implemented in a manner that addresses SRT guidelines 1-2 and 4-15 (see Appendix 1).
[15] This policy should be implemented in a manner that addresses SRT guidelines 1-2 and 4-13 (see Appendix 1).

release size or migration times. Decisions to deviate from the biological characteristics of the naturally spawning population should be documented through an explicitly stated biological rationale and carefully evaluated. In addition, the efficacy of programs that mimic natural populations should continue to be tested to reduce uncertainty.

- With regard to the possibility of adverse impacts of artificial production on naturally spawning fish, much of the recent literature suggests that using local broodstocks and mimicking natural rearing conditions will reduce the impacts of artificially produced populations on naturally spawning populations and the ecosystem. There is a counter-hypothesis that, at least in some situations, it is best for artificial production managers to avoid mimicking the release times, places, and conditions of natural populations to avoid harmful competition, predation and other adverse interactions. Again, any decisions to deviate from the biological characteristics of the naturally spawning population should be documented through an explicitly stated biological rationale and carefully evaluated.

- The final working hypothesis, which applies to artificial production for the *restoration* purpose, is that through the use of locally adapted or compatible broodstocks and natural rearing and release conditions, artificial production can benefit or assist naturally spawning populations. This is the least established hypothesis of the three, and the one most in need of experimental treatment and evaluation.

6. **The entities authorizing or managing a artificial production facility or program should explicitly identify whether the artificial propagation product is intended for the purpose of augmentation, mitigation, restoration, preservation, research, or some combination of those purposes for each population of fish addressed.**[16]

Existing determinations of the purpose(s) for all artificial production facilities and programs should be revisited within the next three years, and periodically thereafter. These evaluations should take place *only* in the larger context of decisions on fish and wildlife goals and objectives for the Basin, provinces and subbasins (*see* the next part of the report for more detail). Also, a decision to build or continue artificial production for a specified purpose must include an explicit identification of the underlying biological problem, an explicit determination that the assumptions or conditions relating to that artificial production purpose do exist, and an explicit expectation of the duration of the program:

- A decision identifying an artificial production program as a "permanent" *mitigation* program should be accompanied, for example, by an explicit identification of the permanently lost habitat that it replaces.
- A decision identifying a *restoration* program should include, for example, an explicit determination that suitable restored habitat exists or will soon exist for re-seeding. It should also include a statement of the expected duration of the program, by which it is expected the natural population will be rebuilt and the facility withdrawn (or continued with a different identified purpose).
- Similarly, a decision identifying a *preservation/conservation* program should include, for example, an explicit determination that the underlying habitat decline or other problem-

[16] This policy should be implemented in a manner that addresses SRT guidelines 3, 9 and 14 (see Appendix 1).

threatening extirpation will be addressed and how. This decision should also include a statement of the expected duration of the program, the time by which the program will be evaluated to determine if it is a success (meaning the time by which it is expected that natural processes can once again sustain the population, and the facility withdrawn or converted to another identified purpose) or a failure (meaning that it is time to end or reorient the program).

7. **Decisions on the use of the artificial production tool need to be made in the context of deciding on fish and wildlife goals, objectives and strategies at the subbasin and province levels.**

While decisions on the use of artificial production are best made in the subbasin context, these decisions also need to be consistent with basinwide and regional considerations and objectives. The monitoring and evaluation framework for artificial production facilities and programs should also have a regional/basinwide aspect as well as specific subbasin elements.

8. **Appropriate risk management needs to be maintained in using the tool of artificial propagation.**[17]

As critically important as monitoring and evaluation are, it is most difficult, and in some cases still impossible, to monitor and evaluate the effects we most care about, such as complex ecological interactions, ocean effects and interactions, and the relationship between changes in artificial production practices and ultimate adult returns. The same is true of other aspects of the complex biological problem of fish and wildlife recovery, so the risk management strategies applied to artificial production should be generally consistent with those applied to other stages of the life-cycle and to other factors affecting the status of populations.

9. **Production for harvest is a legitimate management objective of artificial production, but to minimize adverse impacts on natural populations associated with harvest management of artificially produced populations, harvest rates and practices must be dictated by the requirements to sustain naturally spawning populations.**[18]

10. **Federal and other legal mandates and obligations for fish protection, mitigation, and enhancement must be fully addressed.**

Efforts to address these mandates and obligations have historically been unsuccessful, at least in large part. The principles, policies and purposes identified here are not intended to diminish or otherwise affect these mandates and obligations. At the same time, it is recognized that these mandates and obligations can be, and might be, altered, by the appropriate authorities in response to this document or other events.

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[17] This policy should be implemented in a manner that addresses SRT guidelines 16-17 (see Appendix 1).
[18] This policy should be implemented in a manner that addresses SRT guideline 17 (see Appendix 1).

E. Performance Standards [19]

Artificial production programs can be evaluated against the set of general policies described above. But more can be gained by translating the general policies into specific and detailed performance standards and then evaluating artificial production programs against those standards. For example, the general policy calling for the biological characteristics of natural populations to be the model for artificial production can be further developed into a number of more specific operational standards, such as maintaining sex ratios, migration timing, and age composition.

Over the last few years, a number of agencies, inter-agency teams or scientific panels have developed partial or comprehensive sets of guidelines and standards to be used to evaluate artificial production. The guidelines in the Science Review Team's final report are but one example; the most comprehensive effort is the Integrated Hatchery Operations Team's (IHOT) *Policies and Procedures for Columbia Basin Anadromous Salmonid Hatcheries* from 1995. All of these efforts have been sensitive to the modern concerns for minimizing harm to natural populations. At the same time, it is possible that some of the standards developed even in the recent past are not consistent with the principles and policy statements that the Council recommends in this report.

For this reason, participants in the Artificial Production Review, working with Council staff and facilitators, organized an ad hoc workgroup to pull together a set of performance standards that can be used in a consistent manner to evaluate artificial production operations in the future. Attached to this report is a draft of the performance standards that the group developed, using the policies and purposes in this report, the guidelines in the Science Review Team's report, and the IHOT policies as a foundation for these draft standards. The performance standards are still in draft form, as the Council intends to seek peer and public review before making a final recommendation.

[19] This policy should be implemented in a manner that addresses SRT guideline 18 (see Appendix 1).

III. Implementing Reform in Artificial Production Policy and Practices

A. Six Implementation Recommendations

Declaring the best possible set of artificial production policies is not enough. The policies must be implemented. "Implementation" of the policies for production reform means two different things. First, some of the policies, purposes and scientific principles described above are intended to inform decisions on whether, where, why and when to use the artificial production tool to help meet regional, provincial, and subbasin fish and wildlife goals. The second meaning of "implementation" has to do with how to operate a production facility once a decision is made to have or continue having the facility for a specific purpose. The critical issue in this second meaning is how to apply the policies and performance standards described in this report to help boost the survival of artificially produced fish while minimizing harm to and possibly benefiting naturally spawning populations.

What is required now is an intensive effort to integrate and coordinate the region's resources over the next few years to achieve the goal of artificial production reform consistent with the policies recommended in Part II. To be successful, this program will require leadership not only from the Northwest Power Planning Council, but also from federal and state agencies, Indian tribes, the sport and commercial fishing communities, wild fish advocates, and the scientific community. As a result of the Artificial Production Review, which included the active participation of leaders from all of these communities, the Council is confident that the recommended work plan will succeed in managing and directing the necessary reforms of artificial production in the Columbia River Basin.

Six basic recommendations form the core of the Council's vision for implementation of the policies and standards for artificial production reform:

1. *Evaluate the purposes for all artificial production facilities and programs in the basin within three years, applying the principles, policies and statement of purposes recommended above.*

This recommendation is discussed in more detail below, in Part IIIB. The re-evaluation of artificial production programs should not take place in isolation, but instead in the broader context of a subbasin planning process that considers and adopts comprehensive fish and wildlife objectives and strategies for each subbasin, consistent with fish and wildlife objectives at the basinwide and province levels. Applying the principles, purposes and policies recommended in this report will help decisionmakers analyze whether and how to use the artificial production tool to meet broader objectives.

One task discussed in more detail below is the need to further refine, relatively quickly, the evaluation standards and tools, such as the use of the draft Hatchery and Genetic Management Plan (HGMP) template currently under development, that will enable the reform initiative to proceed efficiently (see Appendix 4). A multi-agency group first developed the HGMP concept as a planning tool to address anadromous fish in the *U.S. v Washington* litigation. The National Marine Fisheries Service is in the process of modifying the HGMP template for use in recovery efforts for listed salmon species under the ESA. The U.S. Fish and Wildlife Service is considering using the

HGMP template, modified as necessary, to address the needs for recovery of resident fish species listed under the ESA. The Council and other participants in the Artificial Production Review are also reviewing and modifying the draft HGMP template so that it can be used to obtain the kind of information needed from artificial production programs throughout the Columbia Basin to be able to implement the production reforms described in this report. The intent is to modify the HGMP template so that it addresses both resident and anadromous fish and is complementary to the performance standards and associated indicators.

2. Applying the policies and standards in Part II, take the necessary steps to evaluate and then improve the operation of artificial production facilities that have an agreed-upon purpose.

This recommendation is discussed in more detail below, in Part IIIC. The main focus in reforming operations should be to increase the survival of the artificially produced fish while minimizing adverse effects on and possibly benefiting naturally spawning populations.

3. Use existing processes as much as possible to implement reform policies and standards.

It would be easy if one body were in charge of all Columbia River artificial production programs, and had the will (or obligation) and the funds for implementation of these recommendations. That is not the case, not even with all federally-funded artificial production programs. Like many things in the Columbia River, responsibility for production programs is spread throughout a number of governmental and non-governmental entities, funding sources differ, operating agencies are often distinct from authorizing or funding agencies, management authority and regulatory or planning authority are often separate, and funds are limited or committed in relatively inflexible ways. All of these factors make coordinating and implementing reform a challenge. Artificial production reform cannot wait while we debate the need for a super decisionmaking body.

On the other hand, the region has a number of potentially effective tools for implementing desired changes in production practices, especially including existing planning processes, project funding reviews, ESA reviews, and the re-negotiation of the Columbia River Fish Management Plan in the *U.S. v. Oregon* litigation. These tools will need to be coordinated and managed effectively. Each is somewhat limited in its reach. These implementation tools are noted briefly below, and discussed in more detail as part of the description of the policy landscape in Appendix 2.

Thus the Council recommends at this point the use of existing planning, review and funding processes for implementing reforms in artificial production policy and practices, but with this understanding: the decisions in these processes must be made consistent with the principles, purposes, policies and standards described in this report. Examples of how these existing processes can be used are discussed below in both Parts IIIB and IIIC. In the next few months, the Council will coordinate with states, tribes, federal agencies and other interested participants to refine further how these existing efforts can be better organized and integrated to accelerate needed reforms.

4. Ensure that the funding necessary to implement the reforms called for in this report is available.

This recommendation is discussed in more detail below, in Part IIID.

5. Form an ad hoc oversight team to oversee the implementation of artificial production reform consistent with the policies recommended in this report.

Responsibilities for artificial production programs and facilities are spread among a number of agencies and levels of government, yet it is important to implement artificial production reform across the basin in a consistent, coordinated and efficient manner. A *small* team of key agency personnel, independent scientists, and representatives of influential non-governmental organizations assigned to watch over and coordinate the reform effort would be of benefit. The Council recommends that such an ad hoc team be formed, and will initiate the discussions to form the team, evolving from the existing participants in the Artificial Production Review and Multi-Species Framework process. One early task for the team will be to further define the approach, work plan and decision points for evaluating the purpose of all the artificial production programs and facilities over the next three years.

6. In five years, assess the success in using existing processes to implement reforms

The Council believes this is not the time for creation of a single new body and process to review all artificial production programs in the basin and make definitive decisions on hatchery reform or closure. That time may come, if the efforts over the next few years do not bear the expected fruits. After five years, the Council, other regional decisionmakers and Congress should assess whether existing review, funding and planning processes are successful in implementing needed reforms in artificial production practices. In the interim, the entities responsible for artificial production programs should issue annual reports on their progress in achieving the policies and standards called for in this report. The Council is willing to act as a clearinghouse to obtain, compile, and distribute these annual reports for review by decisionmakers and the public.

B. Evaluating the Purposes for All Artificial Production Facilities and Programs in the Basin

The policies, purposes and scientific considerations described above are intended to inform decisions on the use of the artificial production tool to help meet regional, provincial, and subbasin fish and wildlife recovery goals. In other words, to help answer the fundamental question, do you want to use x hatchery (or build y hatchery) and for what purpose? That question is essentially a policy question, but it is not open-ended — the answers must be consistent with the biological and policy considerations concerning artificial production described above.

1. Initial evaluation of purposes of artificial production facilities and programs

For existing production programs and facilities, a decision of what the purpose or purposes are has already been made, if not always on a clear foundation. But our understanding of the biological and policy framework for fish and wildlife recovery in the basin has changed in the last decade and will be changing further, as is also true of the biological and policy principles for how artificial production might fit into the broader fish and wildlife objectives.

For this reason, purposes for existing artificial production facilities and programs need to be evaluated immediately, based on the template of purposes described in Part II. A reasonably aggressive schedule for re-evaluation of the purposes of all the artificial production programs in the

Columbia basin appears to be three years. The outcomes of these evaluations might be to continue with existing purposes, change purposes, expand purposes, or shut down the facility. These purposes need to be evaluated in the context of the environment (at the basin, province and subbasin levels) and in relation to overall fish and wildlife goals, objectives, strategies, and requirements.

The ultimate goal, described in the next section (IIIB2), is to evaluate the purposes of artificial production in the context of agreeing-upon new subbasin plans. Regardless, interim evaluations of the purposes of existing facilities should not wait until the region completes the upcoming regional planning efforts (such as the completion of the Framework analysis and the amendment of the Council's fish and wildlife program) and initiates the subbasin planning process. Managers must use whatever existing processes that they already face — such as annual funding reviews — to begin the evaluation of the purposes of their facilities. Until new subbasin assessments and plans are completed, managers and evaluators should rely on information already available or soon to be available, including but not limited to:

- the scientific principles, policies and purposes in this report
- the template for Hatchery and Genetic Management Plans (currently under development)
- the province-level analysis from the Framework process (currently under development, and expected by the end of 1999)
- existing subbasin plans
- Independent Hatchery Operations Team guidelines
- the Science Review Team's report
- *U.S. v. Oregon* products and agreements
- Biological opinions addressing the Endangered Species Act
- Independent hatchery audits contracted by Bonneville Power Administration

<u>Recommendation:</u> ***Over the next three years, review and determine the purpose for every artificial production program and facility in the basin, federal and non-federal, consistent with the principles, purposes and policies described in Part II of this report. These evaluations should be a prerequisite for seeking continued funding or approvals in whatever funding and approval reviews that the facility or program faces in the next few years.***

2. Evaluation of purposes of artificial production facilities and programs over time — the need for subbasin plans

Artificial production is not an end in itself. It is only one of many possible tools for meeting fish and wildlife objectives, and the need for and effectiveness of the tool must be evaluated as objectives evolve. It is generally agreed that the region must come together on medium-term to long-term decisions on fish and wildlife recovery for the Columbia River. More precisely, we urgently need agreements and decisions at the basin, province, and subbasin levels on what we want to accomplish in terms of fish and wildlife recovery in the basin and what strategies seem most promising for rebuilding naturally sustaining populations to healthy, harvestable levels as well as mitigating for habitat irrevocably altered by the construction and operation of the hydropower system. These decisions and agreements need to be based on the best available scientific knowledge of how lake, river, estuarine, and ocean ecosystems function and how fish and wildlife populations survive and interact. And it is as a part of these larger decisions that decisions need to be made on whether and how to use the artificial production tool in each subbasin, consistent with the policies, purposes and principles described in Part II.

The planning and decision making process that this implies is precisely what the salmon and steelhead system and subbasin planning process of the late 1980s was intended to achieve. (See the discussion in Appendix 2.) That process never came to an ultimate conclusion because of significantly changing circumstances, including the first Endangered Species Act listings, just as the planning process was nearing a conclusion. The need still exists, and the time is ripe to return to the task. Although this planning originally was limited to the area below Chief Joseph and Hells Canyon dams, it should address the entire Columbia Basin and include not only salmon and steelhead, but also resident fish species.

There are a number of Columbia basin fish and wildlife planning processes in operation or about to begin that could be, in whole or in part, a vehicle for this effort to evaluate the purposes of artificial production in the broader context of basin and subbasin goals and objectives. Precisely how to proceed, and how to make use of and coordinate the various planning processes, needs serious thought and discussion among the various entities in the basin. The Artificial Production Review is not the forum where these discussions should occur, but the initial evaluations of artificial production purposes called for above (IIIB1) should provide valuable building blocks for anticipated work on subbasin assessments and plans.

One plausible vehicle for re-initiating this subbasin planning effort is the Council's Fish and Wildlife Program amendment process. The 1987 amendments to the Council's Columbia River Fish and Wildlife Program led directly to the first effort at salmon and steelhead system/subbasin planning. The Council will likely begin a Program amendment process later in 1999. An outcome of that Program amendment process could be a policy and biological framework of recovery goals and biological objectives for the basin or system as a whole and for at least the ecological province level; a framework and process for completing the planning process at the subbasin level for anadromous and resident fish; and decisions (or policies and criteria to guide decisions) on whether, where, why, when, and how to use the artificial production tool to try to achieve these objectives. The Council cannot itself make the subbasin planning determinations within the Program amendment process, for a number of reasons. These determinations are better made in decentralized processes involving the relevant participants at the subbasin level, at most guided by a broader policy and scientific framework. Nor can the Council determine conclusively in its Program the future of all the production programs in the basin, since many of them are authorized and funded outside of the Council's Fish and Wildlife Program.

What the Council's Program amendment process can do is be a regionally coordinated effort at developing a policy and biological framework of goals, objectives and policies for the system as a whole and logical ecological provinces. It will also provide the basis and the framework for a subsequent subbasin planning process at which the responsible participants decide on the objectives for each subbasin and the role of the various artificial production programs in meeting those objectives.

The Council's late 1980s Program amendment process, and the salmon and steelhead system and subbasin planning process that came out of it, began with the negotiated agreement of the Columbia River Fish Management Plan by certain states and tribes and the federal government as part of the *U.S. v. Oregon* fish harvest litigation. The Management Plan went beyond harvest management concerns to include a set of rebuilding commitments, production objectives and plans as part of that commitment, and a recommendation for the subbasin planning process. (see Appendix 2). The same dynamic is present now — the Columbia River Fish Management Plan expired at the end of 1998, although the court extended the application of the plan into 1999 while the federal, state and tribal participants negotiate a revised plan. If completed and appropriately structured, the product of the Management Plan negotiations could once again be integrated with the Council Program amendment process.

The dynamics are different than in the mid-1980s, with ever-growing Endangered Species Act concerns and review requirements, an agreement on the magnitude of funds that will be spent on the fish and wildlife program annually, greater consideration of the fish and wildlife needs in areas outside the purview of the *U.S. v. Oregon* participants, independent science review procedures for funding implementation of the Fish and Wildlife Program, and especially a growing scientific and policy emphasis on ecological processes, as opposed to technological processes to rebuild fish and wildlife populations. The Management Plan renegotiations thus cannot take place in a vacuum and be simply handed to the Council to place in the Program — the negotiations and the results have to be sensitive to and coordinated with these other elements. As noted above, the Fish and Wildlife Program has its own limitations, especially the limited focus on hydropower system mitigation in a basin with a multi-faceted problem, the fact that a number of the important production programs are outside the Program, and the Council's lack of direct implementation authority. The Fish and Wildlife amendment process and the Management Plan renegotiations, if properly coordinated, can achieve far more together than either apart, as they can balance each other's limitations.

Another possible vehicle for initiating review of the use of artificial production could be multi-species recovery planning for the Columbia River basin under the Endangered Species Act. The federal agencies are at work on a "4H" paper as a precursor to the recovery plans that will include consideration of the artificial production needs in a broader context. The Council expects that the general analysis in the 4H paper will mirror the considerations and policies in this report. Like the other planning processes, ESA recovery planning has peculiarities and limitations, including a defined approach to recovery of self-sustaining population numbers that may be far too low to be relevant to what people want out of fish populations in the basin. ESA recovery planning and its affects on artificial production in the future needs coordination and shared analysis with the other planning process.

One vehicle that already exists for linking these planning processes into a shared analytical and substantive focus is the on-going Multi-Species Framework process. The Council joined with the other entities in the basin precisely to provide a coordinated and unified biological and social-economic analysis that will help decisionmakers define ecological objectives and strategies for fish and wildlife recovery in the basin as a whole and at finer levels of geographic scale. This analytical process could eventually include, it is hoped, evaluating the efficacy of artificial production techniques in helping to meet broader defined recovery goals and objectives. This will allow for informed decisions on whether and how to incorporate the use of the artificial production tool into basin and subbasin objectives.

***<u>Recommendation:</u>* The Council expects that by sometime in 2000, the ultimate conclusion of various analytical, planning and decision making processes in the region (e.g., the Multispecies Framework process, the Council's Fish and Wildlife Program amendment process, the federal**

agencies' ESA decisions, and Management Plan re-negotiations in U.S. v. Oregon) will be the initiation of a comprehensive subbasin planning process, guided in part by basin and province-level goals and objectives, overarching policies for artificial production based on the policies in this report, and criteria for subbasin planning. The purpose or purposes of all artificial production facilities must be re-evaluated in that subbasin planning effort, consistent with the policies in this report.

C. Applying the Policies and Performance Standards to Evaluate and Improve the Operation of Artificial Production Facilities

The Council assumes artificial production will continue to be used in the basin as one tool for achieving fish and wildlife requirements (although how and why it is used may change as the region revisits its planning assumptions). Thus the second "implementation" issue is how to improve the operations of a facility that decisionmakers want to build or continue for a specific purpose. The critical issue here is how to guide the application of the policies and performance standards in this report to boost the survival of artificially produced fish while minimizing damage to and possibly benefiting naturally spawning populations. This is also the time to ensure adequate monitoring and evaluation protocols intended to evaluate both whether production is meeting its defined purpose and how well its operations improve survival and minimize adverse impacts.

1. General recommendation — immediately implement needed improvements in artificial production programs and facilities

Program managers and review bodies need to begin reviewing artificial production programs and facilities immediately for consistency (or deficiencies) with the policies and performance standards described in this report, and developing plans for upgrading programs and facilities consistent with these standards. Annual funding reviews and ESA consultation and permit reviews are examples of vehicles to be used for evaluating facilities against these standards and assessing whether improvements are needed. One of the reasons the Council recommends allowing production reform to take place over the next few years within existing processes is the expectation that recently issued and forthcoming ESA reviews analyzing the effects of artificial production will be a powerful agent for identifying and requiring changes. But biological opinions and their ESA cousins carry no funds to allow for change, and do not consider all the issues of concern to managers and planners, so the ESA reviews and the performance requirements that result need to be integrated into the funding processes and standards that are a prerequisite for continued funding of an artificial production program.

These reforms will require significant transition funding, the ability to reprogram resources and a commitment to a multi-year action program. During this transition period, the region will need an annual review of the progress, decisions, and actions necessary to achieve these reforms.

<u>Recommendation:</u>* All facilities must be evaluated for consistency with the policies and standards in this report relating to artificial production. Evaluating the facility, developing a workplan to meet the standards, and showing progress toward meeting the standards should be a pre-requisite to obtaining continued funding (in whatever funding process the facility sits) or obtaining ESA approval for continued operations. Transition and re-programming funds need to be available (see Part IIID) to make this transition a reality.

The Council intends to use the funding reviews that it oversees (of the Bonneville direct fish and wildlife program and Bonneville's reimbursable programs, such as the Lower Snake River Compensation Plan facilities) as a vehicle for evaluating and improving the operations of artificial production facilities measured by the standards in this report. The Council intends to do this in a cooperative fashion. Existing authorities not funded through Council programs will continue their own funding and management decisions, but there is much to recommend a single review process, especially if it can become a "one-stop shop" for a scientifically credible review of facility operations in the context of review of other actions in the relevant subbasins. The Council is prepared to host such an effort, not as the ultimate decisionmaker, but as the body that is already planning to oversee rolling, in-depth reviews of production and other activities province-by-province and subbasin-by-subbasin throughout the basin, as part of how the Council is re-designing its funding review processes. Programs not already included in those reviews could integrate information about their facilities for review in the appropriate province review, and take back the review analysis as information for their funding decisions.

2. How to evaluate for consistency with policies and standards and identification of deficiencies; use of independent audits; independent scientific review

In order to make decisions in the performance reviews, the managers, scientific panels and decisionmakers will need information as to whether and how any particular program or facility is succeeding or deficient in meeting the regional performance standards. Some of that information already exists, especially in the independent audits of anadromous fish hatchery performance initiated by the Council, using performance measures developed by Independent Hatchery Operations Team (IHOT) that are at least partially consistent with the policies and standards described above. (For more details on IHOT and the audits, see the discussion in Appendix 2.)

<u>Recommendation:</u> Entities seeking funding for artificial production programs should analyze their programs and facilities against the policies and performance standards described in this report to identify deficiencies and needed improvements, making use of the existing audit information where appropriate. These entities should use a combination of self-evaluations and independent evaluations, using scientific resources to focus on critical areas of uncertainty. The end result of this self-evaluation process should be a demonstration of consistency with the policies and standards or an explanation of inconsistencies and a proposal for correction. The evaluations and conclusions should then be presented to the review bodies, including independent scientific panels, for review as part of the funding processes. And, until the decisions on use and purpose are revisited as described in Part IIIB above, the proposals and decisions in the funding reviews should include an explicit if interim evaluation of the more fundamental questions about purpose, which would balance the magnitude of needed operational improvements against the potential for a change in purpose, as part of a judgment on funding priorities.

D. Establish Transition Fund and Opportunities for Reprogramming of Funding

1. Transition Funding

Funding this reform effort will be critical to reaching good informed decisions. The initial requirements will include funding the subbasin planning effort and funding for the initial modifications of facilities and programs necessary to comply with ESA biological opinions and the first round of requirements out of the funding reviews. Use of the HGMP's and existing processes will continue to determine the initial transitional needs until the subbasin plans are completed. As the subbasin plans are completed they will define the future purposes for artificial production and any investments that are required to modify or improve hatchery operations, any costs to close a facility, and whatever new programs will be undertaken in the subbasins. These actions could all involve significant one time capital costs. In addition, the participants in the production review have identified the potential need for a limited number of target research efforts on certain critical topics.

In order to meet the needs of funding for reform activities, transition funds should be estimated and reserved. These funds need to be large enough to facilitate reform, but should not lock in long term funding of artificial production activities before the review decisions are made and reform proceeds. The request for the appropriate size of this fund will need to be developed over the next several months. It is anticipated that funding for the transition activities will come from ratepayers, federal taxpayers, and others. Without providing the funds needed for reform, managers will be reluctant to undertake the work required to evaluate their programs against the standards.

***<u>Recommendation:</u>* Estimate the magnitude of the transition funding needed and identify criteria for its use. All relevant funding sources will need to provide transition funding necessary for artificial production reform.**

2. Reprogramming of funding

Congress, the Council and other decisionmakers need to ensure that changes resulting from this effort do not lead to a diminishment of funding to fulfill mitigation and treaty responsibilities. One of the key concerns of the participants in the Artificial Production Review is that this reform effort will be used as a cover for reducing program investments instead of increasing the value of those region's fish and wildlife efforts. As a result many decisions about the future of certain facilities or programs might be frozen by agencies, tribes and communities that fear change will equal a net loss. It is essential that we create a situation in which tough decisions on production facilities and programs can be made to create the greatest value for fish and wildlife recovery, which will require some assurances that funding and other resources can be re-prioritized or reprogrammed to other actions to meet the fish and wildlife objectives.

***<u>Recommendation:</u>* Authorize reprogramming of funding from existing artificial production programs or facilities where necessary so that funding can be retained and applied to other appropriate tools (whether new artificial production or some other strategy) to meet fish and wildlife responsibilities.**

Attachment

FINAL DRAFT

Artificial Production Review

Proposed Performance Standards and Indicators

Compiled by an ad hoc work group of the Production Review Committee
to the Artificial Production Review

September 24, 1999

I. INTRODUCTION

The performance standards and indicators (PS&I) are an outgrowth of discussions in the regional Production Review Committee (PRC) of the Northwest Power Planning Council (NWPPC) Artificial Production Review (APR) process initially and more specifically, from an adhoc PS&I work group. The PS&I work group met as a committee on a number of occasions and have developed the document to its present Working Draft #9 format. The working philosophy has been to extend the NWPPC document on Artificial Production Programs and Policies for Hatcheries in the Columbia River Basin into the next level of detail incorporating the Science Review Team (SRT) guidelines (see page xxii), the Integrated Hatchery Operations Team (IHOT) performance standards and indicators and the Pacific Northwest Fish Health Protection Committee (PNWFHPC) guidelines into the present set of measurable PS&I's. These PS&I's attempt to quantify both benefits and risks of using artificial production programs and facilities as management tools within the five purposes of artificial production outlined earlier (Table 1). It was recognized by the PRC that if artificial production programs in the Columbia River Basin are to be evaluated in a comprehensive manner it must be done by applying a consistent set of PS&I's uniformly for all purposes and for all individual hatcheries. With regard to applying these indicators to specific hatcheries it should be understood that the intent is to provide a menu of Performance Indicators (PI) for regional guidance and that a greater level of detail will be required at the individual hatchery consistent with the appropriate subbasin goals, objectives, and strategies. The intention of the ad hoc PS&I work group was to articulate PI's which were:

1. Measurable
2. Realistic
3. Feasible
4. Clear and understandable
5. Affordable
6. Consistent application in policy and law

In the context of artificial production reform it is critical to ask how are we going to evaluate artificial production success or how will we know success when we see it? In the ad hoc PS&I work group, the main criterion for success was to achieve the identified benefits of artificial production while managing the risks through a research, monitoring, and evaluation (RM&E) program focusing on performance indicators. Essentially, estimating success is a complex enterprise, but it has never been as simple as only documenting juvenile hatchery production. Instead, in order to accurately estimate artificial production success, for example, as in anadromous salmon, it involves partitioning survival at key life history stages within the artificial environment, post hatchery release in freshwater (tributary and mainstem), estuary, nearshore and marine habitats. Clearly, the true measure of the hatchery product, whether resident or anadromous, is to contribute adult fish not juveniles to the Tribal Treaty and non-treaty fisheries, and to optimize spawning ground escapement. Basically, the development of the PS&I evaluation system is to set up accountable, performance based management of artificial production programs to assure a focus on adults or the appropriate life history stage for resident fish, for harvest of resident and anadromous fish and for viable population numbers on the spawning grounds. The development and application of the proposed PS&I's are not in anyway meant to limit the Tribal Treaty/Executive Order fishing rights, C&S obligation, Tribal trust responsibilities or any other rights of Indian Tribes.

In an effort to respond to the permitting needs of the Endangered Species Act (ESA) it is being proposed that the PS&I's be incorporated into the hatchery and genetic management plan (HGMP). The HGMP represents an opportunity to standardize the reporting of data for the ESA purposes and also to incorporate more comprehensive data useful to evaluate all anadromous or resident artificial production programs from specific hatcheries in the Columbia River Basin.

Aside from enumerating the Benefits and Risks and their respective performance standards and indicators, the Benefit and Risk Matrix attempts to preview how specific benefits and risks are unique and/or common to each artificial production purpose. This is an important insight because the level of risk is not equal across all artificial production purposes. However, critical research topics need to be initiated in order to scientifically evaluate the level of risk associated with specific artificial production programs within a given purpose. The approach recommended by the ad hoc PS&I working group requires conducting critical regional research studies by species at a specific hatchery within a subbasin and extrapolating the results to the rest of the region where appropriate.

II. PERFORMANCE STANDARDS AND INDICATORS

BENEFITS

Performance standards	Performance indicators
1. Provide predictable, stable and increased harvest opportunity - Treaty/Executive Order and non-treaty - C&S obligation - Recreation (consumptive and non-consumptive) - Apply Scientific Review Team (SRT) Guideline (G)17[1]	Predictable, stable, and increased harvest opportunities met. Managed for increasing, stable, or decreasing trend line, comparing past trend with future. Developed RM&E plan by species to measure and collect data. Evaluated juvenile, smolt to adult survival or contribution to harvest trends. 1. Anadromous a. Recreational– Increased number of angler days and harvest - Catch/unit effort/year - Catch #'s/harvest/year - Units of effort/year - Established baseline at Year One, compare with 5 year survey or one generation b. Commercial – Tribal treaty and non-treaty fishery harvest needs met. - Deviations from 50% of the ocean and river fishery for fall chinook and steelhead allocation, and other specific indicators determined by species - Report annually on deviation from 50% allocation of all fisheries, Tribal and Non-Tribal hatcheries above Bonneville - Absolute # harvested (a) all fisheries (ocean, in-river) (b) Tribal fisheries (ocean, in-river) - Number of pounds and value (quantity) harvested 2. Resident (native or non-native)

[1]Brannon, E.L., et al. 1999. Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin, Part 1: A scientific basis for a Columbia River production program, Northwest Power Planning Council.

BENEFITS

Performance standards	Performance indicators
	a. Recreational – Tribal Treaty / Executive Order and Non-Treaty fishery. Key statistic is increasing number of angler days to be able to harvest fish with as little effort as possible. Indicators measured should be population specific by species - Numbers, length, weight, age, and pounds harvested or released - Deviations from 50% harvest allocation - Area and time of harvest - Production cost of hatchery fish harvested - Deviation from sport minimum threshold by species - Perceived value of fish harvested - Angler satisfaction determined every 5 years or after one generation - Condition factor of fish in creel - Catch per unit effort goals 3. Complied, where applicable, with HGMP
2. Conservation of genetic and life history diversity - Establish baseline for hatchery and/or wild populations - similar to wild or - isolated from wild - Evaluate at yearly increments depending upon - generation time for the selected species - Make changes to correct for divergence from baseline - Apply SRT – G1-2, 4-17	A. Used number of adults necessary to achieve minimum effective population size (MEPS). Trend target in 4 out of 5 years ± 10% B. Evaluated whether life history characteristics were maintained by comparing baseline at year 1 with 5 year survey, or after one generation. Life history characteristics measured: 1. Age composition 2. Fecundity (#, and size) 3. Body size (size, length, weight, age, and maturity index) 4. Sex ratio 5. Juvenile migration timing 6. Adult run timing

BENEFITS

Performance standards	Performance indicators

7. Distribution and straying
8. Time and location of spawning
9. Food habits

C. Evaluated broodstock genetically in year 1 and compare after 5 years, or one generation, in terms of DNA or allozyme profile

D. Captive broodstock
   1. Increased number of individuals in captivity to substantially greater numbers than wild survival standard (% survival standard)
   2. Progeny represented full range of life history traits of parent population in the wild. Surrogate: genetic analysis (DNA or allozyme frequencies)
   3. Implemented RM&E plan to document survival of juveniles and returning adults
   4. Followed NMFS interim standards for captive broodstock

E. Cryopreservation
   1. Implemented RM&E plan to represent full range of life history traits (see Risk A10, 1-9)
   2. Equaled or exceeded quality control standard for sperm viability

F. Promoted regional gene bank to preserve existing populations not under threat of extinction

G. Complied, where applicable, with HGMP

H. Relevant APR-SRT guidelines evaluated and implemented

BENEFITS

Performance standards	Performance indicators
3. Enhance tribal, local, state, regional and national economies	A. Established increasing trend in the value of harvest by documenting: 1. Commercial and sport fisheries value 2. Economic return from ex vessel, wholesale value 3. Opportunity or angler days translated to dollars 4. Cannot value tribal fisheries only in dollar terms for the commercial and sport fishery 5. Production cost of hatchery fish harvested B. Developed overall economic impact model to compute direct, indirect and induced effects from hatchery production.
4. Fulfill legal/policy obligations	A. Legal and policy obligations of the hatchery goal met, in terms of numbers of hatchery fish to the fishery in 4 out of 5 years $\pm$ 10% 1. Marine and freshwater fisheries 2. Resident fisheries in pounds of fish harvested B. Decreased litigation
5. Contribution of hatchery fish carcasses to ecosystem function by subbasin and by hatchery -Stream/river nutrification from hatchery carcasses -Nutrient input for fisheries and wildlife -Food web impacts	A. Hatcheries developed RM&E plans with stringent disease standards as identified by PNWFHPC and IHOT protocols for using the carcasses as a nutrient source 1. Collaborative agency, tribal and university research implemented a pilot project

BENEFITS

Performance standards	Performance indicators
6. Provide fish to satisfy legally mandated harvest in a manner which eliminates impacts on weak hatchery and broodstock wild populations - Apply SRT – G17	A. Developed harvest management plan for hatchery fish B. Computed ratio of wild fish to harvest 1. Evaluated trend analysis of past/present hatchery contributions to harvest. 2. Defined an upper maximum ratio of wild fish allowed in the harvest C. Documented total harvest of hatchery fish 1. Used appropriate techniques of selective harvest and rearing by separation in time, space, gear and hatchery fish identification, where appropriate D. Determined that total harvest of wild populations of concern does not exceed upper maximum of absolute number of wild fish E. Established and met natural population escapement goal, where applicable, in 4 out of 5 years ± 10 % F. Hatchery broodstock goals and objectives established and met in 4 out of 5 years ± 10% G. Complied, where applicable, with HGMP H. Relevant APR-SRT guidelines evaluated and implemented
7. Will achieve within hatchery performance standards - Apply SRT – G1-2, 4-13, 16, 19	A. IHOT standards achieved B. Relevant APR-SRT guidelines evaluated and implemented C. Complied, where applicable, with HGMP
8. Restore and create viable naturally spawning populations - Apply SRT – G1-2, G4-16	A. Managed for increasing trend of redd counts as index of natural spawning B. Managed for increasing numbers of adult fish C. Managed for increasing trend in adult resident fish

BENEFITS

Performance standards	Performance indicators
	D. Managed for increasing trend in juvenile anadromous or resident fish rearing densities in #'s/m^2 by habitat E. Managed for increasing trend in nutrients from adult carcasses in tributaries F. Managed for increasing F_2 spawners G. Complied, where applicable, with HGMP H. Relevant APR-SRT guidelines evaluated and implemented
9. Plan and provide fish with coordinated mainstem passage and habitat research in the Columbia Basin - Apply SRT – G17	A. Developed a project with a regional perspective for a multi-year funded research plan with funding support B. Described funding umbrella to provide context for individual project research C. Developed plan consistent with subbasin goals, objectives and strategies, including Mainstem

BENEFITS **Performance Standards**	Performance Indicators
10. Conduct within hatchery research, improve the performance or cost effectiveness of artificial production hatcheries to address the other four purposes - Apply SRT – G1-2, 4-13, 15-17	A. Developed comprehensive regionally coordinated RM&E plan that includes a website for all hatcheries in the basin 1. Bonneville Power Administration, National Marine Fisheries Service, United State Geological Survey/Biological Research Division, Federal Energy Regulatory Commission, universities, private aquaculture industry, utilities, states, tribes, land management agencies, etc. B. Developed a research study plan which: 1. Implemented genetic studies of straying, introgression, and outbreeding depression at a specific hatchery by species 2. Conducted focused carrying capacity study 3. Evaluated potential hatchery/wild competition by ecosystem 4. Evaluated the fate of hatchery population mimicking the wild population in terms of adult return or yield to the creel 5. Conducted hatchery evaluations on selected hatcheries within eco-systems to estimate post-release survival by tributary, mainstem, estuary, and ocean in order to accurately evaluate hatchery performance by species by hatchery C. Integrated hatchery and programs into subbasin management plan within 3 years using: 1. Hatchery Genetic Management Plan (HGMP) as part of the plan by species 2. RM&E plan 3. Hatchery specific harvest management plan D. Improved marine survival and yield of adults in the fishery or spawning grounds F. Research priorities have been set by evaluating performance indicators which haven't been met. Standard is adaptive management

BENEFITS

Performance Standards	Performance Indicators
11. Minimize management, administrative and overhead costs. - Reduce process - Respond to performance indicators - Conduct annual performance review - Reduced manpower / overhead rates - Integrate with other programs - Apply SRT – G19	A. Managed the process to accomplish declining expenditures for administrative overhead B. Achieved annual budgeting based on a results-oriented, performance-based management framework C. Annual reports addressed 1. Program performance based on indicators 2. Consistency with Columbia River Fish Management Plan (CRFMP) production reports D. IHOT audits conducted as scheduled and results integrated into future funding and program decisions E. Implementation of IHOT policies and procedures and hatcheries documented
12. Improve performance indicators to better measure performance standards - Apply SRT – G18	A. Evaluated effectiveness of performance indicators using adaptive management in order to more accurately measure performance through audit process. B. Relevant APR-SRT guidelines evaluated and implemented

RISKS

Performance standards	Performance indicators
1. Develop harvest management plan to protect weak populations where mixed fisheries exist - Apply SRT G17	A. Maximum allowable impact to weak populations not exceeded in 4 out of 5 years ± 10 % B. Life history characteristics of weak populations monitored for change from baseline by comparing at year 1 with 5-year survey or after one generation C. Maintenance of unique life history characteristics evaluated by comparing baseline at year 1 with a 5 year survey, or after one generation. Characteristics measured: a. Age composition b. Fecundity (#, and size) c. Body size (size, length, weight, age, maturity index) d. Sex ratio e. Juvenile migration timing f. Adult run timing g. Distribution and straying h. Time and location of spawning i. Food habits D. Documented that natural population escapement goal not adversely affected in 4 out of 5 years ± 10 % for specific species and populations E. Relevant APR-SRT guidelines evaluated and implemented
2. Do not exceed carrying capacity of fluvial, lacustrine, estuarine and ocean habitats - Apply SRT G1-2, G4-13, G17	A. Developed an appropriate RM&E plan 1. Freshwater a. Snorkel survey conducted to quantify microhabitat partitioning

RISKS

Performance standards	Performance indicators
	b. Emigration rate, growth, food habits, condition factor, and survival rate evaluated 2. Conducted control vs. treatment carrying capacity evaluation a. estimated #/m ^{2} by year class by habitat type C. Reservoir, estuarine, and ocean research, monitoring, and evaluation plan developed – implemented ISRP recommendation to define monitoring and evaluation research approach D. Relevant APR-SRT guidelines evaluated and implemented
3. Assess detrimental genetic impacts among hatchery vs. wild where interaction exists - Apply SRT G1-2, 4-18	A. Initially, it is assumed that stray rate is a surrogate for a thorough and more complex measurement of genetic impact. More specific measurements to be implemented on a selected basis: 1. Experimental design for evaluating genetic impact recommended by ISRP. 2. Evaluated hatchery population agains standard stray rate (<5% non-indigenous populations; <20% indigenous populations – NMFS standard) 3. Measured introgression by comparing allele frequencies between hatchery and wild 4. Implemented an appropriate experimental design to quantitatively measure outbreeding depression 5. Conducted RM&E on selected basis at a specific hatchery and/or on selected species 6. Experimental design for evaluating genetic impact recommended by ISRP. B. Implemented HGMP where appropriate. C. Relevant APR-SRT guidelines evaluated and implemented
4. Unpredictable egg supply leading to poor programming of	A. Achieved percent egg take goal in 4 out of 5 years

RISKS

Performance standards	Performance indicators
hatchery production to maintain Treaty/Executive Order and non-treaty fisheries and broodstock escapement	B. Achieved MEPS in 4 out of 5 years ± 10 % C. Implemented PNWFHPC, IHOT disease protocols, and HGMP, where appropriate, in terms of egg transfer to the hatchery
5. Production cost of program outweighs the benefit - Apply SRT G18-19	A. Evaluated trends in the ratio of hatchery juvenile production cost per cost of juvenile production from habitat projects by subbasin by hatchery per adult production 1. Hatchery production cost is equal to or less than 1 in 4 out of 5 years ± 10 % B. Relevant APR-SRT guidelines evaluated and implemented
6. Cost effectiveness of hatchery ranked lower than other actions in subregion or subbasin - Apply SRT G19	A. Developed cost effective methods of producing benefits to recreation fishery such as: 1. Cost per angler day a. Habitat and fish passage compared to hatchery b. Self-sustaining population compared to continuing artificial production 2. Cost per experience (economic model) 3. Cost per fish harvested in the recreational fishery B. Achieved highest numerical ratio of returning adults or recovery to healthy viable resident population levels per cost of action (habitat, passage, hatchery) C. Achieved highest ratio of intrinsic social value (satisfaction survey) of returning adults or recovery of healthy viable population levels per cost of action D. Achieved highest ratio of value of harvest per cost of hatchery by species to the non-treaty commercial fishery E. Achieved least cost production of behaviorally adapted juveniles

RISKS

Performance standards	Performance indicators
	complying with NMFS interim standards for captive broodstock F. Relevant APR-SRT guidelines evaluated and implemented
7. Will not achieve within hatchery performance standards - Apply SRT G1-2, 4-13, 16, 19	A. Conducted comparative evaluation of actual within hatchery performance and exceeded or equaled performance standards as enumerated by IHOT B. Defined resident fish within hatchery performance standards if different from IHOT and equaled or exceeded standard C. Conducted an audit to determine compliance with IHOT standards

RISKS

Performance standards	Performance indicators
8. Evaluate habitat use and potential detrimental ecological interactions - Apply SRT G4-5, 8, 17-18	A. Selected tributaries by subbasin and hatchery by species (anadromous and resident) – conducted comparative evaluation of prestocking population with post stocking after five years or after one generation by measuring some of these parameters: 1. Evaluated emigration rate a. Anadromous or resident stocked fish and naturally reproducing anadromous or resident population 2. Conducted comparative evaluation of rearing densities (# / m^2) by habitat before and after stocking hatchery fish vs. wild fish 3. Computed growth rate, condition factor, and survival of 1a above 4. Evaluated direct intra- and inter-specific competitive interaction between stocked anadromous or resident fish and wild resident fish 5. Conducted snorkel surveys to quantify microhabitat partitioning by species 6. Computed prey composition in diet of 1a above 7. Determined predation rate a. Fish, birds, marine mammals B. Implemented tributary RM&E plan by subbasin by specific hatchery by species, and extrapolated to other subbasins and hatcheries in the basin C. Developed and implemented RM&E plan for reservoir habitat 1. Trophic level disruptions a. Species and prey population composition before and after stocking 2. Implemented experimental design for specific research applications recommended by ISRP

RISKS

Performance standards	Performance indicators
	D. Developed RM&E plan for estuary and near shore marine habitat 1. Implemented experimental design recommended by ISRP E. Natural habitat improved to double survival by species by specific life history stage within 10 years F. Implemented HGMP where appropriate G. Relevant APR-SRT guidelines evaluated and implemented
9. Avoid disease transfer from hatchery to wild fish and vice versa - Apply SRT G17, 19	A. Established comparative annual sampling of disease incidence in hatchery and wild populations B. Complied with IHOT standards and PNWFHPC guidelines C. Applied disease standards to resident fish rearing and stocking activities, including net pens, acclimation ponds, and direct releases D. Evaluated incidence of drug resistant pathogens by comparing to baseline in year 1 to survey every five years E. Implemented HGMP where appropriate F. Relevant APR-SRT guidelines evaluated and implemented
10. Evaluate impacts on life history traits of wild and hatchery fish, from harvest and spawning escapement - Apply SRT G1-15, 18	A. Tracked trends to evaluate change by comparing a baseline at year 1 with a 5-year survey, or after one generation. Specific life history characteristics measured are: 1. Age distribution 2. Fecundity (#, and size) 3. Body size (length, weight, age, maturity index) 4. Sex ratio 5. Juvenile size and migration timing 6. Adult run timing

RISKS

Performance standards	Performance indicators
	7. Distribution and straying 8. Time and location of spawning 9. Food habits B. Conducted RM&E program on selected hatchery by species and extrapolated to others C. Implemented experimental design recommended by ISRP D. Implemented HGMP where appropriate E. Relevant APR-SRT guidelines evaluated and implemented
11. Assess survival of captive broodstock progeny vs. wild cohorts - Apply SRT G1-10, 13-19	A. Achieved increased survival threshold for captive broodstock over wild adults – Implemented RM&E plan with appropriate experimental design to measure: 1. % survival of viable eggs, fry, and offspring 2. % survival to release 3. Pre-release juvenile quality, equal to or exceeded physiological, morphological, and behavioral threshold compared to wild population 4. Achieved post-release criteria in terms of survival, growth, condition factor, and behavioral adaptation B. Implemented HGMP where appropriate C. Relevant APR-SRT guidelines evaluated and implemented
12. Depleting existing population spawning in the wild through broodstock collection - Apply SRT G8, 10, 12, 15-17	A. Documented stable or increasing trend of redd counts as index of natural spawning B. Documented stable or increasing numbers of adult fish. C. Documented stable or increasing trend in adult resident fish. D. Documented hatchery spawner to recruit ratio equal to or greater than 1 E. Relevant APR-SRT guidelines evaluated and implemented

RISKS

Performance standards	Performance indicators
13. Depleting existing population spawning in the wild through broodstock collection - Apply SRT G8, 10, 12, 15-16	A. Documented stable or increasing trend of redd counts as index of natural spawning. B. Documented stable or increasing numbers of adult fish. C. Documented stable or increasing trend in adult resident fish. D. Documented hatchery spawner to recruit ratio equal to or greater than 1. 1. Compare broodstock numbers to biological escapement needs on spawning grounds. Establish egg take schedule 2. Implemented RM&E studies E. Established that spawning distribution was not adversely affected by broodstock collection (weirs). F. Documented no change in availability of nutrients from deceased adults prior to broodstock collection

III. BENEFIT AND RISK MATRIX

Benefits and Risks Matrix

Benefits	Augmentation[a]	Mitigation[b]	Restoration[c]	Preservation/ Conservation[d]	Research[e]
1. Provides predictable, stable, and increased opportunity for harvest.	✓	✓			
2. Achieve genetic and life history conservation.			✓	✓	
3. Enhance local, tribal, state, regional, and national economies.	✓	✓	✓	✓	
4. Fulfill legal/policy obligations.	✓	✓	✓	✓	
5. Contribution of fish carcasses to ecosystem function by subbasin and by hatchery.		✓	✓		
6. Provide fish to satisfy legally mandated harvest.	✓	✓	✓		
7. Will achieve within-hatchery performance standards.	✓	✓	✓	✓	
8. Restore and create viable naturally spawning populations.		✓	✓	✓	
9. Plan and provide fish with coordinated mainstem passage and habitat research in the Columbia Basin.					✓
10. Conduct within-hatchery research, improve performance or cost effectiveness of artificial production hatcheries to address the other four purposes.					✓
11. Minimize management, administrative, and overhead costs.					✓
12. Improve performance indicators to better measure performance standards.					✓

a. Purpose is to increase harvestable numbers of fish.

b. Purpose is to replace or compensate lost habitat capacity of naturally-producing fish with artificially-produced fish (anadromous or resident, native and non-native) for harvest or some other reason.

c. Purpose is to hasten rebuilding or reintroduction of a population to harvestable levels.

d. Conserve genetic resources or fish populations impacted by habitat loss or degradation, including preservation of populations faced with imminent demise, using methods such as captive propagation and cryopreservation.

e. How to effectively use artificial production to address the other motivations.

Risks	Augmentation	Mitigation	Restoration	Preservation/ Conservation	Research
1. Harvest management plan to protect weak populations where mixed population fisheries exist.	✓	✓	✓		
2. Do not exceed the carrying capacity of fluvial, lacustrine, estuarine, and ocean habitats.	✓	✓	✓	✓	✓
3. Assess detrimental genetic impacts among hatchery vs. wild where interaction exists.	✓	✓	✓	✓	✓
4. Unpredictable egg supply leading to poor programming of hatchery production.	✓	✓	✓	✓	
5. Production cost of program outweighs the benefit.	✓	✓	✓	✓	
6. Cost effectiveness of hatchery ranked lower than other actions in subregion or subbasin.	✓	✓	✓	✓	
7. Will not achieve within-hatchery performance standards.	✓	✓	✓	✓	
8. Evaluate habitat use and potential detrimental ecological interactions.	✓	✓	✓	✓	✓
9. Avoid disease transfer from hatchery to wild fish and vice versa.	✓	✓	✓	✓	
10. Evaluate impact on life history traits of wild and hatchery fish, from harvest and spawning escapement.	✓	✓	✓	✓	
11. Assess survival of captive broodstock progeny vs. wild cohorts.				✓	
12. Depleting existing population spawning in the wild through broodstock collection.			✓	✓	

IV. SRT Suggested Guidelines on Hatchery Practices, Ecological Integration and Genetics

Guideline 1. Technology should be developed and used to more closely resemble natural incubation and rearing conditions in salmonid hatchery propagation.

In developing hatchery technology, hatchery programs should work toward the goal of providing environments that resemble natural conditions during artificial propagation. These may include:

- Incubation in substrate and darkness;
- Incubation at lower densities;
- Rearing at lower densities;
- Rearing with shade cover available;
- Exposure to in-pond, natural-like habitat;
- Rearing in variable, higher velocity habitat;
- Non-demand food distribution during rearing;
- Exposure to predator training;
- Minimize fish-human interaction;
- Acclimation ponds at release sites;
- Volitional emigration from release sites.

Guideline 2. Hatchery facilities need to be designed and engineered to represent natural incubation and rearing habitat, simulating incubation and rearing experiences complementary with expectations of wild fish in natural habitat.

Guideline 3. New hatchery technology for improving fish quality and performance needs to have a plan for implementation and review at all hatchery sites, where appropriate, to assure its application.

Guideline 4. To mimic natural populations, anadromous hatchery production strategy should target natural population parameters in size and timing among emigrating anadromous juveniles to synchronize with environmentalselective forces shaping natural population structure.

Guideline 5. To mimic natural populations, resident hatchery production strategy should target population parameters in size and release timing of hatchery-produced resident juveniles to correspond with adequate food availability and favorable prey to maximize their post-stocking growth and survival.

Guideline 6. Supplementation hatchery policy should utilize ambient natal stream habitat temperatures to reinforce genetic compatibility with local environments and provide the linkage between stock and habitat that is responsible for population structure of stocks from which hatchery fish are generated.

Guideline 7. Salmonid hatchery incubation and rearing experiences should use the natal stream water source whenever possible to enhance homestream recognition.

Guideline 8. Hatchery release strategies need to follow standards that accommodate reasonable numerical limits determined by the carrying capacity of the receiving stream to accommodate residence needs of non-migrating members of the release population.

Guideline 9. Hatchery programs should dedicate significant effort in developing small facilitates designed for specific stream sites where supplementation and enhancement objectives are sought, using local stocks and ambient water in the facilities designed around engineered habitat to simulate the natural stream, whenever possible.

Guideline 10. Genetic and breeding protocols consistent with local stock structure need to be developed and faithfully adhered to as a mechanism to minimize potential negative hatchery effects on wild populations and to maximize the positive benefits that hatcheries can contribute to the recovery and maintenance of salmonids in the Columbia ecosystem.

Guideline 11. Hatchery propagation should use large breeding populations to minimize inbreeding effects and maintain what genetic diversity is present within the population.

Guideline 12. Hatchery supplementation programs should avoid using strays in breeding operations with returning fish.

Guideline 13. Restoration of extirpated populations should follow genetic guidelines to maximize the potential for re-establishing self-sustaining populations. Once initiated, subsequent effort must concentrate on allowing selection to work by discontinuing introductions.

Guideline 14. Germ plasm repositories should be developed to preserve genetic diversity for application in future recovery and restoration projects in the basin, and to maintain a gene bank to reinforce diversity among small inbred natural populations.

Guideline 15. The physical and genetic status of all natural populations of anadromous and resident fishes need to be understood and routinely reviewed as the basis of management planning for artificial production.

Guideline 16. An in-hatchery fish monitoring program needs to be developed on performance of juveniles under culture, including genetic assessment to ascertain if breeding protocol is maintaining wild stock genotypic characteristics.

Guideline 17. A hatchery fish monitoring program needs to be developed on performance from release to return, including information on survival success, interception distribution, behavior, and genotypic changes experienced from selection between release and return.

Guideline 18. A study is required to determine cost of monitoring hatchery performance and sources of funding.

Guideline 19. Regular performance audits of artificial production objectives should be undertaken, and where they are not successful, research should be initiated to resolve the problem.

Guideline 20. The NPPC should appoint an independent peer review panel to develop a basinwide artificial production program plan to meet the ecological framework goals for hatchery management of anadromous and resident species.

V. REFERENCES

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Appendix I

Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin

A Scientific Basis
for Columbia River Production Programs

April 1999

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Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin

Part I: A Scientific Basis for Columbia River Production Programs

I. Introduction

In July 1997, the U.S. Senate[20] directed the Northwest Power Planning Council, with the assistance of the Independent Scientific Advisory Board (ISAB),[21] to "conduct a thorough review of all federally funded hatchery programs operating in the Columbia River Basin…" with the intent to ensure that federal dollars are spent "wisely" and "in a cost-effective manner that maximizes the benefits to the fish resource." The Council is to assess the "operation, goals and principles of state, tribal and federal hatcheries..." with regard to the effectiveness of their role in the broader context of fisheries management. The Council is to recommend to Congress a set of policies that would guide the use of Columbia River hatcheries.

In response to the Congressional directive, the Council consulted with the ISAB and appointed a Scientific Review Team (SRT) to provide an independent assessment of the basin's artificial production program. The SRT includes four members of the ISAB, two additional independent scientists, and a scientist from the Council staff as chair of the team. The SRT will review hatchery programs in the basin, analyze their effectiveness in meeting mitigation responsibilities, assess their success in enhancing salmonid production, and evaluate their role in supplementation of natural salmon and steelhead runs. The SRT analysis will provide the biological basis for the Council's recommendations to Congress.

To provide timely advice for the Council's report to Congress, the SRT is conducting the analysis as three sequential tasks:

1. A summarization of current scientific knowledge on artificial production and its implications for Columbia River programs.
2. A compilation of the data relating to the performance of artificial production in the Columbia River Basin.
3. An analysis of this information in light of current knowledge to assess the performance of artificial production in the Columbia River Basin.

This report addresses the first task, which is to provide background information on the state of the science that relates to artificial production in the basin. The scientific rationale developed in this report takes the form of guidelines that could form the basis of recommendations regarding artificial propagation, in the context of ecosystem management. The second task, assembling the

[20] U.S. Senate Energy and Water Development Appropriation Bill, 1998, Report 105-44.
[21] The ISAB was created jointly by the Northwest Power Planning Council and the National Marine Fisheries Service to provide independent scientific advice regarding fish and wildlife management in the Columbia River Basin. The ISAB consists of 11 scientists appointed with the assistance of the National Research Council.

database of all past and current records on artificial production in the basin, has been assigned to a contractor. The third task will be the analysis of hatchery programs and the database, and finalizing the report. Each task will be summarized in separate reports to the Council and then integrated into a final report.

This paper provides the SRT's analysis of the history of artificial production and other hatchery evaluations related to the Columbia basin. Hatcheries initially were used to augment the fishery, later to mitigate for habitat destruction by development activities, and more recently to supplement natural production and conserve salmon using captive brood stock techniques. These roles are defined and discussed in this report, and the state of current knowledge of the genetic and ecological effects of hatcheries is summarized, as well.

The next phase of the SRT report, where applicable, will use guidelines associated with uncertainties as a basis to evaluate hatchery performance. The evaluation should identify production and operational strategies that can assist in development of hatchery policy. Performance evaluation will use production return criteria and/or fulfillment of mitigation objectives as the basis of assessment. The two evaluations, with recommendations emanating from both the scientific analysis and hatchery performance evaluation, will be articulated in a proposed conceptual foundation for the Columbia River Basin's artificial production program. Whether or not this conceptual foundation is adopted as the basis for regional hatchery policy, it is imperative that policy is based on a scientific foundation and that adaptive management is pursued using performance criteria.

A. Scope of the Review

Artificial production has been used in the Columbia River Basin for many purposes during this century. Although basin hatcheries have produced resident species, such as sturgeon and rainbow trout, hatchery production has focused almost exclusively on anadromous salmonids — primarily coho and chinook salmon and steelhead trout.

These three species also have been the focus of sport and commercial fisheries management in the basin and, ironically, recovery measures, as well. Due to the ecological, economic, recreational and cultural importance of these species, the Council's policy recommendations must address anadromous salmonids primarily, but also apply to a much broader spectrum of species.

In the Columbia River Basin, there are hatcheries for both anadromous and resident fish.[22] Many resident fish hatcheries in the basin, like many anadromous fish hatcheries, are intended for mitigation and are located upstream from Grand Coulee and Hells Canyon dams, which are complete barriers to anadromous fish passage. Netboy (1986) estimated that 40 percent of the original spawning areas for Columbia Basin salmonids had been lost because of blockage due to dams. *Return to the River* estimates a 55-percent loss (45 percent remaining; Page 353). Of the original salmon and steelhead habitat available in the basin, 55 percent of the watershed area and

[22] Newsdata Corp., a Seattle-based news service on fish, wildlife and energy issues, estimates there are 148 fish hatcheries in the Columbia River Basin, but this number does not include privately financed hatcheries. The information is online at http://www.newsdata.com/fishweb/.

31 percent of stream miles are now inaccessible to anadromous salmon, having been blocked by dam construction (NRC 1996, pg. 63). Furthermore, much of this inaccessible habitat was irreplaceable natural spawning habitat, located mainly in headwater regions of the basin. Thus, successful artificial production of resident fish is a necessary and crucial component to fully mitigate anadromous fish losses in these blocked areas. In addition, many native resident fish species are currently federally listed as threatened or endangered under the U.S. Endangered Species Act, based on their imperiled biological status. As with anadromous salmonids, numerous at-risk resident fish populations (e.g. bull trout, white sturgeon, and various resident salmonids) are also the focus of recovery measures.

The scope of our review concentrates on artificial production of anadromous salmonids in the Columbia Basin. However, most, if not all, of the scientific information relating to ecological impacts of anadromous salmonid hatcheries applies to the use of hatcheries that currently produce more than a dozen ecologically and economically valuable species of resident fish. Therefore, resident fish hatchery policy must be consistent with the principles in the conceptual foundation that the SRT will recommend to the Council for anadromous salmonids. In fact, because resident species do not have the distribution range of salmon and steelhead, and thus are not exposed to the same risks facing anadromous salmonids over their migratory corridor, we expect that resident species will be very responsive to the principles guiding policy in anadromous salmonid management. Throughout the review, we make connections between anadromous and resident fish production with regard to principles and technologies.

B. Definition of Artificial Production

Artificial production and hatcheries are generally viewed as synonymous terms in that both refer to the same range of fish culture technologies, encompassing everything from releases of unfed, substrate-incubated fry to captive rearing of migrant juvenile salmonids on formulated diets in concrete raceways. The most common type of fish hatchery is a cluster of buildings and concrete raceways located adjacent to a tributary stream. But a hatchery also can be a gravel-lined incubation box in which artificially spawned eggs are incubated to enhance fish production. Or, a hatchery can be an engineered spawning channel that salmon enter to spawn naturally on graded substrate, where water flow is controlled to enhance egg-to-fry survival. Or, a hatchery even can be an earthen acclimation pond in which fingerlings are fed before dispersing into the natural stream on their own volition for rearing or migration.

In this report, our focus is on the “standard” public hatchery design — the cluster of buildings beside a tributary, with tray incubators and concrete raceway rearing systems that provide the entire freshwater feed and residence requirements before the fingerlings are released to migrate seaward. Columbia River hatcheries were designed around variations of this “standard” incubation and rearing system. It is a system that has been used for most chinook and coho salmon, and steelhead trout, hatcheries over this century.

This type of hatchery generally controls the entire freshwater juvenile life cycle, except the migratory passage. Adults are intercepted and spawned artificially, based on a breeding plan that varies from simply crossing multiple females with a composite of two or more males, to a breeding matrix that maximizes the available genetic variability. Eggs are usually incubated in trays until hatching or to the point of emergence when yolk stores are nearly exhausted. Some form of substrate is often included in the incubation compartment to reduce alevin activity and prioritize stored energy for growth. At or before the emergence phase, the young fry are placed in troughs or tanks for swim-up and early rearing, and then transferred to raceways for production rearing until they are distributed for release as smolts or presmolts to natural waters. Formulated diets are used throughout rearing, based on nutritional requirements, and fed as mash or graded pellets to accommodate the size of the fish as they grow. The system is well defined in a program to maximize efficiency of operations.

Hatchery performance assessment understandably has been limited within the rather narrow definition of variables in facility design and operations common to such facilities. Because Columbia River hatcheries use the standard technology, performance differences have as much to do with management as with application of the technology itself. Variables such as the source of fish, release strategies, relative size and condition of smolts, water supplies, location of the hatchery and its location on the migratory corridor over the length of the river will affect performance. Therefore, the context of our evaluation is the relative performance of a particular class of hatcheries within the confines of river conditions in the Columbia Basin, under agency management responsibility. Consequently, our assessment will be an assessment of the policy and location as much as the technology involved.

C. Relationship Between this Review and Development of the Regional Multi-Species Framework

As this review is being undertaken, states, tribes and agencies of the federal government in the Pacific Northwest are collaborating on a multi-species planning process for fish and wildlife in the Columbia River Basin. The multi-species planning process is guided by a framework that links Columbia Basin fish and wildlife policy to a vision that balances the many values provided by the natural resources of the Columbia River and its tributaries. The multi-species framework will be based on an ecological, conceptual foundation that recognizes that the river and its species are interrelated parts of a whole.

The multi-species framework will include principles, goals and objectives that reconcile seemingly inconsistent and uncoordinated approaches to fish and wildlife policy in the region. These principles, goals and objectives will be expressed in a set of scientifically supportable alternatives for the future of the Columbia River — especially as it relates to management of fish and wildlife resources.[23] As they are developed, these alternatives will be analyzed for their ecological impacts, based on an explicit conceptual foundation. The conceptual foundation includes a set of scientific principles that define the scientific context for the analysis.[24]

Once it is developed, the multi-species framework will provide systemwide direction and specific strategies for fish and wildlife programs, as well as objectives against which results can be evaluated. The conceptual foundation for artificial production developed in this review should be consistent with the set of scientific principles guiding development of the multi-species

[23] Ecological Work Group 1998, "An Ecological Framework for the Multi-species Planning Process." Available from the Northwest Power Planning Council, Portland, OR., or at the Framework Project website at www.nwframework.org; click on Ecological Analysis.
[24] "Proposed Scientific Foundation for Development of a Regional Multi-Species Framework," Northwest Power Planning Council Report 98-16. Portland.

framework. In this sense, a conceptual foundation for artificial production is a refinement of the more general conceptual foundation for the multi-species framework, and serves to focus scientific principles on decisions about how to use artificial production. We believe that a scientifically supportable conceptual foundation, such as that guiding development of the multi-species framework and potentially refined by our assessment, should be the basis for developing future hatchery policies.

D. Definition of the Columbia Basin Ecosystem

Natural and cultural attributes define an ecosystem (ISG, 1999). The modern Columbia River ecosystem is far different than the ecosystem that existed before the encroachment of modern civilization — as that ecosystem was different from the one that existed before Native Americans began exploiting the Columbia River fishery. Man's actions irrevocably altered the Columbia River ecosystem, and those impacts define the parameters for ecosystem management today.

As major hydroelectric facilities multiplied in the Columbia River Basin, the free-flowing river became a series of linked reservoirs. This new environment favored species previously limited by higher velocities and cooler water temperatures. Predator and competitor species assumed new levels of abundance in the river system previously dominated by salmonids. For example, the northern pikeminnow (previously named the northern squawfish), a native salmon predator, increased in number — and impact on salmonids — as a result of the increased reservoir habitat. (Zimmer 1953, USFWS 1957, Thompsom 1959, Beamesderfer and Rieman 1991, Poe et al. 1991, Rieman et al. 1991.

Perhaps even a more serious impact in the evolutionary sense, however, were the many exotic fish brought into the basin by private, state and federal entities, such as American shad, channel catfish, largemouth and smallmouth bass, blue gill, yellow perch, brown trout, brook trout and lake trout (Simpson and Wallace 1982). While many of these fish were introduced for sportfishing diversity before the ecological impacts were fully appreciated, and have now become an important part of the species selection offered the sportfishing public, they nevertheless have permanently changed the Columbia River ecosystem. Although most of the exotic species were introduced half a century ago, interactions among the various non-native and native fish species are likely to continue to evolve toward a new equilibrium (as yet unknown).

Substantive and even drastic changes in species composition and habitat utilization have occurred over the last several decades. Preliminary surveys in the lower reaches of the Yakima River over the last half of 1996, for example, revealed that about two-thirds of the species encountered were exotics, and smallmouth bass represented over 60 percent of all fish intercepted (Monk 1997). Sampling gear tended to exclude fish larger than 10 centimeters in length, but as an index of general abundance, the survey demonstrated how dominant these species have become in some areas of the Basin. The impact of these newcomers, through competition or predation on endemic species, is unknown, but the success of exotic species has come at a cost to native fish.

Major changes in the operation or configuration of the hydrosystem also will affect interactions among fish species. Changes that increase normative conditions, such as natural river drawdown in the lower Snake River or a major drawdown of John Day Dam (system configuration alternatives currently being studied by the National Marine Fisheries Service or the U.S. Army Corps of Engineers) would promote an equilibrium that favored coldwater native fish species over warmwater native and non-native fish species.

This dynamic mix of native and non-native species defines the modern Columbia Basin ecosystem. Where anadromous species have been eliminated by barrier dams, mitigation has been in the form of replacement resident fisheries, and sometimes those fisheries include exotic species. Moreover, resident fish hatchery programs often will not be complementary with the ecosystem management perspective adopted for anadromous hatchery production. Nor can mitigation in these cases necessarily imply that hatchery production will be temporary until natural production can sustain the population. In some cases resident fish populations have been established where none existed before and will be entirely dependent on artificial production. Thus, in some cases the concept of using supplementation hatcheries to rebuild naturally reproducing populations does not necessarily apply to resident fish .

Another difference between anadromous and resident fish hatcheries is performance measurement. Traditionally for anadromous programs, we have measured hatchery production success in terms of harvest return. This is often an inappropriate statistic in resident fish hatchery performance. More realistic performance goals for resident fish might include catch and release only, or simply having fish in the system available for viewing. Thus, for both anadromous and resident production, performance criteria should be matched with the fisheries management objective of the specific program or facility and in recognition of the community of fishes that are now in the basin. What constitutes the Columbia Basin ecosystem, therefore, is basic in how hatchery production is viewed, and why “normative” is such a key concept that accommodates the biological realities with the cultural and economic changes that define the present ecosystem.

II. Hatchery Management and the Salmon Crisis

There is no doubt among fisheries managers that there is a crisis of major proportions confronting anadromous salmon and steelhead runs in the Pacific Northwest. This crisis is characterized by depleted populations especially in Oregon, Washington, Idaho and California, massive shrinking of the salmon’s range, collapsed fisheries and large-scale protection under the federal Endangered Species Act, and nowhere in such proportions as the Columbia River Basin. Although the salmonid crisis receives a majority of scientific, managerial, and public attention in the Columbia Basin, inspection of the status of all Columbia Basin fish species reveals a wide array of resident fish also involved in crisis situations (e.g. bull trout, white sturgeon, and various native non-anadromous salmonids).

Hatcheries play a unique role in this predicament. They have been identified as one of the causes of the current crisis, while at the same time they are also considered part of the solution. Many salmon biologists and culturists recognize this dual role of artificial propagation of anadromous and resident fish. These biologists and culturists resolve the apparent contradiction by declaring that the hatchery programs made mistakes in the past, but things are different now.

At the present time, hatcheries consume about 40 percent of the annual budget for the Council’s Fish and Wildlife Program (ISRP, 1997). If artificial propagation is going to consume such a large proportion of the tens of millions of dollars spent on salmon restoration, it is critical that there be specific answers to the following questions:

1) What problems did the programs have in the past, and
2) Specifically, how were those problems resolved?

Because of the unique dual role of hatcheries, we have to be sure that the past is really passed, and that hatchery fish are able to fit in the larger picture of ecosystem function that is being advocated as the new management paradigm.

Anadromous and resident fish hatchery technology has continuously changed over the past 120 years. Improvements include:

- Better operational design,
- Increased nutritional value of feeds,
- Better disease treatments,
- Development of tagging technology to allow monitoring the contribution and survival of hatchery-reared fish,
- Increased control over hatchery environments such as water temperature and pathogens, and
- Integration of life history traits and requirements and genetic principles in fish husbandry practices.

In short, many of the operational problems that plagued hatchery operations in the past have been resolved. However, the distinction between intrinsic hatchery operations and management of hatcheries must be addressed separately. Included in management resolution is the effect of sustained fisheries on adult salmon of hatchery origin (Campton, 1995). It is the latter, Campton argues, that is the source of most genetic effects of hatcheries on wild stocks. Moreover, management is the major source of ecological impact of hatchery fish on wild stocks, and the subject of controversy regarding poor survival of artificially propagated fish. If the manner in which hatcheries are used is, in fact, contributing to poor performance of hatchery fish, the negative effects of hatcheries due to poor management decisions can be resolved by changing the philosophy and priorities of management (Campton, 1995).

To determine if changes in management philosophy and priorities have corrected the past problems of hatcheries, we have to look beyond the changes in technology that have occurred over the past century. Changes in philosophy are directly related to changes in fundamental assumptions that underlie hatchery and fisheries management. To determine if things really are different, it is critical to identify the fundamental assumptions that guided hatchery management in the past and compare them to the assumptions that guide hatchery management today. That can only be done through a historical analysis. Culturists who believe that "things are different now" often see little value in such analyses, with the result that fishery scientists have produced few analytical studies of earlier program performance (Smith, 1994). Consequently, the specifics that would clarify past programs and the assumptions that guided them are not well known. Information is generally good with regard to hatchery operations. Hatchery population inventory, health status, feeding levels, condition and outplanting dates are in the archives of daily logs kept by the agencies. The missing detail is the rationale behind their hatchery programs. Understandably, the objective was increased production for harvest, but what motivated the approach is primarily anecdotal.

As noted earlier, restoration programs that intend to produce a new future for anadromous and resident fish populations in the Columbia River Basin must be historically informed, because in a sense the past is never really abandoned. Programs and their philosophical underpinnings evolve, and this means "new" programs carry strands of ideas and assumptions that have their roots in the distant past. We cannot merely assume that hatchery programs today are detached from their historical roots without a review of those roots and their influence on current assumptions that drive the program.

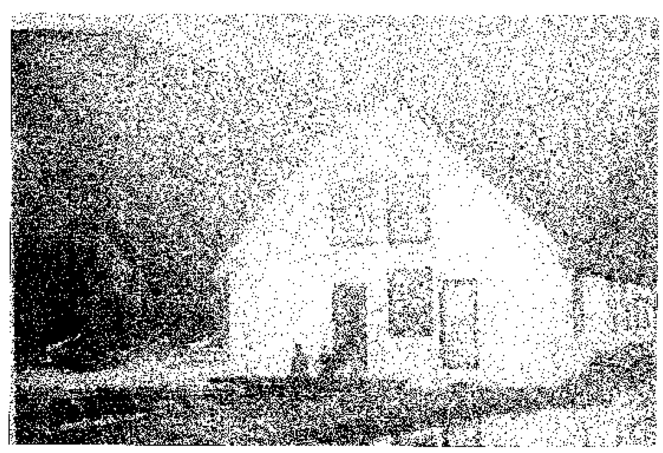
III. Historical Overview of Artificial Production

In this section, we explore the history of Columbia River Basin hatcheries to1960. Post-1960 operations will be analyzed in our next report, when reliable data about individual hatcheries will be available.

A. Growth of the Artificial Propagation Program

Spencer Baird, the U. S. Fish Commissioner, set the stage for the arrival of artificial propagation in the Columbia basin. In a report he completed in 1875, Baird listed the threats to the continued productivity of Pacific salmon in the Columbia Basin — dams, habitat change and overharvest — and he recommended artificial propagation as the solution to those problems. According to Baird, an investment of $15,000 - $20,000 in artificial propagation would make salmon so abundant that there would be no need for restrictive regulations (Baird 1875).

Given his scientific background, Baird's endorsement of hatcheries in 1875 is puzzling. The first hatchery for Pacific salmon had been opened in the Sacramento River just three years earlier in 1872, and so the first brood of artificially propagated chinook salmon had not yet returned as adults. Baird had no credible scientific information upon which to base his recommendation. However, the concept of maintaining and increasing the abundance of salmon through artificial propagation was consistent with the prevailing ideology. For example, the belief that hatcheries could eliminate the need for restrictive regulations supported the laissez-faire access to natural resources, a policy the public supported and the government encouraged. It's clear Baird's endorsement had social and political roots rather than scientific. From this rather inauspicious start, hatcheries quickly became the preferred approach to maintaining salmon production.



Typical turn-of-the-century salmon hatchery. (Dungeness River)

The first hatchery in the Columbia Basin was a joint venture composed of private capital, largely from cannery operators, and expertise supplied by the U. S. Fish Commission. In 1877, Baird sent Livingston Stone to Astoria to meet with the board of directors of the Oregon and Washington Fish Propagating Company (OWFPC). The company had raised $31,000 to build and operate a hatchery, and Stone was one of the few individuals on the West Coast with experience in artificial propagation. (Stone 1879; Hayden 1930). Stone selected a site on the Clackamas River, built the hatchery building, raked the stream, and supervised initial operation. OWFPC closed the hatchery in 1882. In 1888, it was leased to the State of Oregon and reopened (OSBFC 1888; Cobb 1930). After 1888, there would never be another year in which the reproduction of salmon in the Columbia basin was entirely natural.

By 1928, 15 hatcheries were operating in the basin and a total of 2 billion artificially propagated fry and fingerlings had been released into the river (Figure 1).

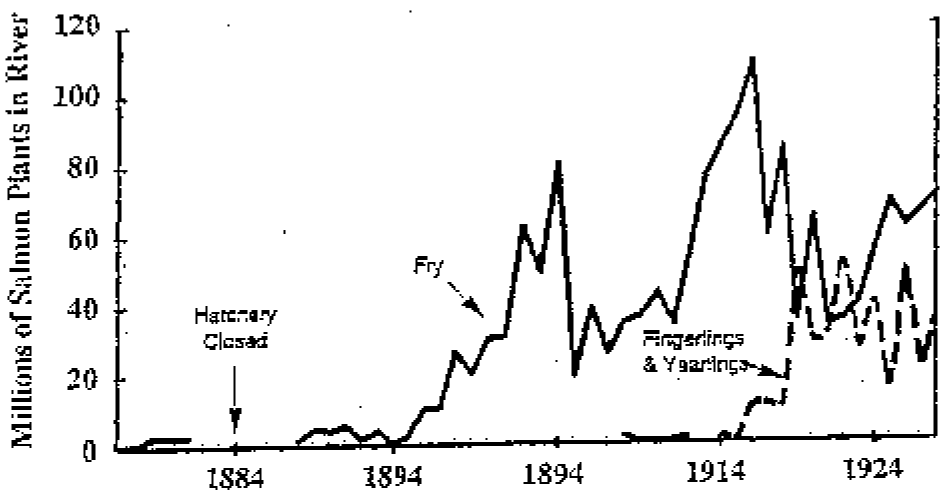


Figure 1. The number of juveniles of all salmon species released from hatcheries in the Columbia River (1877-1928). (Cobb 1930)

Because chinook salmon, especially the spring and summer races, made the highest quality canned product and brought the highest prices, fishermen targeted that species in the early fishery (Craig and Hacker 1940). The early hatchery program also focused exclusively on the chinook salmon (Figure 2); however, when the abundance and harvest of chinook salmon began to decline, the fishery switched to other species, and that switch was mimicked by the hatchery program. Coho salmon and steelhead were propagated in hatcheries beginning about 1900; chum and sockeye salmon were propagated beginning about a decade later (Cobb 1930).

The chinook harvest appeared to enjoy a period of relative stability from 1889 to 1920 (Figure 3). However, later analysis clearly demonstrated that the apparent stability was an artifact of significant qualitative shifts in the fishery (Figure 4). In fact, the prime spring and summer runs were in decline, and to maintain the catch, the fishery had shifted to fall chinook (Thompson 1951). After 1920, the decline in all races of chinook salmon in the Columbia Basin was obvious.

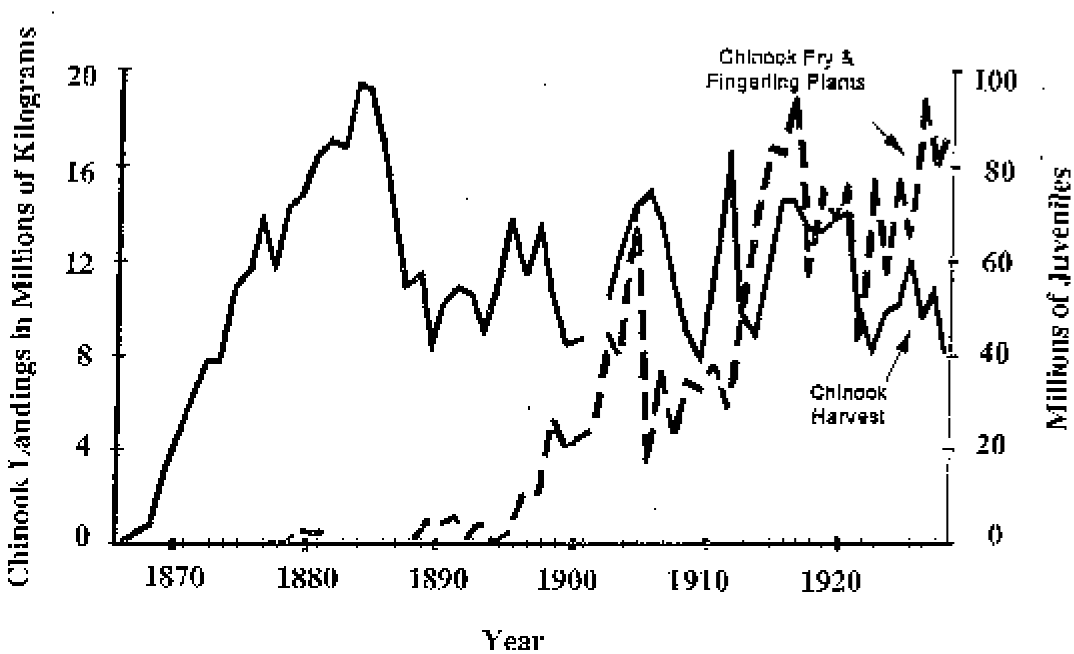


Figure 2. Harvest of chinook salmon and the release of chinook salmon fry and fingerlings from hatcheries in the Columbia basin (1877-1927). (Beiningen 1976; Cobb 1930)

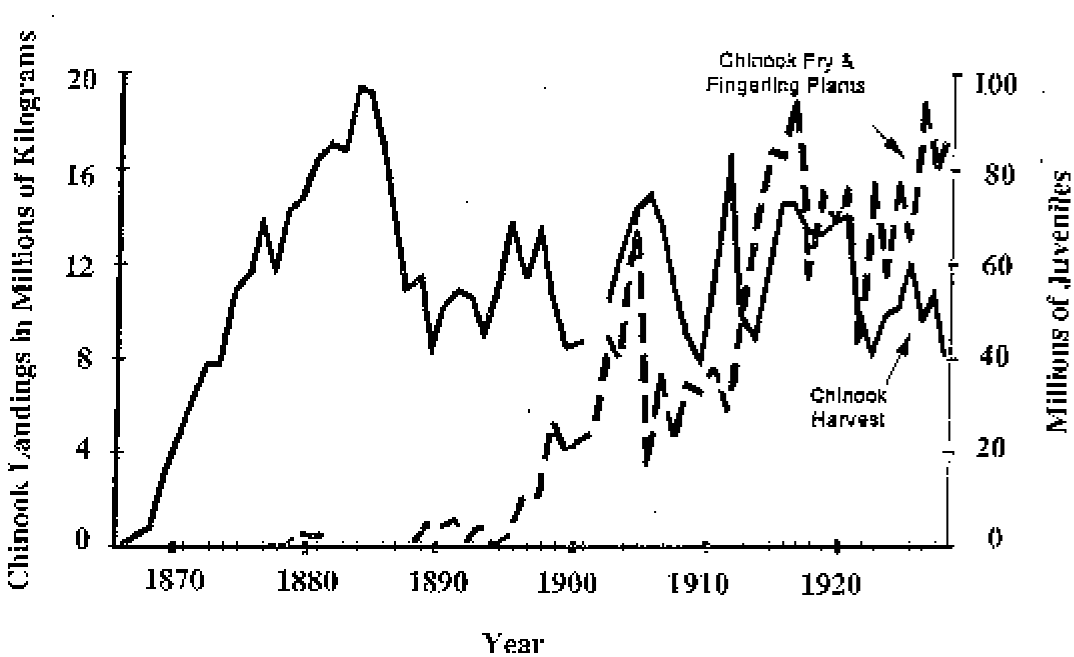


Figure 3. Five year average of chinook harvest in the Columbia River (1866-1992). (Beiningen 1976; ODFW & WDF 1993)

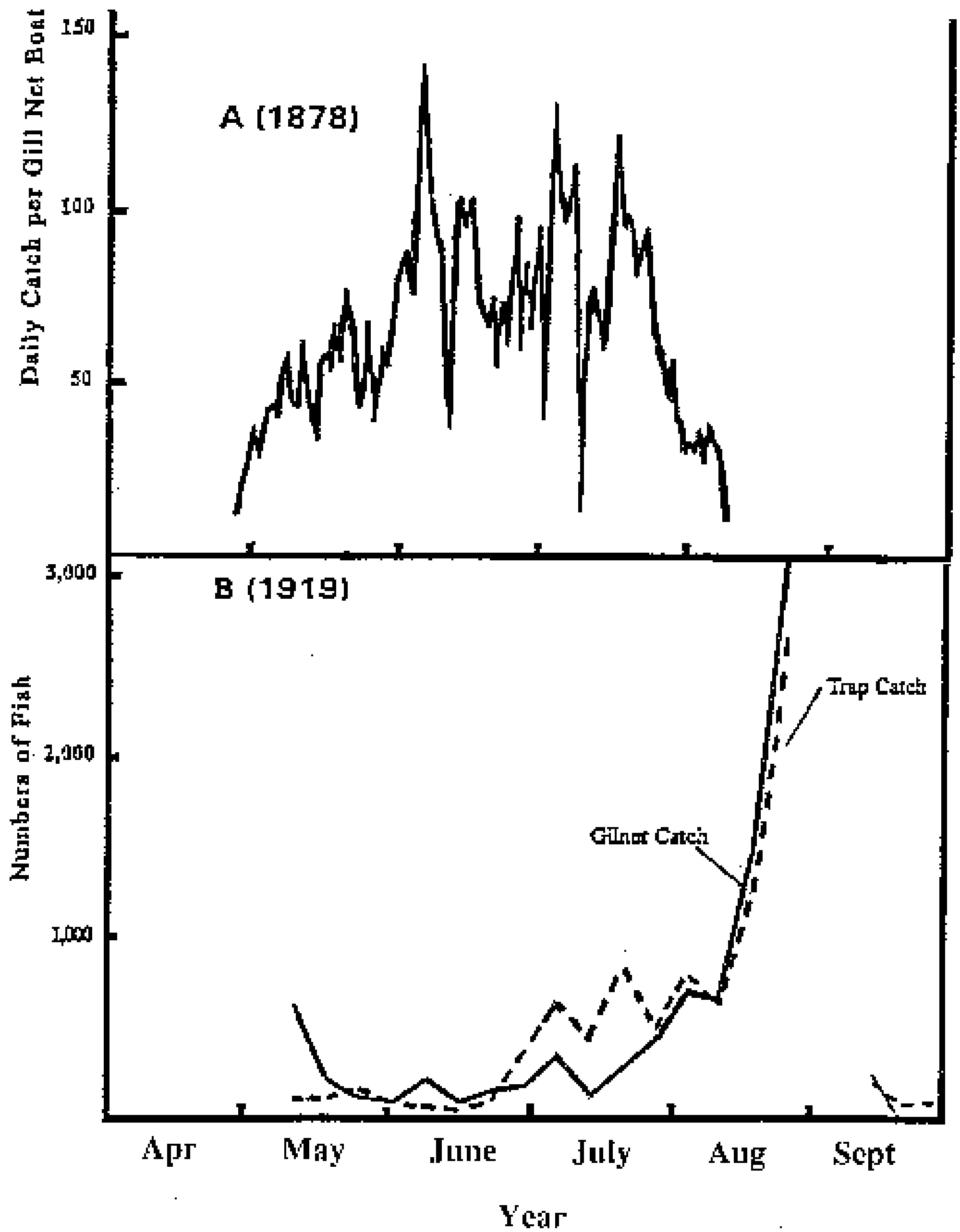


Figure 4. Comparison of the seasonal distribution of the chinook harvest in the Columbia River in 1878 (A: daily catch per gill net boat) and 1919 (B: weekly catch of 16 gill net boats and 22 traps). (Source: Thompson 1951)

In their contemporary analysis of salmon harvests, competent biologists like Willis Rich were deceived by the aggregated catch statistics: “the chinook salmon has held up remarkably well...”

in spite of an intense fishery, "but the record since 1920 is one of constantly decreasing catches" (Rich 1948). He attributed the resiliency of chinook salmon and the apparent stable harvest to hatchery programs. Rich admitted that he had no evidence that hatcheries were in fact supplementing the production of chinook salmon. However, he believed it was "quite possible that there is a causal relationship that we do not understand between intensive artificial propagation and the resistance to exploitation that the species [chinook salmon] has shown" (Rich 1941).

Rich's positive speculation regarding benefits of hatcheries, like Spencer Baird's earlier recommendation, is curious because he had completed the only study of the effectiveness of artificial propagation in the Columbia basin. In that study, Rich concluded:

> "… that there is no evidence obtainable from a study of the statistics of the pack and hatchery output that artificial propagation has been an effective agent in conserving the supply of salmon. The writer wishes to emphasize the fact that the data presented here do not prove that artificial propagation may not be an efficient measure in salmon conservation. These data prove only that the popular conception, that the maintenance of the pack on the Columbia River is due to hatchery operations, is not justified by the available science."
> (Rich 1922).

During the 1930s and 1940s, questions about the efficacy of artificial propagation, combined with budget problems during the Depression, resulted in many hatchery closures. Given their poor prior performance, hatcheries would not have played a big a role in salmon management in the Columbia River following World War II except for the fact that rapid construction of mainstem dams required a mechanism to address the impact anticipated on fisheries. Artificial propagation was once again chosen to compensate for development even though scientific support for that decision was lacking. (CBFWA 1990)

Prior to 1960, hatcheries in the Columbia River contributed little to the overall salmon production (CBFWA 1990). After that date, with the development of better disease treatment, more nutritious feeds and better hatchery practices, survival from smolt to adult improved dramatically. However, the ability to produce large numbers of hatchery adults created a new set of management problems. The genetic and ecological effects of hatchery programs are discussed in Section VI of this report.

B. Compensation for Loss of Habitat

Most of the hatcheries built during this century were intended to mitigate the impact of human activities (National Research Council (NRC) 1996). Since the construction of Grand Coulee Dam, most of the growth in the hatchery program in the Columbia River has been tied to mitigation for the construction of the basin's hydropower system. Many of the mitigation hatcheries are part of specific programs including:

<u>Grand Coulee Fish Maintenance Project</u>: The first major hatchery program designed to compensate for hydroelectric development in the Columbia River Basin was the Grand Coulee Fish Maintenance Project. Construction of Grand Coulee Dam blocked access to 1,400 miles of

salmon habitat (Fish and Hanavan, 1948). Salmon production above the dam has been estimated to have been 21,000 to 25,000 thousand fish (Calkins et al. 1939). This included some of the largest chinook in the Columbia River, the so-called “June Hogs.”

With a height of 350 feet from the base of the spillway to the top of the dam, Grand Coulee was too high to successfully pass salmon via a ladder or elevator. Salmon managers considered the construction of a hatchery immediately below the dam, but engineering problems made an alternative necessary. The final plan had three key elements: 1) adult salmon and steelhead were trapped in the ladders of Rock Island Dam from 1939 to 1943 and the fish taken to holding areas; 2) some adults were released into tributaries below Grand Coulee Dam and allowed to spawn naturally; and 3) the remaining fish were held and spawned at Leavenworth hatchery. The streams that received the transplanted fish were Wenatchee, Entiat, Methow and Okanogan rivers and Lake Osoyoos (Fish and Hanavan 1948).

The results of the fish maintenance program were evaluated by comparing the contribution of relocated stocks to the Columbia River escapement above Bonneville Dam before and after Grand Coulee cut off salmon migration. Counts at Rock Island Dam were used as estimates of the escapement of relocated stocks. Based on this analysis, Fish and Hanavan (1948) regarded the Grand Coulee Salmon Salvage Program a success. However, twenty-four years later Ricker (1972) gave a more pessimistic appraisal of the program and concluded that it salvaged nothing. More recently, Mullan et al. (1992) concluded that the fish maintenance program conserved the genetic diversity of the salmon stocks in the area. An examination of the historical record combined with an analysis of allelic variation in the chinook salmon led to the conclusion that the large-scale capture, mixing and relocation of chinook salmon stocks above Rock Island Dam permanently altered the population structure and was the genesis of the present stock structure of salmon in the mid-Columbia (Utter et al. 1995). Grand Coulee mitigation is implemented through Entiat, Methow, and Leavenworth hatcheries.

<u>Lower Columbia River Fishery Development Program:</u> The initial Lower Columbia River Fishery Development Program (LCRFDP), was strongly influenced by the concepts and design of the Grand Coulee Fish Maintenance Project. Originally, LCRFDP had an implementation life of 10 years; however, the program has continued to the present with some modifications. The program is closely associated with the Mitchell Act, the enabling legislation that permitted federal cost sharing at state hatcheries. As the title suggests, the program’s initial objective was to concentrate salmon production in the lower Columbia River below McNary Dam. At the time, in the late 1940s, it was believed that the construction of McNary Dam and the other proposed dams in the upper Columbia and Snake rivers eventually would eliminate salmon in the upper basin. In 1956, Congress changed the purpose of the LCRFDP by adding fishery restoration above McNary Dam and the word “Lower” was dropped from the program title (Delarm et al., 1987).

The original LCRFDP had six principal parts:

1. Remove migratory obstructions in the tributaries to the lower Columbia River. This part of the program included stream clearance work that removed large woody debris and probably reduced habitat quality in some streams;
2. Clean up pollution in major tributaries like the Willamette River;
3. Screen water diversions to prevent the loss of juveniles in irrigation ditches, and construct fishways over impassable barriers in the tributaries of the lower Columbia River;
4. Transplant salmon stocks from above McNary Dam to the lower river;
5. Expand the hatchery program by rebuilding existing hatcheries or new facilities; and
6. Create salmon refuges by setting aside the lower river tributaries exclusively for the maintenance of salmon and steelhead runs (Laythe 1948).

Stream clearance was consistent with management understandings and attitudes at the time, (e.g., WDF 1953), but it is no longer practiced unless the obstruction presents a complete unnatural block to migration. The relocation of stocks from the upper to the lower Columbia followed the approach used in the Grand Coulee program. Artificial propagation was one of six parts of the program, but within a few years it became the dominant part (Lichatowich et al. 1996). In 1986, 79 percent of the program budget was expended on the hatchery program and about 10 percent on habitat improvement and screening of irrigation ditches (the remainder was mainly for administrative costs). Today 20 hatcheries are supported through Mitchell Act funds (Table 1). The original goal of the LCRFDP was to maintain a harvest of about 32 million pounds of anadromous salmonids from the Columbia River (Laythe 1948). However, it was conceded that this might not be possible.

Table 1. Major hatcheries that are part of the Columbia River fisheries development program (Mitchell Act Hatcheries). (Neitzel 1998, personal communication Steve Smith NMFS and Rich Berry ODFW)

Facility Name	Agency	First Year Operated
Beaver Creek Hatchery	WDFW	1957
Big Creek Hatchery	ODFW	1941
Bonneville Hatchery	ODFW	1909
Cascade Hatchery	ODFW	1959
Clackamas Hatchery	ODFW	1979
Eagle Creek NFH	USFWS	1956
Elokomin Salmon Hatchery	WDFW	1954
Fallert Creek Hatchery	WDFW	1895
Grays River Salmon Hat.	WDFW	1961
Kalama Hatchery	WDFW	1958
Klaskanine Hatchery	ODFW	1911
Klickitat Salmon Hatchery	WDFW	1949
Little White Salmon NFH	USFWS	1989
North Toutle Salmon Hat.	WDFW	1951
Oxbow Hatchery	ODFW	1913
Ringold Springs Hatchery	WDFW	1963
Sandy Hatchery	ODFW	1951
Skamania Hatchery	WDFW	1956
Spring Creek NFH	USFWS	1901
Washougal Salmon Hat.	WDFW	1959

Mid-Columbia Mitigation: Construction of the five mid-Columbia projects (Priest Rapids, Wanapum, Rock Island, Rocky Reach and Wells) eliminated 149 miles of mainstem habitat from Chief Joseph Dam to the Hanford Reach below Priest Rapids Dam. Spawning and rearing habitat was lost from the production of several thousand fall and summer chinook in this reach (NPPC 1986) with additional impacts to the survival of downstream-migrating salmon produced in tributaries above Priest Rapids Dam.

Mitigation programs in the mid-Columbia evolved in three phases. The first phase was the Grand Coulee Fish Maintenance Project described above. From 1961 to 1967, four hatcheries and a satellite facility were constructed to mitigate for mainstem habitat inundated by the five PUD dams. This second phase originally consisted of three spawning channels (Priest Rapids, Turtle Rock and Wells) and two conventional hatcheries (Rocky Reach and Chelan). The spawning channels were later converted to conventional hatcheries. Implementation of the third phase began in 1989 and is composed of the Methow hatchery and two satellite ponds, the Eastbank Hatchery with five satellites, and Cassimer Bar Hatchery. This phase is intended to mitigate for juveniles produced in the tributaries that are lost in passage at Wells and Rock Island dams.

Lower Snake River Compensation Plan: The Lower Snake River Compensation Plan (LSRCP) was developed to mitigate the loss of fish and wildlife resources resulting from the construction of Ice Harbor, Lower Monumental, Little Goose and Lower Granite dams. Construction of these dams eliminated 137 miles of mainstem fall and summer chinook habitat and the annual production from that reach. The dams also impacted survival of downstream- and upstream-migrating salmon produced upstream from Ice Harbor Dam.

The Lower Snake River dams were completed between 1961 and 1975 (Lavier 1976). Planning for the program began in 1966, Congress gave its approval in 1976, and the first hatchery (McCall) was completed in 1979. Over the next eight years, several other hatcheries and satellite facilities were constructed. Currently, there are nine hatcheries funded under the LSRCP (Table 2). The LSRCP hatcheries were originally designed as conventional hatcheries, however in some cases, conventional hatchery operations have evolved into supplementation programs (e.g., Messmer et al. 1992).

The Lower Snake River Compensation Program did not include production objectives for Snake River coho salmon or Snake River sockeye salmon. Few resources were devoted to Snake River fall chinook, with only one hatchery being devoted to this race at Lyons Ferry. Coho salmon populations currently are extirpated from the Snake River Basin, sockeye salmon are nearly extinct, and under the Endangered Species Act fall chinook are listed as threatened. The adult return goals for the Lower Snake River Compensation Program include: 18,300 fall chinook, 58,700 spring/summer chinook, and 55,100 summer steelhead (Herrig 1998).

Table 2. Major hatcheries that are part of the Lower Snake River Compensation Plan. (Neitzel 1998, Herrig 1998)

Facility Name	Agency	First Year Operated
Clearwater Hatchery	IDFG	1992
Hagerman NFH	USFWS	1933
Irrigon Hatchery	ODFW	1984
Lookingglass Hatchery	ODFW	1982
Lyons Ferry Salmon Hatchery	WDFW	1984
Magic Valley Hatchery	IDFG	1987
McCall Hatchery	IDFG	1979
Sawtooth Hatchery	IDFG	1985
Wallowa Hatchery	ODFW	1920

<u>Other Mitigation Programs</u>: Other mitigation programs include the Willamette River Basin hatcheries, and hatcheries operated by Native American tribes and private industry. Five hatcheries mitigate for dams constructed in the tributaries of the Willamette River Basin (Table 3). The program is funded by the U. S. Army Corps of Engineers. The Nez Perce Tribe has a springwater-fed hatchery developed on Sweetwater Creek near Lewiston, Idaho, and the Yakama Tribe has a large state-of-the-art hatchery located near the Yakima River at Cle Elum, Washington. The Kootenai Tribe of Idaho has been operating a hatchery near Bonners Ferry, Idaho, originally in conjunction with the Idaho Department of Fish and Game, to protect the endangered Kootenai River population of white sturgeon from extinction. This facility was just

upgraded to more reliably fulfill its conservation function, and to address the needs of other at-risk populations in the Kootenai River Basin, including native kokanee salmon. Most of the tribal production facilities are funded by Bonneville Power Administration ratepayers through the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program.

Table 3. Major hatcheries that are part of the Willamette mitigation program. (Neitzel 1998)

Facility Name	Agency	First Year Operated
Leaburg Hatchery	COE	1953
Marion Forks Hatchery	COE	1951
McKenzie River Hatchery	COE	1975
South Santiam Hatchery	ODFW	1968
Willamette Hatchery	COE	1911

Several hatcheries have been financed by private industry to mitigate for loss of salmon and steelhead habitat by the construction of dams. Some of the main projects are listed below:

- The effects of dams constructed in Hells Canyon by the Idaho Power Company are mitigated through four hatcheries operated by the Idaho Department of Fish and Game.
- On the Deschutes River, Round Butte Hatchery mitigates for the construction of Pelton and Round Butte Dams by Portland General Electric Company.
- Two hatcheries on the Cowlitz River mitigate for dams constructed by Tacoma City Light.
- Two hatcheries on the Lewis River are funded by PacifiCorp to mitigate for hydroelectric development on that river.

As demonstrated by the history of artificial production in the Columbia River system, there has been extensive variation in how hatcheries have been used to address needs of fisheries management. In the earlier years, the basis on which hatcheries were developed was opinion and adherence to a popular concept for increasing the magnitude of salmon runs. As hatchery programs developed better technology over the years, there were concomitant changes in what constituted hatchery management policy, and changes in the extent to which biological rationale influenced that policy. There have been differences in the quality of hatchery fish and improvements in the survival performance of fish released from hatcheries, but also a performance that has been highly variable among hatcheries. It is instructive, therefore, to look simultaneously at the evolution of the role of science as the hatchery concept developed and at the history of hatcheries on the Columbia.

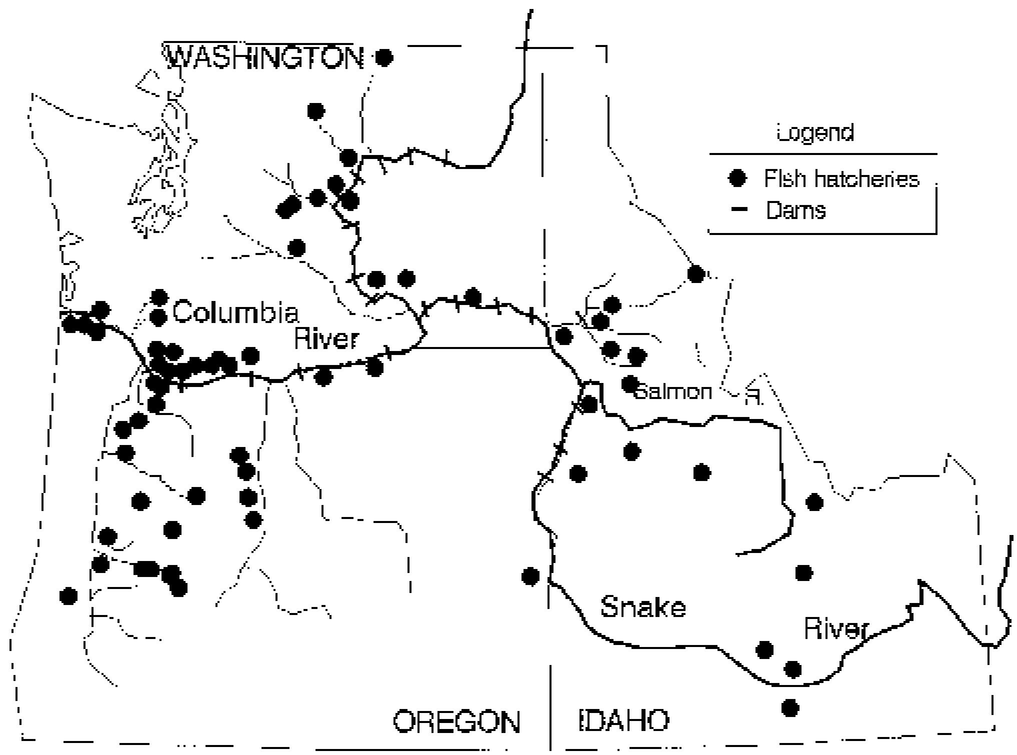


Figure 5. Columbia River Basin state, tribal and federal hatchery locations.

IV. Scientific Foundation

All salmon management programs are derived from a scientific foundation — a set of assumptions, theories and principles that describe how the salmon ecosystem functions (ISG 1996 The foundation is a powerful part of any management program. It is used to interpret information, identify problems (impediments to achieving objectives) and select restoration strategies. Unfortunately the conceptual foundation is rarely explicitly stated or evaluated, and as a consequence programs can suffer from errors in concept. When limited scientific inquiry and false assumptions are a part of the process, the program derived from them will have a high likelihood of failure.

The conceptual foundation of the Columbia River hatchery program has never been specified or examined in detail. In this section, we describe the set of assumptions we believe were the basis of the hatchery program. Because it has never been explicitly stated, the conceptual foundation described here had to be derived from our review of the program — its apparent objectives, assumptions stated by practitioners and its measures of performance. The conceptual foundation we present is thus qualified as our interpretation of the historical record, and accounts for the period ending in the 1960s; the point at which the hatchery assessment (the second phase of our report) begins.

A. The Early Conceptual Foundation of Hatcheries

The early hatchery program was consistent with the overarching assumption that salmonid production systems could be simplified, controlled, and made more productive. Hatchery technology not only simplified and controlled production, it circumvented the need for natural ecological processes and freshwater habitat. This philosophy was also reflected in the subsequent development of resident fish hatcheries. The program intention was simply to increase catch by protecting the eggs, maximizing the number of fry released, and harvest fish returning from the sea. Given the hypothetical fecundity of 3,000 eggs, a spawning pair may successfully produce something in the neighborhood of 500 fry to emergence under natural stream conditions. Under the same scenario, artificially spawning and incubating those 3,000 eggs would result in about 2,500 fry to emergence under the hatchery scenario, or a five-fold increase over natural incubation because of the protection against predation, disease, poor incubation conditions and scouring floods. So the rationale of the early practitioners was not an unreasonable expectation of the advantage of hatchery fry production. Moreover, it was a technique that, when properly employed, had brought substantive results, as demonstrated by an example we discuss in the next section (B).

The problem in the beginning was one of dimension. Even with a five-fold improvement in egg survival, the number of females intercepted was insignificant compared to the number spawning naturally, even when the run was seriously depressed. The primary problem, however, was that fry were distributed to a variety of streams with little or no information about the suitability of habitat or risk for young fish. This also was true of the often haphazard stocking of non-native or exotic fish. In Idaho alone, 30 exotic species of resident fish have been introduced since the late 1890s. (Simpson and Wallace, 1982).

It was the natural extension of the concept that if protecting the incubating eggs from such harm would result in a five-fold improvement in fry production, and hence the extrapolation to a five-fold improvement in adult returns, then why not control the rest of freshwater rearing to reduce losses from predation, disease, starvation, and environmental alterations in the natural stream? Therefore, taking the simple equation one step farther, of the 500 wild fry emerging naturally, 45 might be expected to reach the smolt stage and enter marine waters, from which two to five adults would return. However, extrapolating the hatchery survival advantage to the next life history stage, if the now 2,500 fry successfully incubated from 3,000 eggs in the hatchery were reared and protected through the succeeding freshwater rearing period, 2,000 fingerlings could be produced to the smolt stage, equating to a total hatchery production benefit nearly 44 times greater than natural production of the original 3,000 eggs. Rather than two to five adults returning per pair of natural spawners, given marine survival equal to natural fry, the hatchery benefit would equate to over 100 returning adults from the same pair of spawners. The simple extrapolation of hatchery survival to return success was the presumptive expectation of the hatchery enthusiasts, and the basis for the expansion of the hatchery building program that has spanned a half century to the present distribution of artificial production throughout the Columbia basin (Figure 5).

Experience has demonstrated, however, that successful production of juveniles in hatcheries is not so simple and that hatchery production by itself cannot guarantee a sustained increase in catch. However, the point in laboring the expectation that ushered in the development of hatcheries is that the fundamental premise is very similar to the basic assumption inherent in the subsequent development of Pacific salmon and many resident fish hatcheries throughout the Pacific Northwest. That presumptive view has not changed substantially, and production augmentation currently is being undertaken in at least the Columbia River Fishery Development Program, but with a more conservative expectation of benefit.

Part of the problem is that early salmon managers viewed rivers as agri-ecosystems capable of being simplified, controlled and through cultivation (artificial propagation) brought to higher levels of production (Bottom 1997; Lichatowich et al. 1996). The agricultural approach to management led to an emphasis on single species production objectives that separated the development of fisheries science from the major developments in ecology for anadromous and resident species. Fisheries adopted agricultural objectives and supporting science instead of the holistic approach advocated by early fisheries workers such as Forbes (McIntosh 1985; Bottom 1997). Viewing rivers as farms led to the belief that individual enterprise alone could overcome any natural limits to production (OSBFC 1890). As late as 1960, the Washington Department of Fisheries still believed that fish farming was closely linked to farming on land and shared the same principles and rewards (WDF 1960).

An agricultural model for salmon production was expressed by several early salmon managers. The following is a sample of their statements:

> *"Professor Baird often said 'one acre of water was worth seven acres of land, if properly cultivated,' but I am convinced that the Professor erred only in this, that I believe one acre of the waters of any salmon stream in Oregon, if judiciously cultivated under favorable circumstances, and if not paralyzed by ignorant vicious legislation, is worth more as a medium for the product of a food supply than forty acres of the best land in the State."* (Hume, 1893)

> *"It has been the habit to cultivate the land and neglect the water…. We have tilled the ground four thousand years; we have just begun to till the water…. Less care and labor are needed to raise fish than to raise other animals, or even to raise vegetables."* (Oregon State Board of Fish Commissioners, 1890)

> *"Modern incubation equipment for fish propagation compares with greenhouse methods to increase the survival of plants… As man makes ready the soil for growing of better crops, so may he improve the water for the growing of fish. The steps to be taken in the harvest of surplus seed, the surplus crops, the preparation of land or water follows the same fundamental requirements."* (Washington Department of Fisheries 1960)

Commercial aquaculture, or fish husbandry for commercial markets with other agricultural commodities in the Pacific Northwest, has demonstrated production capabilities even better than the original hatchery practitioners envisioned. This is because fish farmers control the entire life cycle from spawning to adult harvest and realize the equivalent of 1,800 marketable adult-size fish per spawning pair. However, while the application of agricultural principles has been beneficial in some aquacultural enterprises, it generally has failed when applied to anadromous salmonids, which are released to experience more than three-quarters of their life in the natural environment.

In retrospect, when we look back to the era of “farming nature,” in light of the major leaps that agriculture has made and continues to make in animal husbandry, the assumption that watersheds could be treated as farms and managed like agricultural enterprises was understandable. This logic led to the belief that natural limits on production could be ignored and, through fish culture levels of production greatly increased. Initially production from natural populations was assumed to be limited by spawning success, and production of the ocean relatively unlimited. Consequently, it was believed that increased survival of fry and fingerlings in the hatchery would translate proportionately to increased adult return. This is epitomized in the following excerpts.

> *"It is imperative, therefore, that some means be adopted to counteract the depletions arising from this source (habitat degradation); but the most important reason for the artificial propagation is the fact that the natural method is extremely wasteful, which is not true of the artificial method.”* (Smith 1919, p. 6)

> *"In my opinion, if the salmon runs of this state are to be maintained and increased, it is going to be necessary to constantly construct new hatcheries. The much greater effectiveness of hatchery operations, as compared with natural propagation, has in my judgment been so effectively proven as to no longer permit discussions among those who are acquainted with the situation.”* (WDFG 1921, p. 17)

> *"There can be no doubt in the mind of anyone who has studied the question, that the future prosperity of our salmon fisheries depend largely upon artificial propagation... I am convinced that not more than 10 percent of the ova spawned in the open streams are hatched, owing principally to spawn-eating fish that prey on them... while from artificial propagation 90 percent are successfully hatched. What more need be said in favor of fish culture?”* (Oregon State Fish and Game Protector 1896, p. 33)

> *“Nature ... produces great quantities of seed that nature does not utilize or need. It looks like a vast store that has been provided for nature, to hold in reserve against the time when the increased population of the earth should need it and the sagacity of man should utilize it. At all events nature has never utilized this reserve, and man finds it already here to meet his wants.”* (Stone 1884, p. 21)

The assumptions that watersheds could be made more productive through agricultural practices and that natural limits on production could be circumvented were the foundation of the Columbia Basin hatchery program. Moreover, hatchery production was assumed to be additive to natural production, with no interaction or impact on natural populations. Given the expected translation of hatchery survival to adult returns, practitioners also assumed that the principle measure of success for a production hatchery should be the numbers of juveniles released. Obviously, there would be an associated expectation that harvest level should also increase, but accounting for catch over many fisheries and jurisdictions was much more difficult and less practical than simply monitoring numbers of juveniles produced.

In summary, the fundamental assumptions governing the development of the Columbia River hatchery program before 1960, and the genesis of the early conceptual foundation of hatchery production, was centered on five general assertions:

- It was not only possible but also desirable to simplify and control production of anadromous salmonids to increase their abundance.
- Anadromous salmonids could be effectively managed through the application of agricultural practices and science.
- Production limitations during freshwater life stages could be circumvented by hatcheries, and the capacity of the ocean was relatively unlimited.
- Artificially propagated fish released to the rivers added to production from natural populations. There were no negative interactions.
- The probability of success was so high that evaluation of adult returns was not necessary.

B. The hatchery framework as an adaptive process

Development of a conceptual foundation applicable to Columbia basin hatchery programs has to be consistent with what is known about salmonid life history and ecological processes. Any fisheries management effort that does not integrate the management criteria around the inherent life history strategies that have evolved among the specific salmonid and native resident fish species, including stock-specific differences, will fail. Pacific salmonids have evolved specific life history patterns and population structures compatible with their native habitat (Brannon, in press), and ignorance, or disregard, of that compatibility will weigh heavily against any management attempts to sustain or build wild fish populations. In essence, the conceptual foundation must be flexible enough to accommodate derivations in life histories among all fish species, including those differences within the mixture of stocks representing the species.

Natural populations of salmonids are genetically programmed to survive and behave in ways that maximize long-term fitness in their natural environments. Disconnecting the organismic and environmental linkages effectively disrupts the timing and reduces fitness back to the level of a founding population. Survival success returns to the odds of happenstance, and adaptive evolution must start over again. Typical central hatchery programs that follow such management plans, and repeatedly distribute fish around the watershed can not effectively address the concept of ecosystem management. These fish will have little contribution value to natural production, and by continually or even intermittently spreading stocks around the system, fish will remain biologically incompetent for those foreign environments.

The challenge in developing the conceptual foundation for hatcheries is to re-prioritize production and operation goals to address the biological needs of the stock being propagated. In freshwater, chinook life history strategy is the most complex among the anadromous salmonids and pink salmon the simplest, with coho, steelhead, sockeye, and chum salmon intermediate. Stream-dwelling species, such as chinook, coho and steelhead, are limited most often by the rearing capacity of their stream. Generally, factors associated with spatial and nutritional requirements of stream-dwelling salmonids determine the upper limit of population biomass that can be sustained within the stream, and strategies to maximize productivity around those parameters evolve to define the population. Sockeye, chum, and pink salmon use freshwater streams only for spawning, with the juveniles immediately migrating to their nursery environments in lake (sockeye) or marine (chum and pink) waters for rearing. Only the spawning area of the stream generally limits these species, as the productivity of their nursery environment most often exceeds the capacity of the spawning grounds available.

In developing a conceptual foundation for hatchery programs, the process must allow for differences inherent in the fish targeted and whether they have adopted anadromous or resident life histories. It appears that successful applications of the hatchery concept are those cases that do not deviate significantly from the biological repertoire of the fish, and were successful in addressing the limiting factors in the natural life history of the species. The Prince William Sound (PWS) pink salmon hatchery program is a good example (Linley, in press). In the early 1970s the commercial fishery on pink salmon was threatened by the low return of fish into the sound, and hence it was believed the relatively small numbers of fry naturally produced were insufficient to rebuild the run. The non-profit hatchery program was started, involving the artificial spawning and incubation of fry for release into PWS. Fry releases were synchronized with the beginning of the spring plankton bloom, which was the biological optimum for rapid growth. Their success was unprecedented (Figure 6). Adult returns improved four-fold over the previous ten-year average of 5 million adults, and has reached numbers as high as 45 million returning fish. Percent survival of fry released to achieve those levels of return success ranged from 0.9 percent to 13.0 percent (Figure 7) at the Armin F. Koernig hatchery (Linley, in press), far exceeding the survival performance of any fingerling or smolt production hatchery on the Columbia. The survival variability was attributed to variations in marine productivity, temperatures, and predation, based on annual monitoring of those conditions in the sound (Willette 1992). Success in the PWS hatchery program was experienced by working within the life history definition of the species, and has succeeded for ten generations.

Similar success addressing production restraints from loss of habitat was experienced with sockeye returning to Weaver Creek on the Fraser River (IPSFC and PSC annual reports). Logging had caused high variability in flows, and the loss of redds and low returns were threatening the viability of the run. The Salmon Commission built an artificial spawning channel on the stream in which flow was controlled and much of the silt and fine material prevented from infiltrating the graded spawning substrate. Natural spawners used the channel with egg-to-fry survival rates averaging well over 60 percent, or about 10-fold better than survival in the adjacent stream. Adult returns showed a marked improvement, amounting to an average of about 250,000 fish annually (Figure 8).

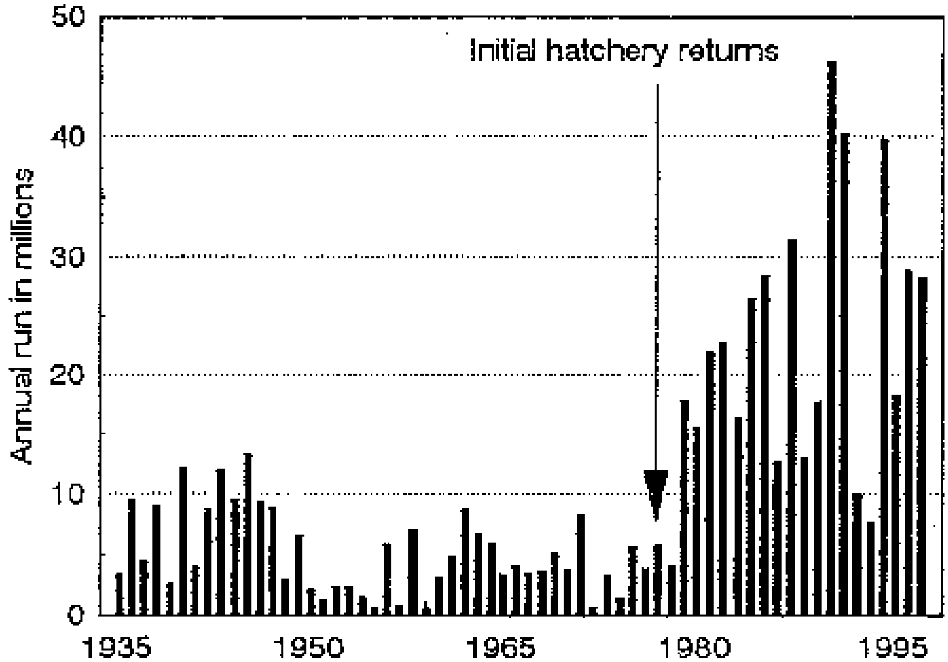


Figure 6. Annual run size of pink salmon returning to hatchery and natural production streams in Prince William Sound, Alaska.

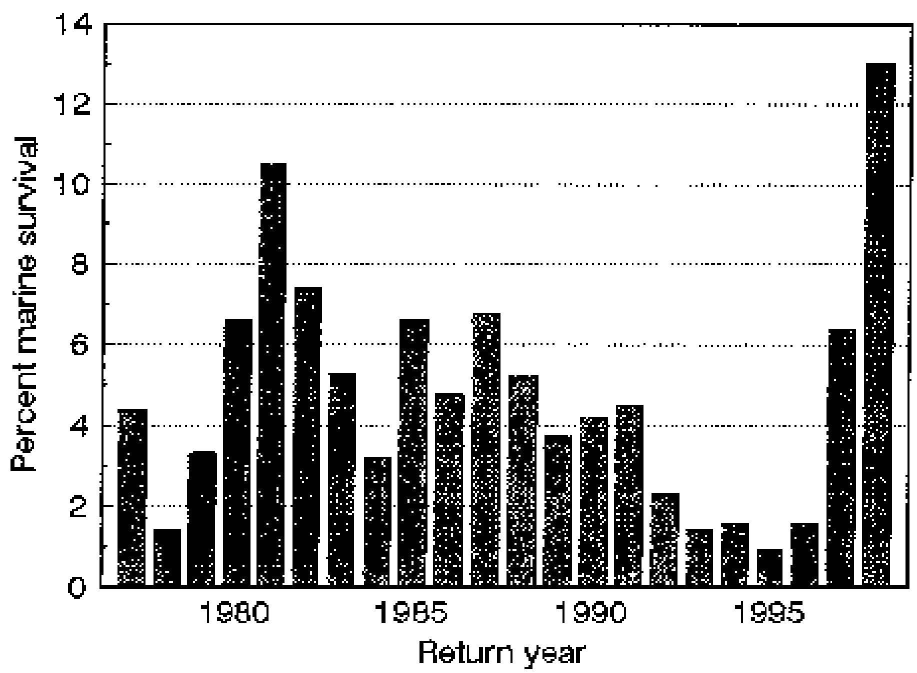


Figure 7. Percent survival of pink salmon fry released from Armin F. Koernig hatchery in Prince William Sound, Alaska.

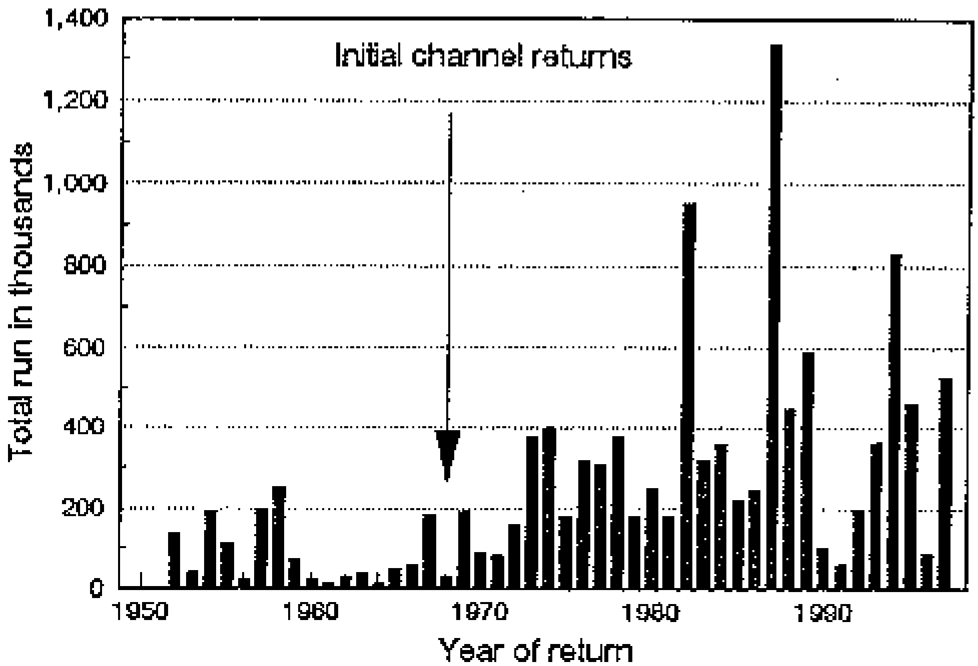


Figure 8. Annual run size of sockeye salmon returning to Weaver Creek in British Columbia (IPSFC/PSC Rept).

The Weaver Creek channel (hatchery) concept succeeded because the operation was complementary to the biology of the species, and addressed only that portion of the life history that was limiting the population. In both the PWS pink salmon hatchery program and the Weaver Creek sockeye salmon spawning channel, the conceptual foundation was consistent with the species life history and integrated the solution to the production problem effectively. However, these species present a different kind of challenge than that facing the Columbia basin hatcheries. Sockeye and pink salmon are normally limited by freshwater spawning area, and the hatchery approaches used in both cases addressed that limitation with relatively minimal intrusion in the ecological system. The stream-dwelling species (chinook, coho, and steelhead) create a different problem when limited rearing habitat is the primary source of population decline. Hatchery rearing programs have a more difficult task of integrating cultured fish into the natural system because, unlike artificial incubation programs, under present hatchery rearing environments the fish are removed from everything that would resemble or prepare them for the natural stream environment they must compete in once they are released. However, even under these conditions, hatchery programs have shown success in increasing production. The Makah Nation Fish Hatchery is a good example.

In the late 1970s, the Makah Indian Nation sought to increase the production of anadromous salmonids associated with the streams on their reservation in far northwestern Washington state. The Sooes River chinook population was being seriously threatened by clear-cut logging watershed instability, runoff from log yards, and overfishing by the coastal and Canadian fisheries. Fewer than 100 fish were reaching the spawning grounds in some years. In cooperation with the USFWS, the Makah National Fish Hatchery was built on the Sooes River, entering the Pacific Ocean just south of Cape Flattery. Plans were initiated to introduce chinook from other hatcheries, but the Makahs insisted that only Sooes chinook be propagated, even if the hatchery was not fully utilized in the first few years. They felt Sooes River fall chinook were uniquely adapted to that coastal system, with large eggs and an early migration timing to marine waters. Therefore, the hatchery program was to enhance the Sooes River chinook population, and a breeding plan was followed to maintain the diversity present. Fish excess to hatchery needs were permitted to spawn naturally, and in theory both the hatchery population and the naturally spawning fish commingled as a single population. Age-3 returns from hatchery propagation started in 1984, and by 1988 hatchery contributions were a significant share of the total return (Figure 9). By the late 1990s well over 2,000 fish were returning from both the hatchery and the natural production.

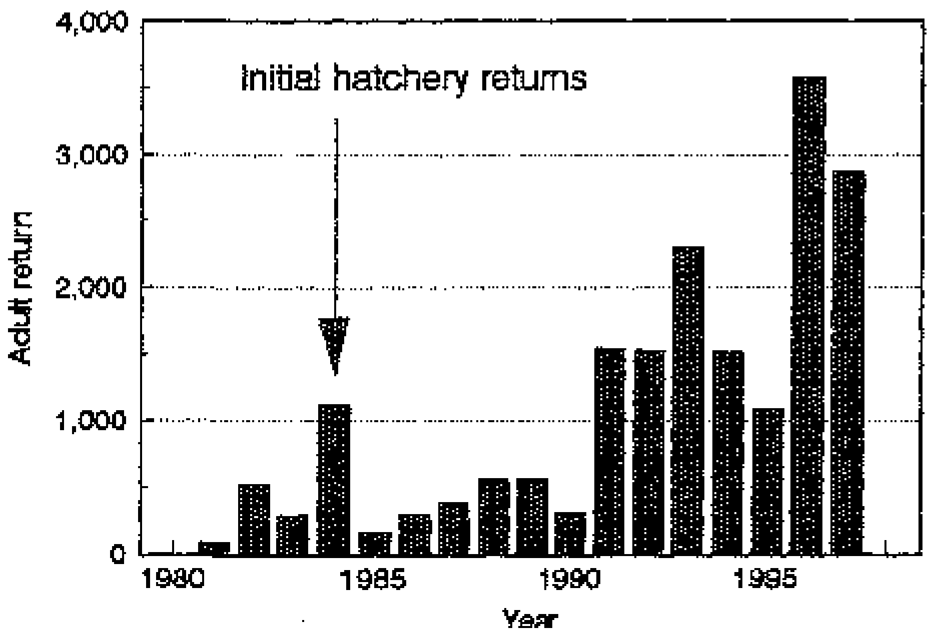


Figure 9. Chinook salmon annual return to Sooes River, Washington, from hatchery and natural production.

The Sooes River chinook salmon hatchery program success is attributed in part to the emphasis on the native stock. The selective advantage of the adaptive traits manifest in the physical and behavioral characteristics of the Sooes stock were not compromised by introductions of another stock that would have been incompatible with that coastal system. Also contributing to their success is the hatchery's proximity to the marine environment. Naturally produced fish have a relatively brief period of freshwater residence, and the hatchery fish can be in brackish water within an hour after release from the hatchery.

These examples of pink, sockeye, and chinook hatchery programs that have had good success in reaching their production objectives demonstrate that the appropriate conceptual framework is critically important to the development of functional enhancement systems. Admittedly, none of the above examples is subject to the severely anomalous conditions facing Columbia River salmon and steelhead. The point in fact, however, is that if Columbia Basin hatcheries are to have success in enhancing natural production and restoring some of the runs to self-sustaining populations, the conceptual foundation has to be that much more specific to the task. To meet the challenge of integrating artificial propagation into the Columbia Basin ecosystem and reach the commercial, tribal, and public fishery objectives, the model has to be rigorously defined and the biology of the component species well understood.

Many of the previous requirements for successful anadromous salmonid hatchery programs also apply directly to resident fish. As with the previous examples of successes with pink, sockeye, and chinook salmon, resident fish hatcheries also share the success of meeting their goals. It is important to note that the goals of anadromous and resident fish hatchery programs can differ considerably due to differences in program application and purpose, as well as differences in life history strategies and requirements of the species targeted. Nonetheless, the two following examples of successful resident fish hatchery programs provide substantial recreational fishing opportunities, increased numbers of angler trips, and very important local economic benefits. Their success was judged by the contribution of recreational fisheries to the local economies and the quality of life in the interior Columbia Basin. These two examples involve Sprague Lake in eastern Washington, and Lake Roosevelt, in northeastern Washington.

Resident hatchery stocks of rainbow trout and Lahontan cutthroat trout were successfully introduced into Sprague Lake following complete elimination of carp , stunted yellow perch and additional undesirable non-native fish species through the use of rotenone (Whalen 1989; Willms 1989; Willms et al. 1989). Prior to rotenone treatment, and the introduction of rainbow and cutthroat trout, the estimated annual angler pressure was believed to be approximately 1,700 angler days (approximately 13,600 angler-hours; Willms et al. 1989). Following rotenone treatment, removal of undesirable species, and introduction of rainbow and cutthroat trout, the estimated 13,600 angler-hours rose to over 200,000 in 1987 and 1988 (Figure 10; Willms et al. 1989). One of the goals of this resident trout introduction program was to generate $500,000 annually for the local economy. The program has since provided over $1 million annually to the local economy — 20 times the original target goal (Willms et al. 1989). These authors also determined that in 1986, 46.6 percent of all rainbow trout stocked into Sprague Lake were returned to the creel during the same year. This return is more than forty times that of documented adult anadromous salmon returns, which illustrates the need for separate and appropriate evaluation criteria of resident and anadromous fish hatchery programs. In this case, the newly established resident trout fishery in Sprague Lake illustrates the benefits of resident hatchery programs, which provided a popular fishery in a previously little-used lake.

The second example of successful resident fish hatchery programs involves Lake Roosevelt, the Spokane Indian Tribe's resident fish hatchery, and rainbow trout. The Spokane Tribal Hatchery program began stocking Lake Roosevelt with rainbow trout and kokanee salmon in 1991 in order to establish and enhance resident fisheries in the lake as mitigation for anadromous salmon resources permanently lost due to dam construction. From 1991 through 1994, rainbow trout catches increased nearly five-fold (Figure 11), angler trips nearly tripled ((Figure 12), and estimated annual revenue generated by hatchery-supported resident fisheries increased nearly four-fold (Figure 13, Cichosz et al. 1996).

Figure 10. Comparison of angler-hours during pre-stocking (1985) and post-stocking (1987, 1988) periods at Sprague Lake, Washington (Data from Willms et al. 1989)

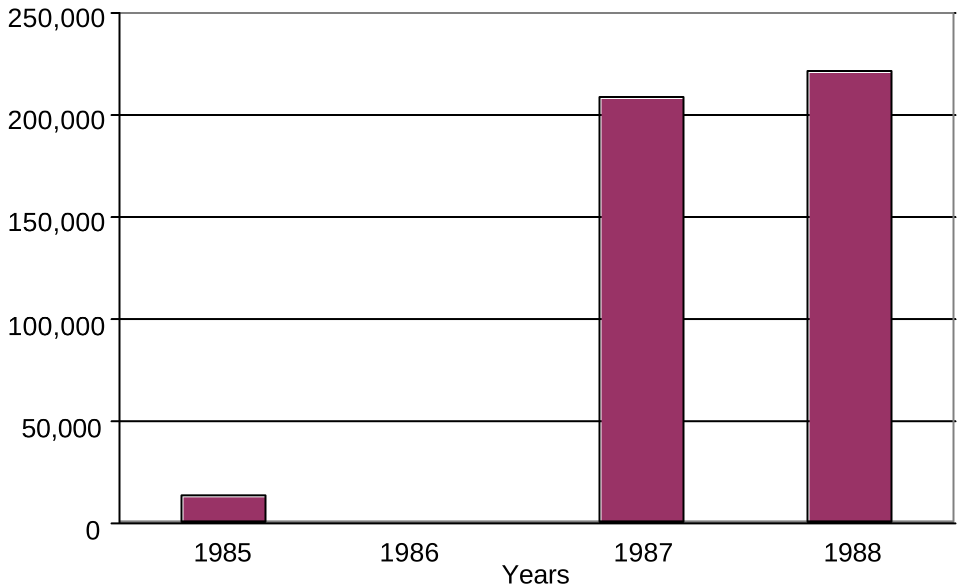


Figure 11. Comparison of rainbow trout catch before (1990,1991) after stocking (1992-1994) in Lake Roosevelt (Data from Cichosz et 1996).

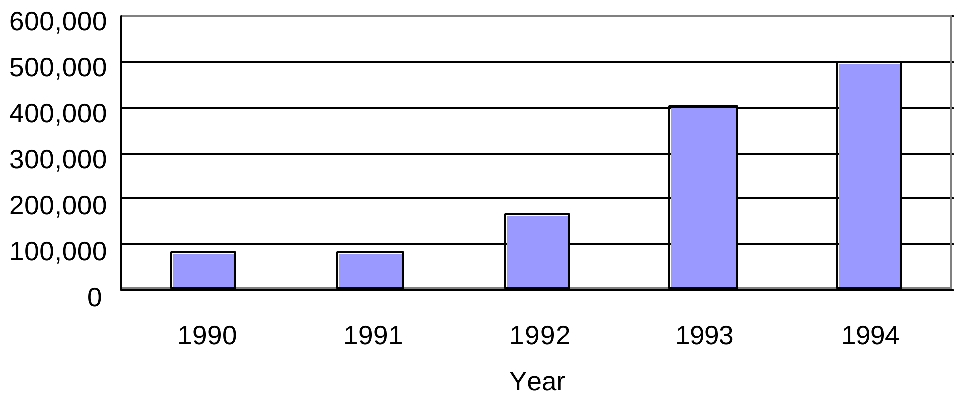


Figure 12. Comparison of angler-trips on Lake Roosevelt before and after rainbow trout stocking (Data from Cichosz et al.)

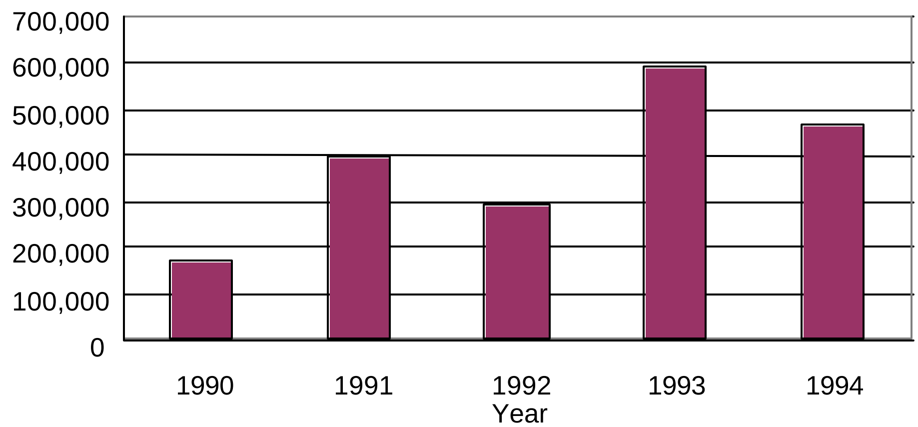
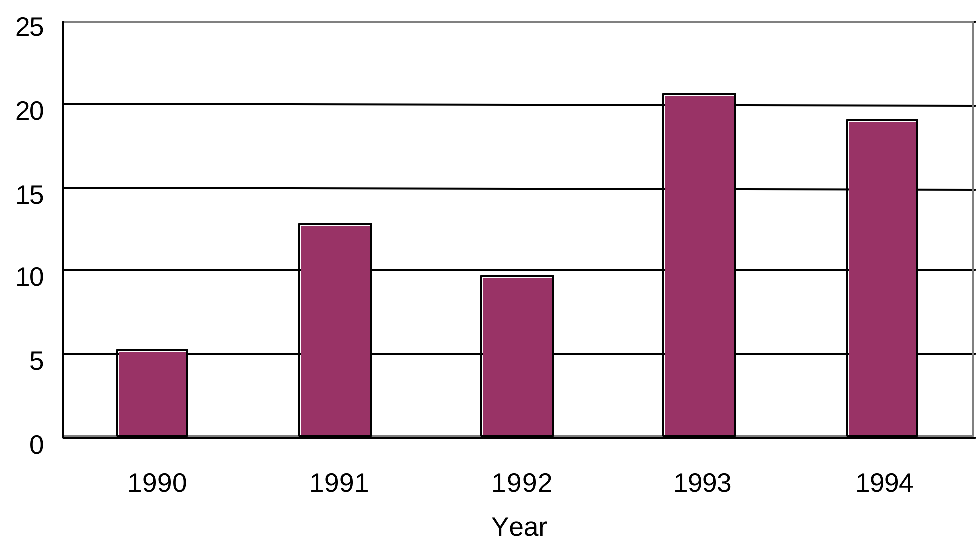


Figure 13. Comparison of economic value (millions of dollars) of fishery before (1990) and after rainbow trout stocking program (Data Cichoz et al.1996)



V. Organization and Classification of Artificial Production

We have stated that implicit in the artificial production of salmon, and the fundamental premise behind development of salmon hatcheries in the basin, was the belief that increases in the number of juvenile salmon produced and released from hatcheries would result in a proportional increase of harvestable adults. Although expectations of artificial production have matured to something more qualified by experience, that basic premise has continued to be a strong impetus behind hatchery substitution for habitat loss and reduced access to historical spawning grounds. New hatcheries are being constructed in anticipation of markedly increased adult returns resulting from such operations. How these new hatchery complexes integrate into the basin ecosystem will be defined by how management applies the conceptual framework to meet the objectives they have for the fishery.

The application of the hatchery model in the management of salmon fisheries, and hence the basis on which performance of such hatcheries must be judged, depends entirely on the objectives or strategies being addressed (Table 5). With the possible exception of hatcheries that are used solely to restore specific populations nearing extirpation, all anadromous and resident fish hatcheries are intended to provide fish for harvest. Management strategies fall under two categories of purpose, one to augment natural production for harvest, and the other to mitigate for the loss of harvest as a result of the diminution or elimination of salmon-producing habitat, and excluding their access to that habitat. It is instructive, therefore, to define more precisely the nature of augmentation and mitigation in the Columbia basin because of their application in mandates of Congress to enhance production or compensate for its loss as the river has developed around other societal needs. It is also essential to understand the classification of hatcheries in this document if assessment of past performance and current status is to provide the intended framework on which future management decisions and policies will be based.

A. Harvest Augmentation

Early in the development of mid-nineteenth century salmon fisheries, and as commercial harvests of Columbia River chinook salmon were doubling every season, artificial production was given serious consideration as a means to augment the harvest of salmon beyond that which could be sustained by natural production. Freshwater production of young salmon in natural river systems was correctly assumed to be limited by spawning success and habitat, and hatcheries were conceived as a means to overcome such constraints on natural production. The fact that egg-to-fry survival could be increased as much as ten-fold through the process of artificial spawning and incubation in hatcheries was the general motivation behind construction of the first Columbia Basin hatchery in 1876, located on the Clackamas River. The expectation followed that adult returns would materialize from such technological interventions, reminiscent of philosophical deductions from technological advancements in agriculture and animal husbandry. This same pervasive philosophy was incorporated into the development and maintenance of mitigation hatcheries that propagated resident fish species. Overfishing reduced the abundance of anadromous salmonids so extensively in the basin that augmentation actually tried to compensate for the fishery and was never able to expand harvests beyond historical natural production.

Although attempts to assess hatchery contribution to the harvest did not occur until more recent times, and in spite of divided opinion within the scientific community about hatchery success (Lythe, 1948), the belief that artificial production contributed to the fishery has been responsible for development of substantial hatchery effort. There were three fundamental assumptions associated with the use of hatcheries for the purpose of harvest augmentation. (1) the freshwater environment limits natural production, (2) ocean carrying capacity exceeds natural production potential, and (3) hatchery production will not negatively impact natural populations. Belief in these assumptions still prevails, and they exist as criteria that need to be carefully assessed in applications of harvest augmentation programs to justify use of such technology for that objective in the Columbia River.

The first and second assumptions have credence, but the lower end of the productivity threshold in the marine environment is a very powerful limiting force on production, regardless of the magnitude of production in freshwater. Augmentation of harvest through hatchery production has been demonstrated most recently with pink salmon in Prince William Sound as seen in Figure 6, and highly correlated with marine conditions (Willette, 1992). Several hatchery programs in Alaska demonstrate very positive augmentation success, routinely above 10-percent survival of fingerling sockeye, and higher than 20 percent among some groups on fingerling coho (Marianne McNair, ADF&G, personal communication).

Successful augmentation hatchery programs are not rare in Washington and Oregon, either. The old Washington Department of Fisheries was formed to manage marine fisheries in the state specifically for commercial harvest, and augmentation was the objective of Washington State hatcheries. Hood Canal chum salmon hatchery production is a good example (Fuss, 1998). The size of the chum salmon run in Hood Canal has been directly related to the level of hatchery fry releases (Figure 14).

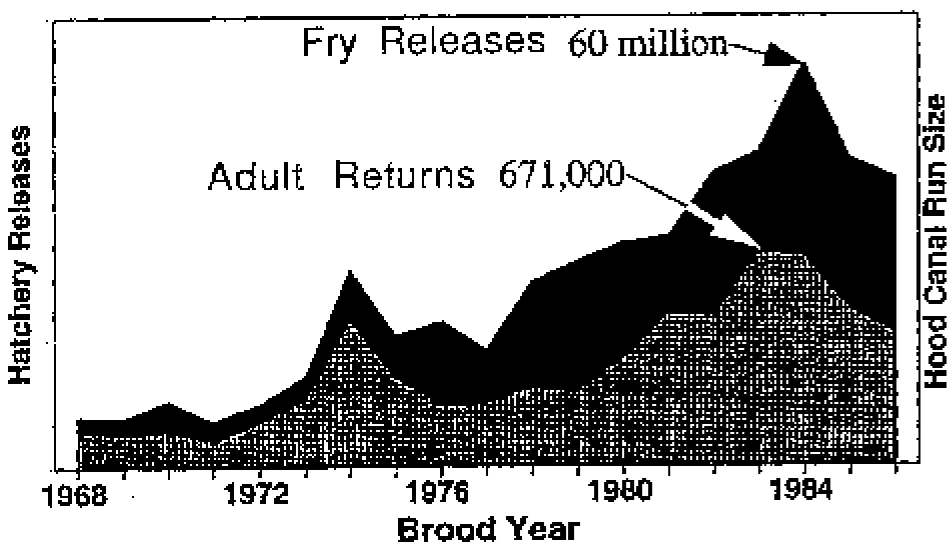


Figure 14. A comparison of Hood Canal chum salmon releases and subsequent run size. (Fuss 1989)

Similarly, coho production in Puget Sound shows a strong relationship between hatchery production and return run size. Fuss (1998) points out however, that regardless of hatchery contributions, if the environmental restraints are limiting the carrying capacity, production levels off or declines to whatever the environment will support (Figure 15).

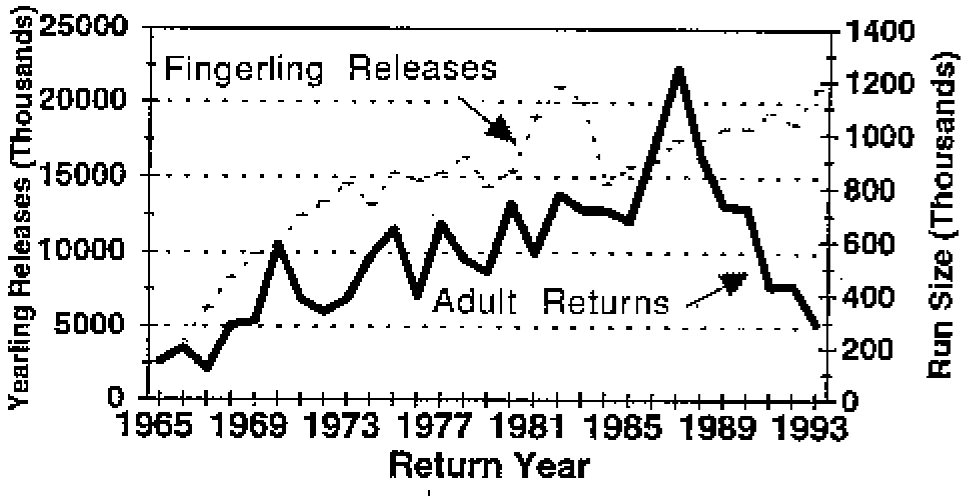


Figure 15. A comparison of hatchery releases of Puget Sound 1+ coho with subsequent run size. (Fuss 1998)

In the context of ecosystem management, the second and third assumptions listed above create major problems for attempts to accommodate harvest augmentation objectives. Ecosystem management and harvest augmentation are basically conflicting strategies that must be resolved consistent with the long-range goals for the fishery. The real question is not whether hatcheries are able to successfully produce salmon and steelhead artificially; that has been demonstrated many times. The deciding issue is whether hatchery production can integrate within the ecological framework on which future salmon management is proposed to operate. It follows, therefore, that before resolution can be addressed on the use of augmentation strategy in the Columbia River, careful assessment of harvest augmentation success through the use of hatcheries outside the basin, and the measured ecological impacts, should be undertaken.

B. Mitigation

With the development of water resources in the Columbia River, about 40 percent of the originally accessible river system is now inaccessible to salmon, and much of the remaining habitat has been significantly compromised for incubation and rearing. These losses were mitigated through artificial propagation, and major hatchery programs now prevail in the Columbia River system, and currently represent a significant and continuing investment. Conceptually, mitigation hatcheries are meant to replace harvest potentially lost as a result of habitat alteration. These losses, related to dams, water diversions, and habitat degradation, have been justified or made “socially acceptable” (Christie et al., 1987) by the precept that the resulting losses in natural production of salmon would be compensated through hatchery production of anadromous and resident species. Consequently, with the extensive development of the Columbia River, most of the 93 artificial production facilities (hatcheries, ponds, and release sites) in the river system are operated for mitigation purposes.

There is concern that these major program developments, like augmentation, have progressed extensively without careful assessment of their effectiveness in meeting their primary objectives. The problem in making such assessments of mitigation hatcheries on the Columbia, however, is that their application has been somewhat equivocal, with some taking on a distinct augmentation role to increase harvest, while others have been applied in supplementation to strengthen the numerical base of wild populations. With the decline of naturally reproducing stocks of salmon and resident fish throughout the Columbia River Basin, and the contemplated further use of hatcheries to overcome these losses, assessment of their effectiveness, limitations, and application must be made. Mitigation must also be viewed in the broader perspective of its present use in the Basin, including measures to stem the risk of extinction. Classification of mitigation hatcheries, therefore, fall within four different categories associated with degrees of salmon extirpation, including maintenance, recovery, preservation, and restoration. An additional category of resident fish hatcheries involves resident fish substitution programs, such as those discussed on pages 34 and 35 of this report and in the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program. These hatcheries propagate resident fish for harvest as either on-site or off-site mitigation for lost salmon resources. Here is a more detailed look at the four classifications of mitigation hatcheries:

(1) Maintenance

Maintenance is consistent with the original objective of mitigation as a mechanism to maintain those runs of salmon that would otherwise be reduced or extirpated by river developments resulting from habitat degradation or migratory impasse. For example, with the construction of dams on the river, especially those without fish passage, the risk of partial or total loss of the run was mitigated by replacement with hatchery fish. The objective is maintenance of the pre-existing run of salmon at or near its previous abundance. Maintenance hatcheries may substitute or circumvent the need for natural habitat, characterized by attempts to mitigate development of the hydro-system in the upper Columbia and Snake rivers, or they can supplement the number of naturally spawning salmon affected by development. Maintenance, in its most basic rendition, is to maintain contribution of salmon and steelhead approximate to those levels immediately preceding developments affecting their productivity.

With the present emphasis on sustaining natural runs of salmon, supplementation has taken a much greater role in maintenance conservation. Conceptually, supplementation is meant to reinforce populations without loss of the genetic structure. Supplementation, therefore, is employed to enhance the native stocks of salmon and steelhead by increasing their reproductive base through artificial propagation, using only the native gene pool in the process.

(2) Recovery

Recovery has become an increasing responsibility of mitigation. Compelled by the decline of salmon and steelhead in the Columbia system, major efforts are being expended on rebuilding runs to levels that are considered sustaining under the stress imposed on these populations in the migratory corridor of the mainstem river, and the condition of their endemic habitat. In the context of mitigation with emphasis on native populations, supplementation is by definition the rebuilding of the native population of anadromous salmonids. Application of artificial propagation in rebuilding populations has been thwarted by the disregard of population genetics and careful breeding programs (Remain and Ståhl, 1980; Allendorf and Utter, 1979; Cross and

King, 1983), as well as poor conditioning of fish while in the hatchery environment (Swain and Riddell, 1990). Salmonids have evolved to be compatible with their environments, and each population, therefore, has adapted to the specific characteristics of their respective habitat. Spawning time, emergence timing, juvenile distribution, marine orientation and distribution are not random, but occur in specific patterns of time and space for each population (Brannon, 1984). In the technical sense, therefore, enhancement of specific wild salmonids must observe this compatibility between native stocks and their environments. This perspective is a central theme of mitigation for recovery for all native anadromous and resident fish species in the basin.

(3) Preservation

Preservation is the most extreme measure used to prevent extinction, and characteristically has been implemented when numbers have degenerated to such low levels that risks associated with emigration and marine life phases threaten extinction. Preservation is approached along two different avenues. The first is to increase the numerical base in captivity through maintenance of captive brood stock. Maximizing reproductive potential under captive breeding over two generations can provide the numerical advantage and genetic predisposition necessary for recovery. Such a preservation approach is meant to be short-term, involving only a limited number of generations. However, when a major cause of the decline persists, such as the problems with the migratory corridor on the Snake and Columbia rivers or habitat destruction or overfishing, for example, then such preservation programs may have to continue until conditions favor natural recovery.

The second avenue in preservation is to provide repositories of genetic diversity for future introduction and recovery. Captive brood can be applied in such approaches, but germ plasm repositories are the most feasible, inexpensive, long-term approach. Rather than the “choice of last resort,” germ plasm preservation should be proactively included in routine population recovery measures. Healthy populations need to be the target for gamete cryopreservation to assure that repositories contain representative genetic diversity, and from which domestication and inbreeding can be avoided in mitigation hatcheries. Both avenues are meant to preserve genetic diversity or to keep stocks from demographic extinction, and assist in recovery when habitat and migratory passage are restored.

(4) Restoration

Restoration is the re-establishment of a salmon or steelhead run in the place of an extirpated natural population. Understandably, establishing a successfully reproducing run requires sufficient similarity between the introduced fish and the extirpated population to ensure compatibility with controlling environmental phenomena. Matching genetic predispositions to optimize the likelihood of success is key to the restoration strategy. Important among the environmental factors are winter stream temperatures and length of the freshwater migratory pathway. These features determine timing and distribution patterns of native stocks. The optimum strategy is to use these features to select candidates for introduction most like those demonstrated by the native phenotype.

Restoration mitigation is a difficult task, and necessarily of greater duration to realize functional re-establishment of a run because of the generation time required for the adaptive evolution or re-creation of the appropriate form. The critical measure of success is not the number of returning fish to the hatchery. Hatchery environments are secure and forgiving of timing inconsistencies that can easily be amended by feeding programs that exaggerate size at time of release. Restoration criteria must target only the naturally reproducing segment of the run, and hatchery programming should be altered to accommodate the spawning, incubation and migratory timing patterns evolving among those fish. Differentiation between what is observed among hatchery contributions and returns from natural reproduction is a difficult and long-term process, but restoration cannot be accomplished with anything less. To have successful restoration is to have established a self-perpetuating wild run, free of hatchery dependence.

C. Determinants of Performance

In determining the performance of anadromous salmonid augmentation and mitigation hatcheries, it is apparent that the objective identifies the determinant criteria. Moreover, the criteria are only satisfied in terms of the adult return response, as measured in the harvest fishery or the return destination. Augmentation has the objective of increased harvest, or contribution of returning adults to the fishery. Mitigation has the objectives associated with maintenance, recovery, preservation, or restoration measured as contribution of reproductive adults in the target population. In both augmentation and mitigation hatchery programs, genetic and demographic concerns must be addressed. In the former, if genetic compatibility is not a management concern, then isolation of the returning fish from neighboring native stocks must be at least be assured or the level of straying non-consequential. In the latter, genetic identity and diversity are basic to the objectives sought in each of the mitigation functions. In this particular document, the key assessment criteria are listed below, and apply to both augmentation and mitigation programs.

1) Has the hatchery achieved its objective?
2) Has the hatchery incurred costs to natural production?
3) Are there genetic impacts associated with the hatchery production?
4) Is the benefit greater than the cost?

These criteria are relatively simple and straightforward. However, their resolution has an uncertain complexity because of the overriding influence of marine conditions, the effects of mixed stock fisheries, interaction among runs of fish, and the influences of the dynamic interaction within ecological communities on the ultimate return success of a run. Therefore, in as much as it is possible, the performance measures involved in the SRT assessment will be qualified based on relative information on annual variations in marine productivity, temperature trends and associated predator occurrence, distance up the freshwater migratory corridor, and other controlling influences unrelated to the actual hatchery variables involved.

Artificial production of resident fish in the Columbia Basin should not be evaluated using specific Basin anadromous salmonid propagation criteria for several reasons. First, the purposes of anadromous and resident fish propagation programs may be considerably different. For example, a resident fish artificial propagation program may represent mitigation for an extinct salmon run, extirpated by blockage of its spawning habitat by dams. Mitigation using resident fish programs or exotic fishes represents an acceptance that the natural ecosystem is no longer sound and intact.. In this case, the resident fish propagation program might raise non-native fish to provide a warm-water fishing opportunity in the newly created reservoir as mitigation for the extinct salmon run. Thus, evaluation of this resident fish propagation program using an anadromous fish propagation criterion — such as the degree to which a hatchery stock enhanced a native run — would be irrelevant because the run is extinct and thus cannot be enhanced. Secondly, life histories and migratory patterns of anadromous salmonids and resident fish in the basin can be completely different. For example, an anadromous salmonid propagation evaluation criterion of percent adult return (i.e. return to the rack) would be an irrelevant measure of the success of a resident fish program with a goal of establishing a put-and-take recreational fishery. Rather, in this resident fish example, perhaps a measure of angler satisfaction, or return to the creel would serve as an appropriate evaluation criteria. It is extremely important, therefore, that serious consideration is given to developing biologically meaningful and accurately measurable evaluation criteria to evaluate the success of resident fish propagation programs throughout the basin with the same rigor as applied to anadromous salmonid programs.

VI. Synthesis of Artificial Production Reviews

Differing points of view on the value and importance of artificial production are not lacking in fisheries science. Hatchery production has been the center of controversy as long as hatcheries have existed on the Pacific Coast. Both the ecological and economic points of view have been debated without resolution because the conclusions usually reflect the preconceived perspective of the reviewers. One side of the issue is dominated by practitioners who base their point of view on the evidence of hatchery returns, but tend to ignore the ecological implications of hatchery fish on endemic stocks or the larger biological community. The other side is dominated by scientists who base their point of view on theory and ecological principles, in spite of societal benefits of a propagated fishery.

Scientists and fish culturists should be concerned about the findings of three independent scientific panels that concluded hatcheries have generally failed to meet their objectives. The findings of those panels are discussed in detail later in this report. As general background, it is informative to examine the reviews on the subject and get a better appreciation of the issues confronting the use of artificial production. It is important to keep in mind, however, that artificial production in these assessments is narrowly defined around the standard production hatchery where tray incubators and concrete raceways provide the artificial incubation and rearing habitat.

A. Early Hatchery Evaluations

It might seem that use of a major program such as hatchery production to augment and mitigate for loss of historical fisheries would be evaluated to determine whether it is achieving its objectives. However, that did not occur in the Columbia River hatchery program. Part of the explanation for this failure comes from the ideological rather than scientific roots of the programs (see Historical Overview of Artificial Production). A major shortcoming of ideology-driven technology is that it is not allowed to fail. Its success is assured by ignoring the signs of failure so by the time the failure is recognized, great damage has usually already occurred (Dyson 1997). This observation clearly describes the Columbia River hatchery program prior to 1960, and to a lesser extent after 1960 as well.

During their first 80 years of hatchery operation, claims of success for the program were based on short-term correlations; evidence that was weak at best, or on no evidence at all. Extravagant and undocumented claims of hatchery effectiveness characterized the early history of the program. For example, in 1883, George Brown Goode of the U.S. Fish Commission told the International Fisheries Exhibition in London, England, that the Pacific salmon fisheries in the Sacramento and Columbia rivers were under the complete control of fish culture (Maitland 1884). When Goode made that claim, the only hatchery on the Columbia River had been closed for two years (Cobb 1930). This again illustrates the disconnect between science and the hatchery program in its early developmental period.

Perhaps the first serious evaluation of the hatchery program came from Marshall McDonald, who succeeded Spencer Baird. He concluded:

> *". . . we have relied too exclusively upon artificial propagation as a sole and adequate means for maintenance of our fisheries. The artificial impregnation and hatching of fish ova and the planting of fry have been conducted on a stupendous scale. We have been disposed to measure results by quantity rather than quality, to estimate our triumphs by volume rather than potentiality. We have paid too little attention to the necessary conditions to be fulfilled in order to give the largest return for a given expenditure of effort and money."* (McDonald, 1894, p.15).

McDonald raised three important concerns regarding the use of hatcheries including:

1) a warning regarding an overdependence on hatchery production as a substitute for stewardship;
2) a criticism that hatchery performance was based on the quantity of juveniles released rather than the quality of the adult populations; and
3) a recommendation to evaluate the quality of the receiving waters in watersheds to be stocked with hatchery fish.

To varying degrees all of these concerns are still valid today.

State salmon managers challenge the assertion that scientific evaluations did not exist in the early decades of the hatchery program. The managers point specifically to a marking experiment carried out from 1895-1900 (Dehart 1997). In this experiment, 5,000 chinook salmon eggs were transferred from the Sacramento River and incubated at the Clackamas Hatchery in the Columbia basin. The fry were marked by removing the adipose fin and released, and for the next several years cannery men recorded the appearance of these fish in their facilities. Sex and weight were determined for some of the fish. However, to label this experiment scientifically valid, the following would have to be accepted:

1) That 5,000 chinook salmon eggs transferred from the Sacramento River and released as marked fry in the Clackamas River achieved a minimum 10 percent return as adults just to the canneries.
2) That the majority of adults returned in their third year, a year earlier than average, and they were five pounds heavier than the average for the Columbia River — one supposed three-year old weighed 57 pounds.

3) That the cannery operators reliably identified the marked salmon and accurately recorded their weights. The fish commissioner apparently did not personally inspect the fish that the cannery operators claimed to be marked.

The validity of the experiment is questionable, and the results were questioned by at least one contemporary biologist (Gilbert 1913).

Other experiments relied on short-term correlations. The common practice before 1910 was to release juvenile salmon shortly after hatching and before they started to feed. In 1911, hatchery managers held a group of chinook salmon and fed them for several months before release. The catch increased in 1914, the year managers expected the first returns from their experiment. After five successive years of improved catches in the Columbia River, the Oregon Fish and Game Commission announced the success of their experiments:

> *"... this new method has now passed the experimental stage, and ... the Columbia River as a salmon producer has 'come back.' By following the present system, and adding to the capacity of our hatcheries, thereby increasing the output of young fish, there is no reason to doubt but that the annual pack can in time be built up to greater numbers than ever before known in the history of the industry..."* (Oregon Fish and Game Commission 1919).

Subsequent review indicated that the claims of hatchery success were premature and the increased catch was not caused by the new methodology (Johnson 1984) and probably had little to do with artificial propagation. Instead, the increase in harvest from 1914 to 1920 was consistent with the pattern of variation in harvest for the previous 20 years (Figure 3) and probably resulted from favorable environmental conditions. For example, the 1914 chinook salmon run into the Umatilla River, which had no hatchery, also increased dramatically (Van Cleve and Ting 1960), supporting the suggestion that the increase in harvest was a response to natural climatic fluctuations.

In 1914, Willis Rich initiated studies of the life history of chinook salmon that had two practical purposes: 1) to determine the value of hatchery work; and 2) to understand the differences in early life history between spring and fall chinook (Rich 1920). Rich also initiated several marking experiments at hatcheries in the basin to test the efficiency of hatchery practices and the homing ability of chinook salmon (Rich and Holmes 1929). The marking experiments were a major improvement over earlier "evaluations," but they did not come close to the standards of experimental design used in later evaluations.

Based on his observations on the timing of the migration of juvenile chinook salmon, Rich (1920) concluded that the release of sack fry should be terminated. He recommended that fry be held in the hatchery and released during the natural migration. He also recommended that juveniles be allowed to migrate out of the hatchery ponds on their own volition.

Nationally, by the 1920s biologists were beginning to question the efficacy of fish culture during its first 50 years. As a result, hatchery programs came under increasing criticism (Wood 1953). Rich (1922) completed a statistical study of the Columbia River hatchery program discussed in the previous section, but that study was never published. The lack of rigorous, scientific evaluation of the hatchery programs for Pacific salmon led Cobb (1930) to conclude that artificial propagation could become a threat to the Pacific salmon fishery. Cobb was not opposed to artificial propagation, but he believed that managers had to put aside their optimism and stop relying on hatcheries alone to increase or maintain the fishery.

By the 1940s, individual hatcheries were fin-clipping juvenile salmon in order to evaluate returns to the hatchery from routine production or to evaluate experimental hatchery practices. Often the experiments had too few recoveries to be conclusive. Wallis (1964) summarizes the results of many of those studies.

Extended rearing in the hatcheries prompted research into the nutritional requirements of juvenile salmon and the prevention and treatment of diseases. Through the 1950s, the development of new feeds, better prevention and treatment of diseases, and improved hatchery practices such as the optimal size and time of release (Hagger and Noble 1976) started to produce tangible results. By the 1960s smolt-to-adult survival had increased significantly.

In the early 1960s, Congress placed a moratorium on new hatcheries until their effectiveness was evaluated. In response, the National Marine Fisheries Service (NMFS) conducted a series of large-scale evaluations of the contribution of chinook and coho salmon from Columbia River hatcheries to various fisheries in the Northeast Pacific. The 1961 through 1964 broods of juvenile fall chinook from 13 hatcheries in the Columbia Basin were fin clipped before release so their contribution to the sport and commercial fisheries could be estimated. Results of the evaluation were positive. The benefit/cost ratio for all hatcheries combined for each of the brood years was 1961: 3.7/1; 1962: 2.0/1; 1963: 7.2/1; and 1964: 3.8/1. The potential catch per 1,000 fish released was 1961: 6.7; 1962: 3.1; 1963: 10.0; and 1964: 6.5. Average survival for all hatcheries combined was 0.7 percent. Overall, an estimated 14 percent of the fall chinook salmon caught in the sport and commercial fisheries from southeast Alaska to northern California originated from the Columbia River hatcheries (Wahle and Vreeland, 1978).

The NMFS repeated the fall chinook evaluation with the 1978 to 1982 broods. Total survival for all four brood years and all facilities was 0.33 percent or about half the survival of the earlier study, however the benefit/cost ratio was still positive at 5.7/1. The overall contribution to the fishery was 1.9 adults for each 1,000 juveniles released (Vreeland 1989). The NMFS used a similar approach to evaluate the contribution made to the West Coast fisheries by the 1965 and 1966 broods of coho salmon. Juvenile coho salmon from 20 hatcheries in the Columbia Basin were marked for the study. Recoveries were monitored from British Columbia to California. Coho salmon from Columbia River hatcheries made up about 16 percent of the total catch in the sampling area (Wahle et al. 1974). These evaluations were well designed and executed, but they only addressed the first question listed among the four criteria on determents of performance.

B. Recent Review Summaries of Independent Panels

Three independent scientific panels recently reviewed the use of hatcheries in Pacific salmon management, including the Northwest Power Planning Council's Independent Scientific Group (ISG), 1996; the National Research Council (NRC), 1996; and the National Fish Hatchery Review Panel (NFHRP), 1994. The three panels were in general agreement on three important points: (1) In spite of some success, hatcheries generally failed to meet their objectives, (2) hatcheries have contributed to the decline of wild salmon, and (3) the region's salmon managers have failed to conduct adequate monitoring and evaluation to determine if the hatchery objectives were achieved. These reviews conclude that over the last century, massive funding for hatcheries not only failed to achieve objectives, but more importantly the lack of monitoring and evaluation meant that the region passed up the opportunity to learn adaptively about artificial propagation of Pacific salmon (NRC 1996).

The individual reviews are summarized below.

ISG – Return to the River **:**

The ISG concluded that artificial production has been institutionalized in the Columbia River Basin. Today 80 percent of the salmon and steelhead in the basin are hatched and reared in hatcheries. From 1981-1991, expenditures on hatcheries accounted for 40 percent of the budget for salmon restoration. Fifty percent of the increase in salmon production under the NPPC's program is expected to come from artificial production. The historical assumption by management institutions was that artificial production could compensate for habitat destruction, which led to less emphasis on habitat protection and more emphasis on hatchery construction. More recently hatchery programs have been intended to augment declining natural production due in large part to habitat degradation throughout the basin and to maintain a supply of salmon for the fishing industry.

In the context of the entire history of the hatchery program and salmon management in the Columbia River Basin, the ISG concluded that artificial production has failed to replace or mitigate lost natural production of salmonids due to habitat degradation. Since 1960, total releases from hatcheries have increased substantially, but the number of adult salmon entering the river has not increased. Furthermore, hatchery-reared fish have become the dominant portion of the run.

It was determined that artificial production can have adverse effects on wild fish including increased mortality in mixed stock fisheries, genetic interactions that can cause reduced fitness of wild populations and loss of genetic variability, spread of disease, and increased competition with wild fish.   The ISG recommended that hatchery populations should be evaluated for evidence of selection, and changes in fitness or genetic diversity associated with residence in the hatchery environment.

The ISG felt that new roles for artificial production need to be defined. Artificial production should likely have a more limited role than at present. The use and role of artificial production needs to be coordinated with the overall Columbia River Basin restoration goal, as well as with subbasin-specific goals. Hatcheries may need to serve as temporary refuges for endangered or critically depressed stocks until factors limiting their abundance can be corrected. Ideally, supplementation should be viewed as a small-scale and temporary strategy to boost natural production. New supplementation projects should follow the guidelines developed by the Regional Assessment of Supplementation Program (RASP). Supplementation should be used in conjunction with, but not in place of, habitat restoration and modification of downstream mortality factors. Supplementation should be approached cautiously in an experimental framework that relies on careful design, rigorous evaluation, and incorporates adaptive management.

The ISG concluded that the role of artificial production in salmon restoration has to be redefined. Hatcheries should have a more limited role in salmon production and restoration and should be integrated into strategies that focus on habitat restoration, reduction of human-induced mortality, and conservation of existing genetic and life history diversity in natural populations. Hatcheries could have a useful role as temporary refuges for dwindling populations while causes of natural mortality are alleviated, or a temporary role in rebuilding depressed populations through supplementation.

A comprehensive evaluation of hatchery programs in the Columbia River Basin has never been conducted. The ISG believes an evaluation should be undertaken and should address the following questions: 1) Do salmon and steelhead of hatchery origin contribute to the fisheries and/or escapement and is the economic value of that contribution greater than the cost to produce it? 2) Is the level of contribution consistent with the purpose or objective of the hatchery? For example if a hatchery is intended to replace natural production lost due to habitat degradation, this question asks did the hatchery, in fact, replace the lost production? 3) Do artificially produced fish add to existing natural production or do they replace it; i.e., does the hatchery operation generate an impact to natural production through mixed stock fisheries, domestication, and genetic introgression?

<u>NRC – Upstream</u>:

The national debate on the use of hatcheries has gone on for most of this century, but with the serious decline of anadromous salmonids across the nation, and hatcheries being proposed as part of the recovery plan, the NRC launched a review of hatchery performance, and made sweeping determinations on how hatcheries should be employed.

The NRC concluded that management of hatcheries has had adverse effects on natural salmon populations. Hatcheries can be useful as part of an integrated, comprehensive approach to restoring sustainable runs of salmon, but by themselves they are not an effective technical solution to the salmon problem. Hatcheries are not a proven technology for achieving sustained increases in adult production. Indeed, their use often has contributed to the damage of wild runs. In many areas, there is reason to question whether hatcheries can sustain long-term yield because they can lead to loss of population and genetic diversity. It is unlikely that hatcheries can make up for declines in abundance caused by fishing, habitat loss, etc., over the long term. Hatcheries might be useful as short-term aids to a population in immediate trouble while long-term, sustainable solutions are being developed. Such a new mission for hatcheries – as a temporary aid in rehabilitating natural populations – could be important in reversing past damage from hatcheries as well as from other causes.

The NRC proposed that the intent of hatchery operations should be changed from that of making up for losses of juvenile fish production and for increasing catches of adults. They should be viewed instead as part of a bioregional plan for protecting or rebuilding salmon populations and should be used only when they will not cause harm to natural populations. Hatcheries should be considered an experimental treatment in an integrated, regional rebuilding program, and they should be evaluated accordingly. Great care should be taken to minimize their known and potential adverse effects on genetic structure of metapopulations and on the ecological capacities of streams and the ocean. Special care needs to be taken to avoid transplanting hatchery fish to regions in which naturally spawning fish are genetically different. The aim of hatcheries should be to assist recovery and opportunity for genetic expression of wild populations, not to maximize catch in the near term. Only when it is clear that hatchery production does not harm wild fish should the use of hatcheries be considered for augmenting catches. Hatcheries should be audited rigorously. Any hatchery that "mines" brood stock from mixed wild and natural escapements should be a candidate for immediate closure. It is useful for all hatchery fish to be identifiable. Marking hatchery fish externally is particularly important when fishers and managers need to distinguish between hatchery and wild fish.

It was concluded that current hatchery practices do not operate within a coherent strategy based on the genetic structure of salmon populations. A number of hatcheries operate without appropriate genetic guidance from an explicit conservation policy. Consistency and coordination of practices across hatcheries that affect the same or interacting demes and metapopulations is generally lacking. All hatchery programs should adopt a genetic conservation goal of maintaining genetic diversity among and within both hatchery and naturally spawning populations. Hatchery practices that affect straying – genetic interaction between local wild fish and hatchery-produced fish – should be closely examined for consistency with regional efforts.

The NRC recommended that hatcheries should be dismantled, revised, or reprogrammed if they interfere with a comprehensive rehabilitation strategy designed to rebuild natural populations of sustainable anadromous salmon. Hatcheries should be tested for their ability to rehabilitate populations whose natural regenerative potential is constrained severely by both short- and long-term limitations on rehabilitation of freshwater habitats. Hatcheries should be excluded or phased out from regions where the prognosis for freshwater habitat rehabilitation is much higher.

The NRC also recommended that decision-making about uses of hatcheries should occur within the larger context of the region where the watersheds are located and should include a focus on the whole watershed, rather than only on the fish. Coordination should be improved among all hatcheries – release timing, scale of releases, operating practices, and monitoring and evaluation of individual and cumulative hatchery effects, including a coast-wide database and wild fish proportions and numbers. Hatcheries should be part of an experimental treatment within an adaptively managed program in some regions but not in others.

<u>NFHRP</u>:

The Director of the U.S. Fish and Wildlife Service (USFWS) asked the National Fish and Wildlife Foundation to conduct a review and assessment of the USFWS federal fish hatchery program and make recommendations for the future role of the National Fish Hatchery Program in ecosystem management of fisheries resources. The National Fish and Wildlife Foundation (through a contract to the Conservation Fund) convened a panel of 16 fisheries and conservation authorities (NFHRP) to conduct the review.

The Panel felt the National Fish Hatchery Program needed a fundamental redirection of programs, personnel and facilities toward supporting ecosystem management whether it relates to restoring depleted anadromous populations or the recovery of ESA-listed stocks. A well-defined national fisheries program with definite goals, objectives, implementation and evaluation strategies did not exist.

The Panel identified habitat alteration or destruction as the primary causes of decline and noted that resource managers have responded to declines in returning salmon by requesting hatcheries to produce more fish for release, with very little assessment or evaluation. The assumption that more fish would solve the problem of decline had very little evaluation to verify the approach.

Mitigation based solely on hatchery production (involving 38 of the 78 USFWS hatcheries) has failed to halt population declines; therefore, as a better alternative, habitat protection and restoration were believed to be the key to survival of native fish stocks.

The Panel concluded its report by proposing a new role for hatcheries and a new approach to resource management in which hatcheries would serve a support function to managers, producing only those species, stocks, strains, races and numbers that were compatible with ecosystem management plans and specifically identified in those plans. Fisheries management plans should include genetic and ecological assessments of native stocks and strains in any ecosystem subject to new fishery resource projects for restoration or enhancement or for the stocking of newly created waters. This should be followed by careful risk assessment. Restoration of sport fishing in altered or newly created waters should involve the use of propagated fish of the most similar native stock known to inhabit the same type of habitats. Before any hatchery fish are planted, a comprehensive assessment, analysis, and a fisheries management plan should have been completed to address concerns about native stocks. Similarly, in efforts to restore depleted populations or to re-establish new populations, resource managers should avoid stocking any non-native strains or species.

It is apparent that considerable attention has been given to evaluation of anadromous hatchery programs. However, no comprehensive reviews of basinwide resident fish artificial propagation have been undertaken. The situation is largely due to the fact that resident fish hatcheries are generally successful in fulfilling their mission to supply fish for management purposes where migratory success or return performance have not been relevant criteria. However, their absence from hatchery evaluations, especially when resident fish are applied in such a diversity of circumstances, leaves a void when addressing the role of resident hatchery fish in ecosystem management, or even the economic benefit of resident fish hatchery programs. This situation illustrates the need to include resident fish hatcheries in the overall hatchery evaluation and to develop appropriate resident fish hatchery evaluation criteria.

State agency and tribal interests in the basin have participated in other reviews or assessments of artificial production. These have been directed at review, determination of research needs, production alternatives, program coordination and monitoring of artificial production. These assessments are based on the experience of practitioners that not only have great confidence in the potential of artificial production, but have developed standards that are expected to improve the performance of hatcheries. In many cases these documents provide a substantive foundation on which such work can proceed. Below we discuss two of these assessments, the Regional Assessment of Supplementation Project and the Integrated Hatchery Operations Team.

RASP: The Regional Assessment of Supplementation Project

In 1992, the first phase of the Regional Assessment of Supplementation Project (RASP) was completed. It provided an overview of ongoing and planned activities associated with supplementation, and development of a model to estimate potential benefits and risks from supplementation. It also was a plan to coordinate research and monitoring on supplementation in the Basin. It provided guidelines for the use of supplementation aimed at minimizing negative genetic and ecological interactions between wild and hatchery-produced fish.

At the core of the RASP guidelines are five steps that address planning, implementation and evaluation of restoration projects. Although specific instructions for carrying out each of the steps are provided, RASP recommends that within the framework of the five steps, each project should develop specific details and approaches that are appropriate for the local situation. The five basic steps contained in RASP are:

1. Objectives:

Project objectives should be clearly stated and contain measurable end points, i.e., criteria for determining when the project objectives have been achieved. The objective should also include consideration of resource quality as well as quantity. Resource quantity refers to a target number of fish — the number of salmon harvested in the sport fishery, the number of salmon escaping to spawn in a stream, or the number of smolts migrating out of a stream into the ocean. Resource quality refers to such things as the distribution of the catch by area or fishery, stock selection or run timing. For example, if the objective were to establish a fishery on the returns from artificially propagated fish, it may be desirable to specify in the objective an extended run timing to spread the fishery over a longer time interval. This specification would place conditions on the quality of the eggs used. They would have to come from all segments of the spawning migration and from an appropriate stock from the genetic standpoint that exhibited normal run timing.

2. Analysis of Limiting Factors:

RASP recommended comparing what is known about the character of healthy habitat and salmon populations in a target stream with current conditions in the stream and the populations to be enhanced. This comparison is used to identify potential limiting factors, and to identify the specific problem the project is or should be trying to overcome.

3. Treatment:

This step simply identifies the activity or restoration tool selected to overcome the problem identified in the previous step. The treatment must be consistent with the objective as well as the problem. It is important that the right tool be selected to do the job described in steps one and two. Treatments might include artificial propagation in one or more of its various forms, habitat improvement, public education, or political activities to change statutes or regulations.

4. Risk Analysis:

All salmon restoration projects contain uncertainties that should be identified during the planning phase. Uncertainties are like red warning flags — they identify the potential risks that must be addressed if the project is to achieve success and avoid unintended problems. Risk analysis helps establish the priorities for monitoring and evaluation.

5. Monitoring and Evaluation:

Part of the reason salmon stocks are in trouble today is that past restoration efforts were approached with so much optimism, especially when hatcheries were involved, that monitoring and evaluation were considered unnecessary. Many programs that produced little or no benefits or were detrimental were continued for several years or decades. The region and the salmon can no longer afford long-term investments in unproductive or counterproductive programs. It is critical to determine whether specific restoration activities are working and, if not, adjust them to improve the chances of success.

IHOT: Integrated Hatchery Operations Team

Hatcheries in the Columbia basin are funded, co-managed, and operated by many different entities for many different purposes. The NPPC's *Strategy for Salmon* (NPPC 1992) recognized the potential for hatcheries to help rebuild salmon production but also the need to improve the co-ordination and operation of these facilities. To address these latter needs, the Council called for the development of the Integrated Hatchery Operations Team (IHOT) to develop hatchery policies for operating within the Basin. The preface of the IHOT report (1994) clearly states the content and intent of this report:

> "The hatchery policies presented in this manual are not intended to establish production priorities. Rather, the intent is to guide hatchery operations once production numbers are established. Hatchery operations discussed in this report include broodstock collection, spawning, incubation of eggs, fish rearing and feeding, fish release, equipment maintenance and operations, and personnel training. Decisions regarding production priorities must be provided by fishery managers through a comprehensive plan that addresses both natural and hatchery fish production."

The IHOT report presents regional policies for hatchery coordination, performance standards, fish health, ecological interactions and genetics. The policies and procedures outlined were a substantive contribution undertaken by the hatchery management agencies to standardize artificial production operations to maximize production performance and minimize impacts on naturally producing stocks in the basin. Because records on hatchery production and operations are maintained by all basin hatcheries under their own state, federal and tribal programs, the implementation and monitoring of these IHOT parameters (see discussion below) at the different hatcheries can be initiated within the present management structure, and will be a valuable contribution to hatchery assessment in the future.

The IHOT report is not a hatchery assessment or review of their technical merit, rather it is an operations manual. The report is notable for establishing regional policy statements and goals that members agreed to pursue in operating the region's hatcheries. The actual procedures and standards to be used to guide operations were identified, and performance measures described how compliance would be monitored and evaluated. The report states that it includes performance standards encompassing all aspects of hatchery facilities and operations that influence the hatchery's "final product." The product is defined as "a fish that has minimal impact on wild stocks and also contributes to harvest opportunities and natural spawning populations." (pg. 19). However, whether the "final product" achieves this goal is not assessed.

The report further recognizes:

- that many of the facilities in the basin originally were developed to meet management objectives that are different from objectives today;
- that hatchery production may be established by several existing authorizations and agreements;
- that production goals for hatcheries have been established through a variety of fish management, political, and administrative processes; and
- that environmental conditions (e.g., ocean conditions and in-river habitats) outside of hatcheries have "overriding influences that control production capacity."

Consequently, IHOT addresses operational guidelines for handling, rearing, and releasing of fish (i.e., issues within the control of facility managers) and notes that these will change over time in response to new management objectives.

The report proceeds to provide detailed recommendations on facility environmental conditions, and general guidelines for hatchery operations, and fish health policies and procedures. Chapters on ecological interactions and genetic policies are much less like a cookbook than the previous chapters (indicative of the state of knowledge in these topics), and IHOT defers to the involvement of experts to assist in these areas. However, the policy statements for these greatly overstate our knowledge and our capabilities to monitor potential impacts. For example, the policy on ecological interactions states "that artificial propagation programs will be designed and implemented to minimize ecological interactions that adversely affect the *productivity of aquatic ecosystems*"(emphasis added). The genetic policy states that these programs will "*maintain adequate genetic variation and fitness in populations* and protect the biological diversity of wild, natural, and cultured anadromous salmonid populations" (emphasis added). IHOT provides some general guidelines expected to be consistent with these policies and to minimize impacts, but the basin lacks evidence that these controls are effective or adequate. It is a notable development, however, that the IHOT members acknowledged an increasing need to incorporate ecological and genetic guidelines in the management and culture of hatchery salmonids.

In reviewing the role of hatcheries in the Columbia Basin, the IHOT report and associated hatchery audits demonstrates a commitment to consistent operational procedures with an aim to improving production efficiency. The report is clearly able to draw on extensive research and experience in fish culture and fish health. However, there is an equally clear need for monitoring and assessment of the ecological and genetic guidelines.

The IHOT report infers an important message: that hatchery staff should be accountable for the quality of cultured fish, but policy makers must clearly communicate objectives and resource managers must advise how to integrate hatchery and natural production. The parties to IHOT agreed to a policy to coordinate the operation of fish hatchery programs to meet basinwide resource management needs. The IHOT report does not consider hatcheries at this programmatic level, nor does it address the adequacy of monitoring and assessment programs to achieve this integration.

In 1995, the draft Programmatic Environmental Impact Statement on Impacts of Artificial Salmon and Steelhead Production Strategies in the Columbia River Basin was prepared for federal hatchery programs by the Columbia Basin Fish and Wildlife Authority. This was a document directed at alternatives for how hatcheries might be used and the effects that alternative strategies would have on overall production, stock diversity, and social/economic conditions associated with the basin.

In 1998, a summary of independent audits of salmonid hatcheries based on IHOT performance measures was compiled for the Northwest Power Planning Council by Sampsel Consulting Services. Following IHOT guidelines, the summary reviewed 20 Oregon Department of Fish and Wildlife hatcheries, seven Idaho Department of Fish and Game hatcheries, 20 Washington State Department of Fish and Wildlife hatcheries, and 12 U.S. Fish and Wildlife Service hatcheries. Considerable detail was provided on facility descriptions and protocols for hatchery operating procedures, with limited production and cost data. Unfortunately and curiously, no overall assessment of these audits has been conducted.

Assessment of hatchery performance has also been conducted by agencies with regard to certain hatchery programs over the years that provided valuable insights on hatchery fish behavior after release to the stream environment. An example of such assessment the annual report of Mitchell Act Hatcheries in 1996, by Ashbrook, Byrne, and Fuss. Stock characteristics in the hatchery, migratory behavior of hatchery fish and evaluation of hatchery practices from selective breeding to hatchery habitat were assessed. The results of this work allowed operations to be altered to change the quality of the product released.

C. Relevance of Past Assessments to the Present Task

The history and evaluations in the preceding sections are valuable to our understanding of the origins of artificial production on the Pacific Coast and the Columbia River. It should be clear that to proceed with artificial production "as usual" would be poorly advised. Even the assumptions basic to the hatchery program that have carried over from the early years need to be modified in light of what is known about specific life history requirements of the different salmonid species that are managed.

The most compelling development point, however, is the change in the general philosophy on resource management that hatchery programs must now address. The human influence on the environment is so pervasive and domineering that resources no longer can demonstrate the resiliency and forgiveness of abuse that was so common in past exploitation. The ecosystem approach to fisheries management is not so much a new paradigm as it is a necessity for the preservation of the fisheries resources. Fish species and their component populations cannot sustain themselves apart from the habitat they evolved with. Ecosystem management is not a revolutionary approach, it is the exercise of common sense to curb the loss of natural productivity and to maintain the health of fisheries resources for public use under the concept of the "normative ecosystem" (Williams et al., in press).

Regarding the three recent independent reviews of hatcheries by the ISG, NRC, and NFHRP, it is noteworthy that apart from primary agreement among reviews that artificial production had generally failed to meet its objective, that it imparted adverse effects on natural populations, and that evaluation of performance was needed, there was further significant consensus on other issues. There was agreement that:

- Supplementation needed to be linked with habitat improvements;
- Genetic considerations needed more emphasis in hatchery programs;
- Stock transfers and introductions of non-native species should be eliminated;
- A new role for artificial production needed to be developed, using more experimental approaches, and using hatcheries as temporary refuges, rather than in long-term production management.

These points of view provided insights that need to be considered in hatchery management. They were comprehensive enough that retracing that ground by the SRT would only be repetitive and add no further resolution to the problems that were identified. It is important to point out that the reviews were not a referendum against hatcheries, but rather a very creditable assessment of hatchery success in reaching their objectives and how programs should change.

We must also recognize that the practitioners' view was not represented on the three panels, nor was the view of commercial harvesters or that of the angling public, all of whom are pertinent to decision-making about hatchery application. University scientists dominated or were well represented on the review panels. The NRC committee, for example, was made up of 15 participants, of whom 12 were associated with universities. There were no members experienced in hatchery production or aquaculture on the NRC panel. Even the NFHRP panel, charged to assess USFWS hatcheries, did not have equitable representation from hatchery production management. Moreover, the reviews were largely based on ecological theory, biological principles, and some empirical evidence, but little rigorous analysis of actual data was undertaken. This is not a criticism of the process, because it is important that the understanding and implications of hatchery production be grounded in the basic science relevant to the subject. This is necessary regardless of how successful hatchery programs are or can become. To adequately manage the resource on a sustained basis, there can be no compromise with the requirements of biological processes. Whether society decides that other priorities supersede the need to maintain a specific population or a habitat is another issue, but if fisheries management is serious about building naturally sustained production, science must be the basis of any approach.

In the agency and tribal hatchery assessments such as RASP and IHOT, the practitioners' viewpoint and the value of their experience was acknowledged as important to improved effectiveness of basin hatchery programs. The forthcoming science-based SRT recommendations serve as an independent confirmation of IHOT's policies, and show that the SRT is addressing elements pertinent to the interests of artificial production.

The RASP effort provided an important overview and also a model for evaluating supplementation in the second phase of the SRT review. The IHOT program primarily was oriented toward operations, and again is most applicable to the second phase of the phase of the independent assessment. However, because both the RASP and IHOT efforts did not conduct actual hatchery performance evaluations, their primary contribution will be the use of their monitoring protocols. Hatchery compliance with the operating protocol will be one criterion of the SRT assessment procedure.

VII. Impacts Associated with Artificial Production

A. Background

As apparent from the historical overview, Columbia basin hatchery programs have been motivated by several goals, with the most recent perhaps incompatible with those of previous years. Attainment of some goals may even be considered detrimental to others, and not merely because of competition for programmatic resources, but because of conflicting outcomes.

The practical science of hatchery management is more than 100 years old. During that time hatchery technology has progressed to the point that the success rate of the "hatchery phase" in the life cycle of salmon and steelhead is very high. In fact, it is expected that a hatchery program will produce more smolts per spawner than natural production. The magnitude of this relative advantage is on the order of 10-fold, but this advantage is restricted to the hatchery phase. It is quite a different story when considering success in the post-release phase of the life cycle. Hatchery fish experience substantially less survival success in the wild. This is another issue of concern in the present assessment. In particular, what is the relative survival of the hatchery-bred fish, their reproductive ability, their ecological costs, and their genetic impacts on wild fish.

In nearly all cases, when hatchery production rationale is assessed under ecological, genetic and evolutionary theory, the result is unequivocally negative, but of an unknown magnitude. There are some limited experimental data, generally from other taxa and in specific situations, that demonstrates the mechanisms that underlie theory. But relevant empirical information related to salmonids is generally anecdotal, lacking in adequate controls, and insufficient in quantity to be conclusive. Thus, while we are confident that such mechanisms can apply to hatchery-produced salmonids, there is limited empirical evidence on hatchery impacts in the Columbia basin. Although some are tempted to attribute the decline of wild stocks in the basin to interaction with hatchery fish, as well as blaming the poor success of hatchery fish on hatchery practices, such evidence, at best, is indirect and neglectful of the other major environmental impacts in the system. The task of making linkages is a formidable one, but necessary in the fair resolution of hatchery assessment.

B. Risk Management

In addressing the various impacts of artificial production, it is worthwhile to first think about the risks associated with hatchery propagation and conflicting outcomes. To address this problem, risk management is an option that needs to be considered, but this may prove ineffective unless the goals are ranked so that priorities can be established to adopt measures that address the resolution of competing risks.

1. Risks associated with failure and success:

Originally, the goal of anadromous and resident hatchery programs was production for harvest; so the measure of success was the number of returning harvestable adults of hatchery origin. However, in actual practice over the years, and perhaps as a matter of convenience, hatcheries tended to report their performance in terms of numbers of smolts released rather than adults returning, with the assumption that adult return responsiveness was in proportion. The problem with this criterion is that the rate of adult return for the number of smolts released varies enormously from hatchery to hatchery and from year to year, leaving smolt production actually an unreliable indicator of expected harvest. Concentrating on smolt production and not adult return diverts attention from the central issue and results in the risk of not succeeding in reaching the harvest goal, or the risk of increasing failure. One component of the present review, therefore, is to assess the effectiveness of hatcheries in meeting production goals for harvest, attempting to find patterns that might account for the success of some and the failure of others.

Unfortunately, with the passage of time native runs of Columbia basin salmon have declined to such low levels that local extinctions have taken place, and many other populations currently are at risk. In this new era of concern for wild fish, the question naturally arises whether the operation of hatcheries is a contributing factor in the decline. In addition to the pessimism raised about even new state-of-the-art production hatcheries, these concerns also apply to supplementation operations as well as to captive brood stock programs. Ironically, there are some plausible scenarios in which the greater the success of the hatcheries in producing harvestable fish under the original set of goals, the greater the damage they would cause to the affected wild stocks that are the focus of new goals consistent with ecological health. These are the risks of success. Accordingly, the second component of the present review is to assess the magnitudes and likelihood of the various negative effects that hatchery operations might have on wild stocks.

2. Risk Analysis and Risk Management:

Fishery scientists must deal with two major factors in making decisions about how to assess and manage risks of hatcheries: (1) the uncertainty in predicting success or failure and (2) the potential conflicts between multiple attributes of success. One major attribute of success is the increase of fish for harvest; another is the impact on wild stocks.

Depending on how fisheries managers and the public value the probability of success in terms of producing fish for harvest, the annual investment in the hatchery system might be considered worthwhile. There is a probability that this investment will deliver a return in harvestable fish, and a probability that it will not, in which case the odds may justify making the investment. Evidence demonstrating that hatcheries contribute to harvest continues to stimulate interest in the use of hatcheries for harvest augmentation and mitigation.

At the same time, it is probable that anadromous and resident hatchery fish may have negative impacts on wild stocks, which can occur even when hatcheries are managed for supplementation or recovery of wild stocks. Negative effects could overwhelm the positive effects of increased survival in the hatchery during the wild phase of the life cycle. Here, the gamble is on wild stock recovery. Managers must not only assess biological uncertainties but also the trade-offs. In a recovery program, balancing may involve the probability of decreasing the risk of extinction during the hatchery phase versus the probability of increasing mortality during the wild phase of the life cycle. On a broader scale, managers must take into account both the harvest goals and goals to protect wild stocks. However, from a strictly ecological perspective to preserve and recover wild fish, there can be no such compromise.

The critical uncertainties that dominate decision making are amenable to empirical resolution if the right things are measured in a controlled, systematic, and powerful experimental design. Getting the information needed to answer hard questions would mean a major reorganization of how hatchery programs are conducted, including interim changes and re-prioritization of hatchery production goals. Hatchery research, focusing on programmed study plans around appropriate experiments to quantify the effects of hatcheries and hatchery practices, would need to be the initial priority. The long-term priority would be to return to production goals with management and technologies reconditioned to maximize the benefits of artificial production in a manner that complements the ecological health of the system.

C. Management Impacts on Artificial Production Effectiveness

Although controversy about the effectiveness and impact of anadromous fish hatcheries has existed since hatcheries first appeared on the Columbia River, there needs to be a distinction in the object and substance of such controversy between those factors associated with hatchery technology and those associated with hatchery management. Hatchery technology occurs in many different forms, from juvenile rearing on formulated diets in concrete raceways to unfed fry releases from incubation in artificial substrate. The chinook hatchery on Sooes River, Washington; pink salmon hatcheries in Prince William Sound, Alaska; and the Weaver Creek sockeye spawning channel in British Columbia, are examples of successful hatchery programs resulting in significant enlargement of their respective salmon populations. In contrast, and yet with similar technology, sockeye production at the Leavenworth hatchery on Icicle Creek, Washington; coho and chinook production at Grays River hatchery on the lower Columbia River; and the Priest Rapids chinook spawning channel in the mid-Columbia, are examples of hatchery programs that have demonstrated no success, and may have had negative impacts on returns. The point is that hatchery propagation takes many different forms, and each can demonstrate highly variable performance, even when the same technology is used. Most certainly, present technology can be improved, and advancements associated with reduced fish density, natural-type habitat, and measures to reduce conditioning of fish to circumstances associated with culture operations offer promise of producing fish more similar in behavior and performance with that of wild fish.

However, the overriding influence on hatchery performance, and the basis of the long-term controversy, is related more to hatchery management practices of the fisheries agencies than to fish culture practices. Variability in hatchery performance is not so much related to technology as it is to the manner in which that technology has been applied. The consistent oversight in hatchery propagation is that management has not been careful to provide for the biological needs of the young salmon after release to the natural environment. Hatcheries are generally managed from the central office, well displaced from the fish and the streams being stocked, with little appreciation of the fact that these fish must integrate into a very complex environmental system. A disregard for stock structure and the compatibility between genetic attributes of populations and the environment associated with their natal systems has generally characterized hatchery management policy in the past. Moreover, objectives such as producing the maximum number of smolts possible with the flow available, and fish release programming based on space needs among competing species or year classes, contributed significantly to poor quality of fish and negative impacts on fish in the receiving environment. More recently, concern about these issues has altered some hatchery operations in an attempt to address problems with fish quality and wild/hatchery fish interaction. The record, however, is dominated by former management practices, many of which are still represented among Columbia River hatcheries.

The compelling issue in assessing Columbia basin anadromous and resident hatcheries is not so much technology, such as whether raceways should be covered or the value of training on artificial diets, but management policy. That is a very different matter. Management policy dictates the manner in which hatcheries are employed. Management policy affects what genetic stocks are used, the breeding protocol, and where and in what numbers hatchery fish are planted. Management policy is what motivates knowing the status of the endemic stock where hatchery fish are planted, making sure the genetics are complementary, and knowing the carrying capacity of the target streams. Technology can help meet artificial production objectives, such as ensuring compatibility with native stocks, but management must assure that it is applied. The impact of management on the application of artificial production is the overwhelming and decisive factor that determines the effectiveness of hatchery programs. Good management is the key to successful integration of hatcheries into a functioning and dynamic ecosystem.

D. Genetic Impacts of Artificial Production

Better understanding of nutrition, disease, stress, and water quality has given aquaculturists increasing control over the unpredictable nature of raising fish. Only recently, however, have salmon aquaculturists become aware of genetic concerns. Artificial production can lead to unwanted or unanticipated genetic changes in wild and hatchery populations. These changes are a concern because the productivity and resiliency of populations to environmental change depend on the genetic diversity they contain. Unlike disease or nutritional problems, which can be controlled nearly immediately, the impacts of unwanted genetic changes can affect productivity for many years.

In recent years, a variety of authors have cataloged the potential genetic impacts of artificial production (Hindar et al., 1991; Waples, 1991; Busack and Currens, 1995; Campton ,1995; Waples, 1995; Allendorf and Waples, 1996). These impacts can be classified into four major types: (1) extinction, (2) loss of within-population genetic variability, (3) loss of among-population variability, and (4) domestication (Busack and Currens, 1995). The impacts are not necessarily independent. For example, domestication — or loss of fitness in the wild of a population adapted to a captive environment — may also be associated with loss of genetic diversity within that population. This has led to increasing awareness that managing genetic impacts will require assessing the trade-offs between the major types of impacts or between using artificial production or not (Hard et al., 1992; Currens and Busack, 1995).

In this subsection, we review the evidence for genetic impacts of artificial production. For each of the four impacts, we ask two basic questions that are important to decision-makers: (1) What is the evidence that the impact occurs? and (2) What is the evidence that the effects can be managed or mitigated?

<u>1. Extinction</u>:

Definition — Extinction is the complete loss of a population and all its genetic information.

Theory — Unlike other genetic impacts, extinction is usually associated with three nongenetic causes of large changes in population abundance (Shaffer, 1981). These include demographic or random changes in survival and reproductive success, fluctuations in the environment, and catastrophes.

Captive environments, such as hatcheries, offer greater control over environmental variation and the potential for increased reproductive success. These should counter natural risks of extinction. Consequently, artificial propagation theoretically could reduce the short-term risk of extinction (Hard et al., 1992).

In certain circumstances, however, hatchery programs can increase the demographic and catastrophic risks of extinction. Hatchery programs may mine small, natural populations if they take fish for brood stock but are unable to replace them. For example, hatcheries that take female salmon with 4,000 eggs would be mining the wild stock if they have much less than 0.05-percent egg-to-adult survival. Inbreeding, a genetic phenomenon, can theoretically contribute to irreversible declines in abundance in very small or wild populations (Gilpin 1987). When most or all of a population is taken into captivity, disease, power failures, predation, and dewatering in the hatchery could be catastrophic.

Evidence for Extinction — We found evidence of conditions that suggest hatcheries could contribute to extinction (Flagg et al., 1995a). To date, however, there are no records of hatcheries directly causing the extinction of stocks. In contrast, artificial propagation has been used to reduce short-term risk of extinction for sockeye salmon (Flagg et al. 1995b), chinook salmon (Bugert et al., 1995; Carmichael and Messmer, 1995; Appleby and Keown, 1995; Shiewe et al., 1997), steelhead (Brown, 1995), white sturgeon (USFWS, 1998), and bull trout (Montana Bull Trout Scientific Group, 1996) and other resident salmonids (Rinne et. al., 1986; Dwyer and Rosenlund, 1988).

Ability to Mitigate — Evidence suggests that the probability of extinction caused by artificial production can be mitigated if the reproductive success of naturally spawning and hatchery spawning fish is monitored and adequate safeguards are established to prevent catastrophes in hatcheries. We did not conclude whether the lack of hatchery-caused extinction indicates that these safeguards are in place or simply a fortuitous turn of events.

2. Loss of Genetic Diversity Within Populations:

Definition — Loss of within-population diversity is the reduction in the quantity, variety, and combinations of alleles in a population. It is associated with two genetic phenomena: genetic drift and inbreeding. Both of these are most important in small or declining populations: the smaller the effective population size, the greater the rate of inbreeding and loss of genetic information through genetic drift.

Theory — The relationship between small population size, loss of genetic diversity, and increased inbreeding is one of the cornerstones of theoretical population genetics. Considerable theory has been developed to explain the generality of this relationship (Wright, 1938; Crow and Kimura; 1970; Goodnight, 1987; 1988; Caballero, 1994) and its importance for short-term and long-term survival (Lande, 1988; Mitton, 1993; Burger and Lynch, 1995; Lande and Shannon, 1996; Lynch, 1996). In addition, general population genetic theories have been refined to fit the specific life histories of Pacific salmon (Waples, 1990a 1990b; Waples and Teel, 1990). They have also been extended to examine the effect of increasing natural population size through artificial production (Ryman and Laikre, 1991; Ryman et al., 1995).

Evidence for Genetic Drift — Many years of experimental work have demonstrated the relationship between population size and loss of genetic diversity (reviewed by Wright, 1977, Rich et al., 1979, Leberg, 1992) in many varieties of laboratory animals.

Support for the theory from natural populations is less available, because fewer opportunities have existed to measure levels of genetic diversity as population sizes changed. Low levels of genetic diversity have been measured in animals that have undergone known drastic reductions in population size. These include elephant seals (Lehman et al., 1993), koalas (Houlden et al., 1996), prairie chickens (Bouzat et al., 1998a, 1998b), and chinook salmon transplanted to New Zealand (Quinn et al., 1996). Island populations of many different taxonomic groups, which were presumably founded and maintained by few individuals, also have lower levels of genetic variability than mainland counterparts (Frankham, 1997, 1998). Where barrier dams have fragmented the range of steelhead, rainbow trout that survive above barrier dams have levels of genetic diversity that are lower than anadromous populations and that are often comparable to small populations isolated above ancient barriers (Currens, in prep.).

Lower levels of genetic variation in anadromous and resident hatchery stocks compared to their counterparts in the wild (Allendorf and Phelps, 1980; Ryman and Stahl, 1980; Vuorinen, 1984; Waples et al., 1990) suggest that genetic variation has been lost under some kinds of artificial propagation. Conditions necessary for genetic drift exist in many Pacific salmon hatcheries, and evidence is growing that it occurs (Gharrett and Shirley, 1985; Simon et al., 1986; Withler, 1988; Waples and Teel, 1990). Salmon aquaculture affects nearly all of the factors that theoretically influence genetic drift and inbreeding. These include the number and proportion of founders or brood stock taken from the wild, sex ratios, age-structure, and variation in family size as measured on adult progeny. Recent increased monitoring of genetic diversity in many hatcheries will help resolve this question further.

Evidence for Inbreeding and Inbreeding Depression — Considerable experimental evidence shows that inbreeding can reduce fitness (reviewed in Wright, 1977 Thornhill, 1993, Roff, 1997, Lynch and Walsh, 1998). Tave (1993) compiled evidence for fish, including trout and salmon, thus representing anadromous and resident life history forms, showing that they respond to inbreeding similarly to other organisms.

In natural populations, concerns arise when estimated levels of inbreeding are comparable to inbreeding that led to depression in experimental environments. For example, estimates of increased inbreeding have been associated with reduced fitness in certain Sonoran and Mexican topminnows (Quattro and Vrijenhoek, 1989; Vrijenhoek, 1996), white-footed mice (Jimenez et al., 1994), butterflies (Saccheri et al., 1998), and the evening primrose (Newman and Pilson, 1997) in natural environments. Frankham (1998) estimated levels of inbreeding in 210 island populations of birds, mammals, insects and plants and observed that based on inbreeding in laboratory studies these levels of inbreeding could explain the higher extinction rates on islands.

Evidence for Loss of Fitness from Artificial Propagation — There is little direct evidence of significant losses of fitness from genetic drift and inbreeding associated with salmon hatcheries, and probably fewer investigations of this phenomenon associated with resident fish hatchery programs. Theory and observation, however, indicate that the ability to predict or measure the effects of fitness using existing tools would be limited. Consequently, such losses, if they occurred, may not have been detectable. First of all, enzyme or DNA markers, which have been used most often to measure loss of genetic variation, are not the best ones to show the effects on fitness (Lynch, 1996). No studies of salmon have attempted to document the loss of multilocus, adaptive genetic variation and its consequences on fitness as have been done for experimental animals (e.g., Bryant et al., 1986; Bryant and Meffert, 1991). Furthermore, logistical difficulties of maintaining a powerful, experimental design may prohibit many such studies (Roff, 1997). Second, changes in fitness in small populations may also reflect the confounding effects of inbreeding depression or accumulation of deleterious mutations. Leberg (1990), for example, observed that mosquito fish populations derived from small numbers of related founders grew at much slower rates than control populations. Similar scrutiny has not been applied to salmon hatcheries. Using evidence from fruit flies, Lynch (1996) argued that under some kinds of artificial propagation, the accumulation of deleterious effects and random genetic drift would interact to reduce fitness even in moderately large populations. This has not been examined in Pacific salmon.

Theory suggests that managing brood fish number, sex ratios, and age structure can control loss of genetic diversity and inbreeding in hatchery populations (Falconer and Mckay, 1996). For integrated programs, where brood stock are taken from the wild and some hatchery fish spawn naturally, theory suggests that controlling loss of genetic diversity may be much more difficult (Ryman and Laikre, 1991; Ryman et al., 1995). Logistically, controlling loss of genetic diversity and inbreeding in captive hatchery programs or integrated programs will be difficult. Monitoring the genetic parameters affecting loss of genetic diversity is also difficult. Few programs have attempted to directly monitor the effective breeding size of the population (Hedrick et al., 1995). Variation in family size, which theory shows as being critical for determining the rate at which genetic diversity is lost, cannot be directly estimated without a pedigree of all the fish in the population. These are currently unavailable and unlikely to become available in the future for most populations.

3. Loss of Genetic Diversity Among Populations

Definition — Loss of among-population genetic diversity is the reduction in differences in the quantity, variety, and combinations of alleles among populations. In artificial production situations, it is caused by unusually high levels of gene flow that arise when fish or eggs from different populations are transferred between hatcheries, when fish are stocked in non-native waters, or when phenotypic changes in hatchery fish cause them to stray at greater rates or to different streams than normal.

Theory — The relationship between gene flow and population differentiation is another of the cornerstones of evolutionary biology (reviewed in Slatkin, 1985). Mathematical models show that unless gene flow rates are low, differences among populations will be lost (Haldane, 1930; Wright, 1931 1943; Hanson, 1966; Barton, 1983). Evolutionary theory predicts that loss of genetic diversity among populations can decrease the evolutionary potential of the species. In addition, theory indicates that extensive interbreeding of genetically differentiated populations (outbreeding) may lead to more immediate losses of fitness or outbreeding depression (Dobzhansky, 1948; Shields, 1982; Templeton, 1986; Lynch, 1991). Documentation of the genetic mechanisms remains elusive (Lynch and Walsh, 1998). At least one model of outbreeding depression is available for salmon (Emlen, 1991). An important conclusion of basic theory is that some forms of outbreeding depression will not be predictable. Consequently, the importance of outbreeding depression may need to be solved empirically (Roff, 1997).

Evidence of Loss of Genetic Diversity — Evidence of loss of genetic diversity among natural populations from gene flow is extensive. It is especially important in western North America, where extensive hatchery programs have spread cultured forms of Pacific salmon and resident trout and other species into watersheds where they have interbred with local populations (reviewed in Behnke, 1992; Leary et al., 1995; Waples, 1995). Loss of genetic diversity from interbreeding with introduced fish has been inferred for populations of the same species (Allendorf et al., 1980; Campton and Johnston, 1985; Gyllensten et al., 1985; Reisenbichler and Phelps, 1989; Currens et al., 1990, 1997a; Forbes and Allendorf, 1991; Reisenbichler et al., 1992; Williams et al., 1996, 1997; Currens, 1997) and different species (Busack and Gall, 1981; Leary et al., 1984; Allendorf and Leary, 1988). Lack of extensive interbreeding in some areas where hatchery fish have been introduced (Wishard et al., 1984; Currens et al., 1990; Waples, 1991; Currens, 1997) indicates that loss of genetic variation cannot be predicted simply from knowledge of hatchery stocking rates or migration.

Evidence for Loss of Fitness — Evidence of outbreeding depression from populations in natural habitats is available from studies of a variety of organisms, including certain marine crustaceans (Burton, 1987, 1990a, 1990b), plants (reviewed in Waser, 1993), *Daphnia* (Deng and Lynch, 1996), and fish (Leberg, 1993). Most concern about outbreeding depression in Pacific salmon is based on evidence that Pacific salmon are locally adapted (reviewed in Ricker, 1972, Taylor, 1991) and theoretical and experimental results from other animals that demonstrate that interbreeding of different locally adapted populations could result in outbreeding depression. Limited evidence suggests that outbreeding depression can occur in Pacific salmon, but rigorous experiments designed to detect outbreeding depression in Pacific salmon are missing from the scientific literature. Gharrett and Smoker (1991) reported that F2 crosses of pink salmon from odd and even-year runs had lower survivals and greater morphological asymmetry than F1 crosses, which is consistent with outbreeding depression. Currens et al. (1997) found that a hybrid swarm of introduced coastal rainbow trout and native inland rainbow trout had lower levels of resistance to a lethal disease, ceratomyxosis, than native populations. They attributed that to interbreeding with introduced coastal rainbow trout, which lacked genetic resistance to the disease.

Ability to Mitigate — Two of the three major sources of loss of genetic diversity — transfer of fish or eggs from different populations between hatcheries and stocking fish in non-native waters — can be mitigated by management measures such as developing local brood stocks or building fish-sorting barriers where marked, non-native returning adults can be removed from a population. Control of straying that is promoted by hatchery practices is more difficult. Although increased straying is correlated with a variety of hatchery practices (Quinn, 1993, 1997), modifying these practices may not always be easy or desirable. For example, transportation of fish to increase post-release survival may also increase straying (McCabe et al., 1983; Solazzi et al., 1991). Monitoring the potential loss of genetic diversity from straying can be accomplished with existing genetic techniques. Monitoring potential outbreeding depression is much more difficult and probably logistically possible for only a few experimental situations.

4. Domestication

Definition — Domestication is the adaptation of a captive population to its captive environment. It reflects the changes in quantity, variety, and combination of alleles within a captive population or between a captive population and its natural complement. Selection is the primary genetic mechanism, although it does not occur independently of genetic drift and mutation. We include both intentional (artificial selection) and unintentional selection (natural selection in a new environment) as domestication. Others have limited domestication selection to unintentional selection (Campton, 1995).

Theory — The theoretical and empirical basis for selection is the foundation of biology (reviewed by Bell, 1997). The main principles were described in the early part of this century (reviewed in Wright, 1968, 1977). The fundamental theory predicts that organisms will respond to selection when they have adequate genetic variation for selection to act on (measured as heritability) and when there is a selection differential. For over 60 years, these principles have provided the theoretical basis for modern plant and animal breeding programs (Lush, 1937; Falconer and Mackay, 1996) and our understanding of domestication. Theory has not yet been refined to answer genetics questions about interbreeding of hatchery salmon and natural populations

Evidence for Domestication — Even before modern genetics, animal breeders recognized and promoted domestication. Darwin (1898) considered domestication inevitable for captive animals. The development of captive populations for experimental genetics in the early 1900s, however, provided the first documentation of the genetic mechanisms of how organisms adapt to captive environments (reviewed in Wright, 1977). Concern about domestication in Pacific salmonids comes from two sources:

First, considerable evidence shows that many behavioral and physiological traits would respond to selection if selection differentials also existed. Tave (1993) compiled estimated heritabilities of many traits. A variety of authors have argued that strong selection differentials exist in novel, captive environments such as hatcheries (Doyle, 1983; Frankham et al., 1986; Kohane and Parsons, 1988). Together, these would lead to domestication.

Second, evidence of behavioral and physiological changes in hatchery populations compared to wild populations is increasing. Few data are available, however, to examine the fitness effects on a natural population interbreeding with hatchery fish that have undergone different levels of domestication. Early studies of domestication found evidence of behavioral change in captive brook and brown trout populations (Vincent, 1960; Green, 1964; Moyle, 1969; Bachman, 1984). More recently, Petersson et al. (1996) documented the change in morphology and life history of a hatchery strain of Atlantic salmon over 23 years. Likewise, Kallio-Nyberg and Koljonen (1997) found that growth rate and age of maturation in Atlantic salmon changed over several generations in a hatchery.

In steelhead, Reisenbichler and McIntyre (1977) found that progeny of hatchery fish only two generations removed from the wild survived in the wild only 80 survived in the wild only 80 cent as well as wild fish, but in the hatchery environment hatchery fish survived better. Fleming and Gross (1989, 1992, 1993, 1994) and Fleming et al. (1996) documented changed behavior and decreased reproductive success of hatchery Atlantic salmon and coho salmon in artificial spawning channels compared to wild fish. Swain and Riddell (1990) concluded that greater aggressive behavior of juvenile hatchery coho salmon than wild fish reared under the same environment was because of domestication selection. Berejikian (1995), however, found that hatchery steelhead raised in the same controlled environment as their wild counterparts were more likely to be eaten by a native predator. Compared to naturally spawning wild steelhead in the same stream, Chilcote et al. (1986) and Leider et al. (1990) found that naturally spawning hatchery steelhead were about 10-30 percent as successful in producing surviving smolts and adult progeny as wild fish. The hatchery stock used in this study, however, was not native to the stream and was of mixed ancestry. Consequently, the reproductive success of this stock reflects more than domestication effects.

Theory indicates that controlling domestication selection may be very difficult. Busack and Currens (1995) reviewed domestication and concluded that it is one of the costs of using hatcheries. The only way to remove domestication selection is to remove the selection differential. In practical terms this translates to removing the differences between the hatchery and wild environments. This is currently unimaginable. Hatcheries are successful because they offer a better environment in which early survival is greater than in the wild. It may be possible to reduce selection for key traits if we could identify the traits, how they correlate with fitness, and what environmental conditions led to selection. This knowledge is not currently available.

E. Ecological Effects of Artificial Production:

A healthy ecosystem is often equated with conditions that characterized river basins prior to encroachment of modern civilization. Ecosystems are dynamic, and any point in time is only a snapshot in the geophysiographic transition in environmental circumstances over time. In many cases, return to historical conditions is not possible even if human influences could be eliminated. Descriptive reconstructions of historical conditions, however, are invaluable in helping to explain current observations that are the outcome of past processes (Lichatowich et al., 1995). Contemporary ecological theory recognizes the importance of considering not only the biology of organisms, but also the biogeochemical processes that control the distribution and production of biota, and human influences on those processes (Stanford et al, in press). Such historical reconstructions viewed under the guidelines of ecological theory provide the descriptive lens through which present population structure can be discerned.

In *Return to the River* (Williams et al., in press), the ISG developed a conceptual foundation for restoration of Columbia River salmonids in which the “normative ecosystem” was defined as a mix of natural and cultural features that typifies modern society. It was implicit, however, and consistent with ecological theory, that environmental equity in the “normative ecosystem” would have to be sufficient to sustain all life stages of a diverse mixture of healthy wild anadromous salmonids, concurrent with cultural and economic development of water resources. The ISG stated, “Restoration requires detailed understanding of the interactive, biophysical attributes and processes that control the survival of salmonids rather than a simple accounting of numbers of fish at various points and time in the ecosystem.” The concept of ecosystem health infers that whatever changes occur through man-made alterations of the river system that define the “normative ecosystem,” maximum effort is exerted to maintain existing habitat for the full exploitation of anadromous salmonids. Restoration, therefore, refers to measures that enhance the natural production of native salmonids, even to their fullest diversity possible within the potential of the “normative ecosystem.”

The fundamental benefits and risks of artificial production rest in the ability of aquaculturists to isolate fish from all or part of their natural habitat and ecological processes. Since their inception, hatcheries have been operated as agricultural enterprises that strived for biological independence from one or more of the ecological processes that fish face in rivers and streams (Bottom 1997). Hatcheries were first used to circumvent natural ecological processes, such as predation and physical damage to eggs, that reduced the potential productivity. Later hatcheries were used to circumvent entire river reaches whose natural ecology had changed from the construction of dams or other human activities. Production from hatcheries was often treated as production from a super tributary without consideration of biological interactions. Consequently, until recently, the ecological effects of raising and releasing hatchery fish have had little research attention.

It is instructional to review the evidence for ecological interactions between hatchery fish and their post-release environments, and in wild fish communities between hatchery and wild fish. The continuing decline of natural populations and listings under the federal Endangered Species Act have focused attention on ecological factors of decline that have been previously ignored, such as predation, competition, disease, and nutrient flows. In addition, the attempt to increase natural production through hatchery supplementation has also stimulated interest in ecological effects. As previously mentioned, in *Return to the River* the ISG developed a “normative ecosystem” concept for restoration and management of both wild and hatchery salmonids in Columbia River salmonids (Williams et al., in press).

In salmonid ecosystems, ecological interactions are complex and occur at different levels of biological organization from the organism to the population to the community. In this subsection, we focus on five main issues: effects on carrying capacity, competition, predation, disease, and behavior, while recognizing that these occur and interact at different levels of biological organization.

1. Effects on carrying capacity

In this subsection, we review evidence that the number of fish released from hatcheries has exceeded the carrying capacity of the ocean or freshwater environments. Competition, which can occur among individuals as a consequence of stocking at or near the carrying capacity, is discussed in another section.

Definition — Carrying capacity is the upper limit on the steady-state population size that an environment can support. Carrying capacity is a function of both the populations and their environments.

Theory — A large body of ecological theory postulates that population growth is limited by the amount of available resources and the relationship between these limits and environmental variation (Krebs 1985). Under steady state models of population growth, as a population approaches carrying capacity, its growth rate is reduced to zero (Lotka 1925, Volterra 1926). This view of population regulation assumes that there is a deterministic relationship between the abundance of a species and the abundance or condition of the available resources. Abundance of populations is density dependent because with each additional individual fewer resources are available. Although the notion of a carrying capacity is conceptually useful, other theorists have suggested that population growth may be largely controlled by unpredictable changes in environments and resources (Andrewartha and Birch 1954, Strong 1986).

A. Ocean carrying capacity impacts

Evidence — The effects of hatchery releases on ocean carrying capacity have been studied for coho salmon in the Oregon Production Index (OPI). The Oregon Department of Fish and Wildlife first addressed the question of ocean carrying capacity relative to hatchery releases by analyzing whether ocean mortality of coho salmon was the result of density-dependent or density-independent factors (ODFW 1982). Density-dependent mortality would indicate that the capacity had been exceeded; density-independent mortality would indicate otherwise.

The results of this analysis were inconclusive, but it did stimulate other studies (Lichatowich 1993). Seven additional papers addressed the question of whether carrying capacity in the ocean for coho salmon in the OPI was limiting production. The question, however, remains unresolved. The studies generally analyzed the same data, but they used different analytical methods and arrived at different answers to the question. The strength of the conclusions varied. In general, three studies concluded that the evidence for density dependence was weak or nonexistent (Clark and McCarl 1983; Nickelson and Lichatowich 1983; Nickelson 1986). Three other studies concluded there was evidence for density dependence or at least enough evidence for caution (McCarl and Rettig 1983; McGie 1983; Emlen et al. 1990). One study pointed out statistical weaknesses in Nickelson (1986) and cautioned managers regarding its conclusion. Studies of salmon in other ocean production areas, including Japanese and Russian chum (Ishida 1993), Bristol Bay sockeye (Rogers 1980), and British Columbia and Bristol Bay stocks of sockeye (Peterman 1984) suggest salmon densities are approaching capacity. As with the studies of Oregon coho salmon, however, the evidence is not conclusive.

Since work on OPI coho salmon, researchers have identified patterns of changing ocean productivity (Ware and Thomson 1991; Beamish and Bouillion 1993; Francis and Hare 1994). This pattern of shifting ocean productivity suggests that the carrying capacity of the ocean, especially in specific areas, is also changing. If that is the case, then continuing to release large numbers of hatchery fish during periods of low productivity (reduced capacity) might not be the appropriate strategy (Beamish and Bouillion 1993).

B. Freshwater carrying capacity impacts

Evidence — Research documenting an effect of hatchery fish on the freshwater carrying capacity of salmonid streams is largely lacking. Many fishery managers assumed that effects on carrying capacity depend on the time and age of release. Large releases of fry or presmolts might have significant ecological effects on carrying capacity because they could use limited food and cover. In the lower Columbia River, for example, stocking hatchery fry in excess of carrying capacity was identified as one of the factors leading to the collapse of wild coho populations (Flagg et al. 1995). The mean density of emergent, wild coho fry in lower Columbia River tributaries was estimated at three fry per lineal stream meter (fry/m). By comparison, hatchery fry were stocked in similar sized streams in Oregon at a rate of 16 fry/m and in Washington at 22 fry/m. This suggests that overstocking streams could have displaced wild fry in the Lower Columbia River tributaries (Flagg et al. 1995). The use of presmolts to supplement natural production in underseeded streams (supplementation) also raises the possibility that large release of hatchery fish could exceed the capacity of the stream habitats unless stocking levels are carefully researched and controlled. Determination of stocking densities for supplementation projects is complicated by the need to consider the existing abundance of wild fish relative to carrying capacity (Stewart and Bjornn 1990).

In contrast, in the 1950s and 1960s many hatcheries adopted the practice of holding juveniles until they smolted. Smolted hatchery fish were expected to use the river only as a conduit to the sea, which theoretically minimized carrying capacity problems. Even where smolts are released, however, and expected to migrate immediately to sea, release of too many fish could exceed capacity of the stream. In his examination of Washington's hatchery program for steelhead trout, Royal (1972) speculated on what he called a "density barrier" that could have resulted from a combination of competition with other species, environmental factors and poor physiological condition of the hatchery fish. Once the barrier was reached, increasing the number of hatchery fish produced little or no additional benefit.

An indirect effect of the hatchery-harvest management strategy on freshwater carrying capacity is the reduction in nutrient recycling to the system from carcasses. With reduced escapement needs to sustain hatchery programs, harvest has been given a greater share of the return, generally associated with the management concept of Maximum Sustained Yield (MSY). This has not only impacted escapements of wild fish in mixed stock fisheries, but it has affected nutrient recruitment from carcasses that enriched otherwise nutrient-impoverished systems. Carcasses undoubtedly were an important source of nutrients to freshwater systems that habitually export nutrients downstream (Bilby, et. al. 1998) The dependence on artificial production has exaggerated the deficit in nutrient transfer caused by management around MSY from that historically experienced, because of even further limited escapements required to sustain hatchery production. Consequently, reduction of carcass contribution to nutrient loads in salmon spawning streams is an indirect, but significant ecological impact of hatchery management.

Because managers have complete control over the number of fish released, preventing hatchery releases from exceeding carrying capacity of freshwater or marine environments is easy if the carrying capacity can be known. Determining the carrying capacities of dynamic, natural systems, however, is very difficult. Attempts to adjust hatchery releases to carrying capacities must take into account changes in climatic patterns, habitat, and communities that can cause variation in capacity. The Council has had a measure in its fish and wildlife program to determine the carrying capacity of the Columbia River relative to the basin's hatchery production levels (Measure 7.1G NPPC 1994). While work on this measure was undertaken, the measure has not been fully implemented, and carrying capacity has not been determined.

2. Competition

Definition — Competition is the negative interaction between two or more individuals that occurs when a necessary resource is in short supply or when demand is greater for higher-quality resources.

Theory — Competition is one of the fundamental ecological interactions between individuals. Many ecologists believe that it is the major factor determining the structure and organization of ecosystems (Cody and Diamond 1975). The theoretical treatment of competition in the ecological literature is extensive and well-developed (see Krebs 1985, or a similar text for an introduction).

Evidence — Competition is very difficult to demonstrate (Fausch 1988). Conditions for competition between hatchery and wild fish may occur, however, if the hatchery fish are released before they are ready to migrate to sea and they residualize or remain in freshwater for an extended period of time. Conditions may be aggravated by differences in size or behavior between the wild and hatchery fish. Salmonids often form dominance hierarchies in streams, where dominant individuals defend the best holding or feeding areas against subordinate fishes (Fausch 1988).

In experiments using enclosures placed in the Teanaway River, Washington, residual hatchery steelhead reduced the growth of wild rainbow trout but did not influence the growth of juvenile chinook salmon (McMichael et al. 1997). When the stocking of catchable-sized hatchery rainbow trout was terminated in a section of the Madison River, Montana, the biomass and numbers of the fall population of two-year-old brown trout increased by 160 percent and the number of wild rainbow trout increased by 868 percent. The impact of stocking may have been caused by the disruption of the existing social structure in the wild population (Vincent 1987).

In an attempt to supplement underseeded coastal streams in Oregon, ODFW stocked some streams with coho salmon of hatchery origin. They left some streams unstocked as controls. The total summer density of juveniles increased by 41 percent in the stocked streams. However, 44 percent of the wild juveniles in those streams were replaced by the hatchery presmolts. Nickelson et al. (1986) attributed the displacement of wild fish to the larger size of the hatchery presmolts at the time of stocking.

An important goal of management programs that make use of hatcheries should be to integrate the natural and artificial production systems (Lichatowich and McIntyre 1987). Hatchery fish should not replace existing wild fish. Such integration requires knowledge of the natural production system. Once obtained, it has to be explicitly used to plan and implement the hatchery program. Follow-up monitoring is critical. This approach is not impossible, but it would be difficult to implement, and at the present time it is the exception and not the rule in hatchery management.

<u>3. Predation</u>:

Definition — Predation is an ecological interaction where one individual becomes a food source for another. Predation is one of the fundamental ecological interactions observed between many species. The theoretical treatment of predation in the ecological literature is extensive and well-developed (see Krebs 1985, or a similar text for an introduction).

Evidence — Under different scenarios, hatchery salmonids can be predators or prey. Predation of one salmonid on another can be an important source of mortality. Hatchery fish released at a large size are potential predators on smaller wild salmonids (Stewart and Bjornn 1990). Parker (1971) observed that predation by coho salmon accounted for a large fraction of early sea mortality in chum and pink salmon. If a predator such as coho salmon is enhanced through artificial propagation it could increase predation and cause the decline of other important salmonid. Johnson (1972) observed that chum salmon returns to hatchery racks was inversely related to hatchery coho production in Puget Sound. Although his study did not show a cause-and-effect relationship, Johnson (1972) concluded that managers should be concerned about the effects of the hatchery coho salmon program on the total production of chum. Stewart and Bjornn (1990) cited a paper by Sholes and Hallock (1979) that reported heavy predation on wild steelhead and chinook fry by larger yearling chinook salmon stocked into the Feather River, California.

Rearing in artificial environments can make hatchery fish more vulnerable to predation than wild salmonids (Olla et al. 1998). Hatchery fish released at a small size are vulnerable to predation by other larger salmonids or other non-salmonid fishes. In addition, hatchery fish may lack appropriate behaviors, perhaps from lack of prior exposure to predation, and may undergo secondary stresses such as disease (Stewart and Bjornn 1990), which may make them more vulnerable to predation. White et al. (1995) speculated that this may explain the poor post-stocking survival of hatchery fish. For example, feeding salmonids at or near the surface of the hatchery pond gives them a surface orientation that can make them more vulnerable to avian predation. Disease infection may also enhance the vulnerability of salmonids to predation (Mesa et al. 1998).

Habitat modification that removes cover, modifies temperature and obstructs passage may increase the vulnerability of hatchery fish to predation (Spence et al. 1996). Habitat alteration may also enhance the predator population and lead to greater mortality. For example, the creation of Rice Island in the lower Columbia River from the disposal of dredge spoils created habitat for Caspian terns. The tern colony on Rice Island has grown dramatically and is now the largest in North America. The terns may be consuming between 5 and 20 million juvenile salmonids annually (ODFW 1998). The recovery of PIT tags on Rice Island suggests that hatchery fish may be more vulnerable than wild fish to predation by terns (Roby et al. 1997). The conversion of the free-flowing Columbia River to a series of reservoirs is another habitat change that has enhanced predation on salmonids by the northern pike minnow (Rieman et al. 1991). Shively et al. (1996) observed a rapid shift in the diet of the northern pike minnow from largely non-fish items to a diet composed mostly of juvenile salmonids following a release from Dworshak National Fish Hatchery. The shift was observed away from the release site in an area where the river changed from free-flowing to impounded.

Any manipulation of hatchery practices to reduce predation will require better understanding of the ecology of the receiving waters than we have today. The size, time and place of release of hatchery fish might be altered to reduce predation on the wild salmonids or reduce predation on the artificially propagated salmonids. The importance of predator avoidance behavior has led to suggestions that salmonids undergo specific training to enhance their recognition of predators, improve their ability to escape and increase their post-release survival (Maynard et al. 1995). Predator training in the hatchery is showing some promise in reducing predation on artificially propagated salmonids, but it is far from being universally implemented. Managers should also consider the indirect effects of habitat change in enhancing predation, especially if a hatchery is operating in the watershed.

4. Disease:

Definition — Disease is the negative ecological interactions between a host, a pathogen, and the environment that results in an impairment that interferes with or modifies the performance of normal functions of the host.

Theory — The theoretical aspects of disease dissemination have been extensively studied in humans and some animal populations (see Anderson and May 1979, 1982; May and Anderson 1979; Grenfell and Dobson 1995). Theoretical treatment of disease processes in fish, however, have been only recently been explored for Atlantic herring, Clupea harengus (Patterson 1996); European flounder, Platichthys flesus (Lorenzenen et al. 1991); guppies, Poecilia reticulata (Scott and Anderson 1984), and domesticated trout (Bebak 1996). Reno (1998) has reviewed many of the critical factors involved in constructing models of disease dynamics for fish populations, but he did not specifically address transmission between hatchery and wild fishes.

Evidence — Diseases and their effects on fish populations result from multifactorial and interacting causes making cause-and-effect relationships difficult to determine (McVicar 1997). Detecting and verifying the transmission of disease between hatchery and wild fish is very difficult. Nevertheless, several examples illustrate the potential. Two examples come from Norway. In 1985, infected Atlantic salmon smolts transferred from Scotland introduced frunculosis into Norway. The disease has spread to 20 Norwegian rivers (McVicar 1995). In 1975, the parasite Gyrodactylus salaris from an infested hatchery in Sweden was introduced into the Lakselva River, Norway. Atlantic salmon parr, (Salmo salar), which were susceptible to the parasite, were heavily infected and within two years the abundance of parr had collapsed (Sattaur 1989).

A recent example from the United States is the spread of salmonid whirling disease (Mysobolus cerebralis). The disease was first found in the United States in Pennsylvania in 1956. Since then it has gradually spread to a least 21 states. The likely cause of the spread of the parasite is the shipment of infected fish to new areas (Bergersen and Anderson 1997, Modin 1998).

The introduction of new diseases to areas with no previous history of that pathogen is one way hatcheries can influence the mortality of wild fish. Another way is through the direct transmission of an endemic disease in a watershed from infected hatchery fish to the wild fish. This would be difficult to identify, and we could find no documented examples.

Management agencies recognize the importance of this problem and have taken steps through the IHOT process to prevent the transfer of infected fish (IHOT 1994). The adequacy of the IHOT policies are discussed elsewhere in this report.

5. Behavior:

Hatcheries may alter the behavior of cultured fish as a consequence of domestication (genetic change) and as a consequence of acclimation to the hatchery environment without genetic change. Evidence for behavioral changes due to domestication is presented in the section on genetic impacts of artificial production.

Differences in spawning behavior have been observed in comparative studies of wild coho salmon and coho salmon that were captured in a stream as emergent fry and reared in a hatchery environment until mature. Salmon reared in the hatchery from fry to maturity exhibited all the normal reproductive behaviors and they successfully spawned. However, when mixed with wild fish their reproductive success was reduced because of a diminished competitive ability (Berejikian et al. 1997). Wild males dominated access to spawning females in 86 percent of the spawning events observed. Hatchery-reared females constructed fewer nests and started the typical spawning behavior later than wild females. Since these differences in behavior were observed after less than one generation in the hatchery, the observed effects were probably due to environmental effects on the phenotype (Berejikian et al. 1997). Fleming and Gross (1992 and 1993 cited in Jonsson 1997) observed similar results in their experiments with hatchery and wild coho salmon. Fifth-generation hatchery Atlantic salmon also showed less aggressive spawning behavior than wild fish (Jonsson 1997).

The obvious way to reduce the effect of the hatchery on spawning behavior is to minimize the differences in the hatchery and natural environments. However, which aspects of the hatchery environment need to be changed and how much change is needed is not known.

F. Populations and Production Trends Over Time

As discussed elsewhere in this document, hatcheries were started in response to the decline of returns from overfishing. Whether or not early hatchery production made any contribution, hatcheries were still viewed as the solution to mitigate for the anticipated loss in harvest resulting from river development. With successive construction of the dams beginning in the 1930s (Figure 16), habitat was not only totally eliminated upstream from the barriers of Chief Joseph/Grand Coulee, Dworshak and Hells Canyon dams, but spawning and rearing habitat were also altered and lost below these dams as the result of the nearly continuous line of reservoirs that now represent the portions of the mainstem rivers “accessible” to anadromous salmonids.

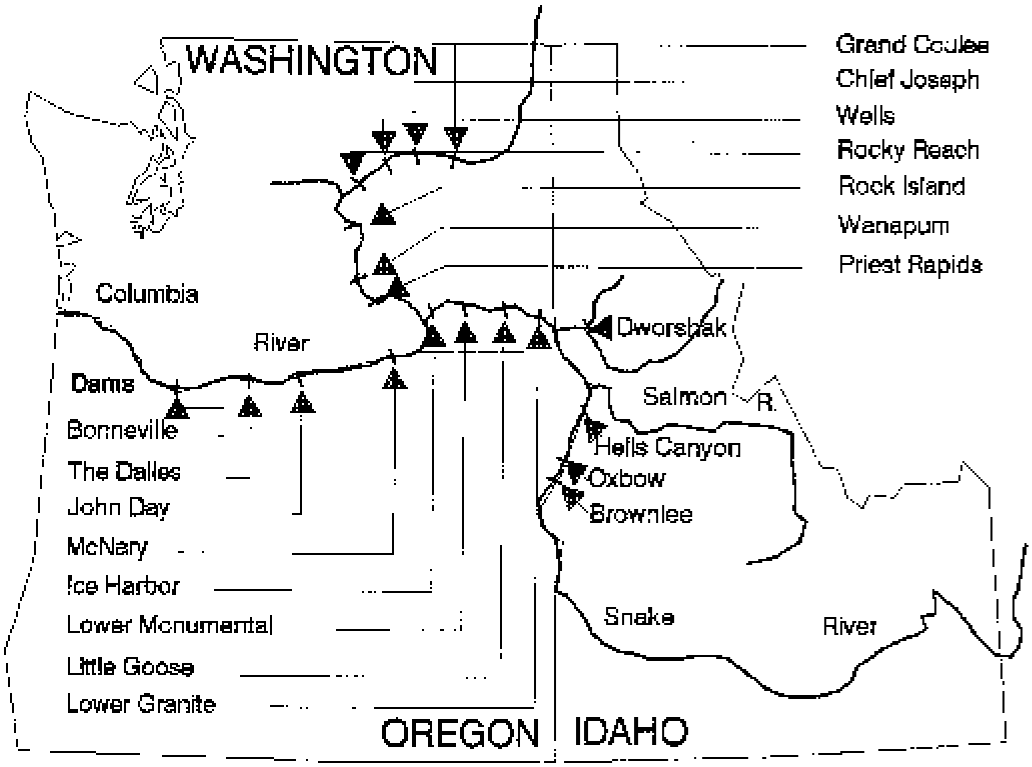


Figure 16. Dams on the Columbia and Snake rivers.

In response to the anticipated reduction in natural production from loss of habitat, hatchery construction went forward with major facilities designed to replace the anticipated loss in harvest. Hatchery production responded with a consistent and growing contribution over the years (Figure 17). Since 1950, the contribution from hatcheries increased from 38 million juveniles to 150 million by 1979, and has remained around 120 million since that time.

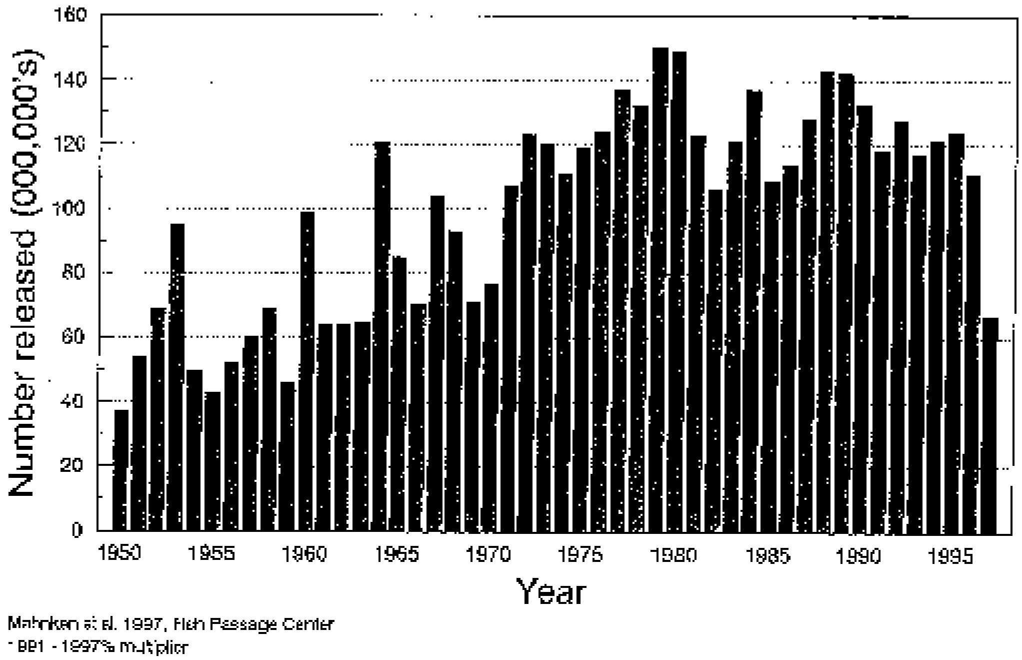


Figure 17. Hatchery contribution to Columbia basin juvenile salmonid emigration. (Mahnken et al, 1997: Fish Passage Center)

In the meantime, the results of increased hatchery production were equivocal in terms of influencing the returning numbers of adult salmon and steelhead. Salmonid populations entering the Columbia River have shown a fluctuating range in escapement from 420,000 to 650,000 fish from counts over Bonneville Dam (Figure 18). The peak return in recent years was in 1987, following a weak but general trend with increased hatchery production. However, while hatchery production surged to an increase of over 100 percent from 1969 to 1980, returning adults are shown to have simultaneously decreased about 30 percent over the same time period.

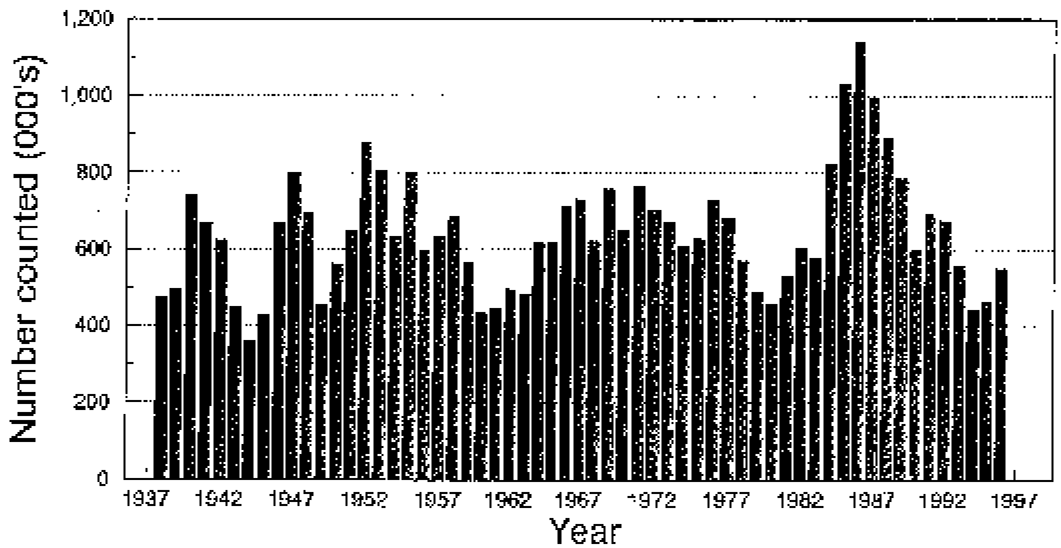


Figure 18. The trend in returning anadromous salmonid populations counted over Bonneville Dam on the Columbia River. (SteamNet 1996)

The contrasting trends between artificial production and return over these years makes it uncertain what portion of the return can be attributed to hatchery production, and underscores the need to complete the intensive examination of hatchery performance. The loss of habitat from dam construction reduced the natural production potential, which hatcheries were intended to replace. Total return of all anadromous salmonids, including commercial landings, has shown a relatively level trend to the 1990s, and a significant decline after that (Figure 19), while hatchery production remained the same. It should be noted, however, that salmon abundance already was depressed by the 1930s — and hatcheries had been operating for 60 years.

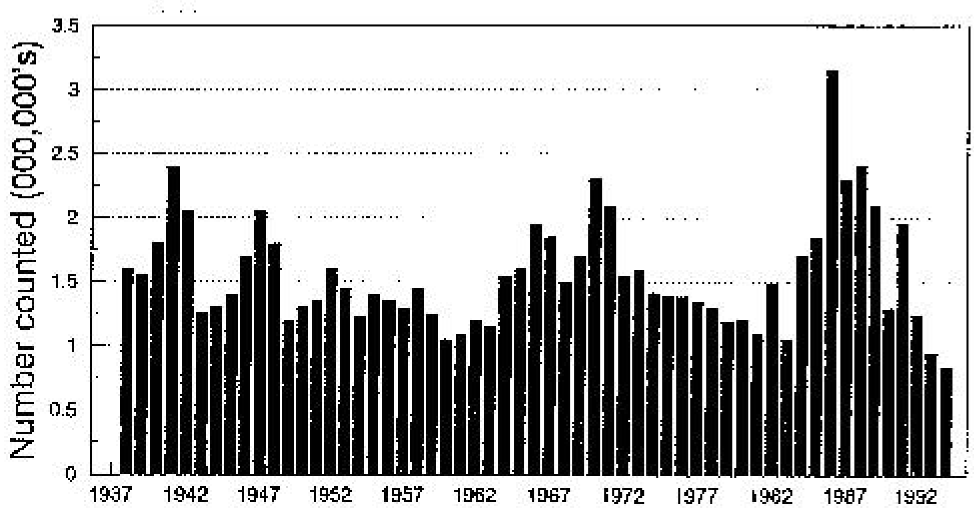


Figure 19. The trend in total production of returning anadromous salmonid populations to the Columbia River plus commercial landings. (SteamNet 1996)

In retrospect, the number of returning adult salmon was relatively level from 1938 through 1990. The precipitous loss of returning chinook entering the Snake River (Figure 20) accounts for a major share of the decline that has occurred in total return to the Columbia.

A serious impact on the recent returns to the Columbia River Basin, therefore, appears to have been from the construction of the four lower Snake River dams. Mitigation has not maintained adult returns to the Snake River at the level that existed prior to the construction of Ice Harbor Dam. However, there has been a high mortality of emigrating juveniles while making their migratory journeys through the altered mainstem corridor. The cumulative effects of the successive developments along the corridor impacted the hatchery fish as well as the wild fish, creating a more complex problem as developments expanded than what was probably anticipated. If there is any hope of reaching the goal of replacement, survival through the lower Snake River will have to improve before the mitigation objective can be reached.

The ascendancy of ecosystem management in the Columbia has further complicated the problem of addressing mitigation responsibilities on the river. Mitigation with hatchery production was not founded on the paradigm of ecosystem management, but simply one of replacing fish for fish in the harvest. Under the new concept, ecosystem health is a priority of equal importance as mitigation for lost harvest, which means the original process of satisfying mitigation will have to change. Hatchery success is no longer measured solely by the number of adults returning. Part of the problem in the decline of wild fish production is attributed to the impact of the very hatchery fish meant to mitigate for harvest reduction through overdrafts of wild fish in mixed stock fisheries. Hatchery fish can sustain higher harvest rates because of lower escapement needs (less than 10 percent) to supply production requirements. Wild fish, requiring higher escapements (30 percent to 60 percent) for adequate production, suffer the same rate of exploitation in mixed stock fisheries targeting hatchery fish. The cumulative effect, uncontrolled, is to drive natural populations down to eventual extinction. Prior to ecosystem management, and the pivotal importance of maintaining natural production in the basin, hatchery fish were viewed as a replacement option for wild fish, and could be used as the rationale for over-fishing wild fish in mixed stock fisheries. It was with the same justification that hatchery fish could be viewed as mitigation for extirpating the runs above Grande Coulee and Hells Canyon dams.

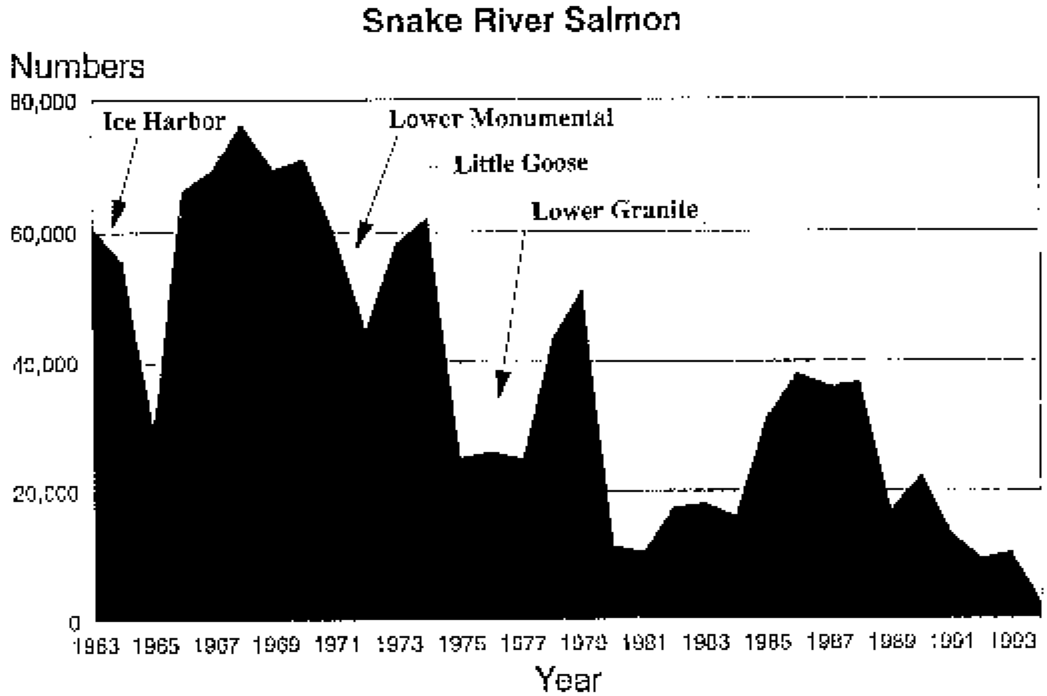


Figure 20. Chinook salmon returns to the Snake River related to the years when lower Snake dams were built.

The ecological impact of hatchery fish is an issue of equal importance to mixed stock fisheries with regard to the long-term health of natural populations. Although there is little evidence to support some of the more theoretical concerns about hatchery fish altering the fitness of wild populations (Campton, 1998), the premise is not disputed, only the direction and degree to which such effects are manifest.

VIII. Conclusions and Guidelines

To briefly review, hatchery production of Columbia River Basin salmon started before the turn of the century for the purpose of augmenting harvest of chinook salmon for the commercial fishery. Science initially had only a small role in the process — primarily the development of fish husbandry. Over time, the role of science evolved to include formal attention to nutrition, genetics and pathology. That attention, however, centered primarily on the technology of fish husbandry, with little attention to concerns about hatchery fish interaction with wild fish, or with the natural (post-release) environment.

With the new paradigm of ecosystem function, science articulated a refreshed interest in community balance, food chain dynamics, population structure, and integration of hatchery fish as a functional component of the ecosystem. Standard hatchery procedures no longer were accepted as a means of addressing augmentation or mitigation, and much greater emphasis is placed on developing a new conceptual foundation under which artificial propagation should proceed. The architects of this new conceptual foundation cannot be oblivious to the fact that the Columbia and Snake rivers are systems substantially altered from the historical conditions in which anadromous salmonids evolved.

This report is not a commentary establishing the role of artificial production in future Columbia River fisheries management, or recommending the degree to which hatchery production should contribute in the basin. That is the responsibility of the state and tribal fisheries managers. This report concerns the state of the science that relates to artificial production, and in that regard presents guidelines that we believe should be the foundation of recommendations on the appropriate use of artificial production in the future. Following the points of general agreement with the three recent scientific reviews that broadly addressed hatchery operations (ISG, NRC, NFHRP), the guidelines are presented in two parts. First are guidelines based on our scientific assessment of artificial production that includes hatchery practices, ecological, and genetic considerations. Second are guidelines that address what we consider the necessary research to resolve problems and questions about the technology and management of hatchery programs.

To provide further background for our guidelines, it is appropriate to discuss generally what is known and not known about hatchery effectiveness and hatchery effects. The level of knowledge varies considerably for different aspects of the effects of hatchery management and policy. The three major divisions of this material are knowledge about:

1. Effects of hatchery practices on the egg to smolt phase of the life cycle of hatchery fish;
2. Effects of hatchery practices on the post-release phase of the life cycle of the hatchery product, and,
3. Effects of the hatchery product on the wild stocks with which they interact ecologically and genetically.

The amount and certainty of the knowledge in each of these three divisions is so different that we cannot reasonably attain the same level of conclusiveness about them from our review of the science.

In order to attune our conclusions with the differing levels of certainty, we offer our advice in the form of recommendations, guidelines and hypotheses. And we urge our audience to be sensitive to the distinction and the implications of these guidelines, recommendations and hypotheses. Basically, the current state of the science can support firm “recommendations” about practices to enhance the performance of the hatchery product in the egg-to-smolt phase of the life cycle. The science is less comprehensive and conclusive about the post-release performance of the hatchery product. For this aspect we can offer tentative “guidelines” for practices that we are reasonably sure will generally improve post-release performance somewhat, but we can’t be sure how much, and we can’t offer assurances that these guidelines in themselves will be sufficient for meeting objectives of the program. The science is even less conclusive about the effects of the hatchery fish on wild stocks. The science can identify specific genetic and ecological mechanisms that must be operating in the interaction between hatchery and hatchery fish, but the degree of quantification and empirical verification in this important aspect of our knowledge is so low, that for the most part we can only state important, plausible “hypotheses.” The monitoring, analysis, and experimentation necessary to arrive at conclusions about these hypotheses should be elevated in priority for the future. In the meanwhile, we advise managers and policy makers to adopt a precautionary approach in the decisions where these hypotheses have a bearing.

The picture is further complicated by the very real possibility of working at cross-purposes by simultaneously attempting to manage for improved egg-to-smolt performance within the hatchery, improved smolt-to-adult returns of hatchery fish, enhancement of wild stocks through supplementation, preservation of wild stocks with captive breeding, and minimization of potential negative effects of augmentation hatchery operations on wild stocks. Practices that are good for one objective could be bad for another. A successful overall hatchery policy will have to be cognizant of these possible effects "between compartments." We will discuss these trade-offs in the third, synthesis phase, of our review.

A. Points of General Agreement with Recent Reviews

The three recent independent reviews of fish and wildlife recovery efforts in the Columbia River Basin addressed hatcheries among other issues — one report addressed hatcheries specifically. These reviews collectively represent a concerted effort to assess hatchery production from the scientific perspective. There was consensus among the three panels, which underscores the importance of their contributions in revising the scientific foundation for hatchery policy. The ten general conclusions made by the three panels are listed below.

1. Hatcheries generally have failed to meet their objectives.
2. Hatcheries have imparted adverse effects on natural populations.
3. Managers have failed to evaluate hatchery programs.
4. Rationale justifying hatchery production was based on untested assumptions.
5. Supplementation should be linked with habitat improvements.
6. Genetic considerations have to be included in hatchery programs.
7. More research and experimental approaches are required.
8. Stock transfers and introductions of non-native species should be discontinued.
9. Artificial production should have a new role in fisheries management.
10. Hatcheries should be used as temporary refuges, rather than for long-term production.

Given the present degree of uncertainty about hatchery success, the SRT agrees that unified hatchery management policies should include plausible hypotheses that test some of the uncertainties inherent in these conclusions.

In particular, with respect to the hypothesis that the future role of hatcheries in fisheries management will evolve considerably, we note that the priorities of fisheries management have changed significantly in recent years, so the needs that hatcheries should serve are also changing. The ongoing reality of increasing numbers of Endangered Species Act listings of anadromous and resident fish puts a much higher emphasis on wild stocks and naturally spawning stocks. This increases the concern over the potential for artificial production to cause genetic and ecological harm to such stocks. But it also raises the possibility that hatcheries may serve some positive role in this era of new priorities.

B. General Considerations of the State of the Science and the Technology

The goals sought by hatchery programs have changed over the years. However, like earlier hatchery programs, the most recent efforts of augmentation, supplementation and captive brood stock production may have succeeded in their numerical production objectives with regard to juvenile releases. The issue is that the effect of that production on increased return has generally not been demonstrated, and that effects on naturally spawning stocks have not been adequately investigated. Agencies have evaluated some hatchery procedures, such as the effect of size and time of release on return success, but there has been a general lack of effort at the programmatic level. Only recently has natural production in the Columbia basin been given priority. Previously, the approach of concentrating artificial production of Pacific salmon downstream from lower Columbia dams was considered a viable mitigation option for providing the necessary production from the system, based on general trends in hatchery production returns. However, if evaluations demonstrating the consistent production benefits of hatcheries have been undertaken, they have not been published in the peer-reviewed literature. Such publications are required to provide fair analysis of these hatchery programs. Issues of genetics, stock transfers and limiting effort to avoid overfishing wild stocks mixed with hatchery fish are symptomatic of the previous philosophy downplaying the role of natural production and the human alteration of the natural Columbia River Basin ecosystem. Given the present emphasis on the ecosystem approach, these issues are now important and should be given priority in the development of the new conceptual foundation for artificial production.

In the past, weak native runs have been replaced with other fish in the development of hatchery programs, such as the original plan regarding Sooes River fall chinook salmon. Such action is inconsistent with present values. Diversity is now believed to be one of the keys to the long-term success of salmonid populations, and adaptive traits should never be willfully abandoned. In situations where a stock has been extirpated, managers need to have the option of introducing non-native fish to establish the nucleus on which restoration can take place. Even in this situation, however, the donor stock chosen should not be simply based on egg availability. Careful analysis is required to assure environmental relationships between donor and target streams are as compatible as possible for the stock selected. Frequently, appropriate donor stocks will come from ecologically similar and geographically adjacent streams or watersheds.

Stock transfers and introductions can place serious risk on native fish stocks and should be discontinued from hatchery programs except when the purpose is to restore an extirpated run or population. Introductions also might be justified when genetic diversity is so low as to threaten the persistence of a population.

The primary role of hatcheries in the basin is mitigation for the loss of harvest as a result of reduction of habitat from economic development of the Columbia and Snake rivers. Given the present encroachment of habitat modification and degradation into the riparian and adjacent lands of these river systems, it is unlikely that natural production in a recovered ecosystem would satisfy commercial, tribal, and sports harvest interests. The options, therefore, are (1) to be content with lower production from managed natural populations and use hatcheries in a more temporary role for rehabilitation, or (2) to manage for greater harvest potential from a combination of natural production and hatcheries mitigating for habitat no longer accessible. Mitigation hatcheries are a long-term commitment involving significant cost. Although

Columbia Basin hatcheries have not satisfied their objective of sustaining production thus far, nonetheless they now account for the majority of production in the basin.

Changing the manner in which hatcheries address their role is the hope that hatcheries can succeed. Based on past hatchery performance in the basin, such expectation is bereft of proof. But abrogation of the concept based only on the past is also imprudent when hatchery management has made such serious mistakes and the fish still persist. As Reisenbichler (1998) reasoned after observing fish in the hatchery environment, ".. substantial adaptation to hatchery conditions [occurs]... and holds promise that modifying hatchery conditions can reduce deleterious genetic differences between hatchery and wild fish." The hope is that with care given to appropriate changes in the hatchery environment, the response of hatchery fish can be compatible and complementary to the natural population structure of the native species. The normative ecosystem is an equitable mix of natural and cultural features with environmental equity to sustain all life stages of a diverse mixture of healthy wild anadromous salmonids, concurrent with cultural and economic development of water resources. Hatcheries can have a mitigation role in the normative ecosystem. These may become rehabilitation programs that secure the endurance of native runs. They may also become perpetual programs to supply commercial or angling opportunities. The challenge is to redevelop the concept of a hatchery to assure enhanced production to meet both ecological and economic objectives.

C. Relation to an Ecological Framework

It is imperative that priority be given to the development of a set of scientific guidelines that serve as a conceptual foundation for the Columbia basin hatchery program. These also must be consistent with the eight elements of the basin-wide ecological framework (NPPC Document 98-6) that is to guide management of the Columbia River as an ecological system. The eight ecologically based elements are listed below.

- The abundance and productivity of fish and wildlife reflect the conditions they experience in their ecosystem over the course of their life cycle.
- Natural ecosystems are dynamic, evolutionary, and resilient.
- Ecosystems are structured hierarchically.
- Ecosystems are defined relative to specific communities of plant and animal species.
- Biological diversity accommodates environmental variation.
- Ecosystem conditions develop primarily through natural processes.
- Ecological management is adaptive and experimental.
- Human actions can be key factors structuring ecosystems.

The set of scientific principles that relate to artificial production, and emphasized by the latter two elements listed, are meant to minimize unintentional human influences on ecosystem structure. These principles can be divided along technological and managerial lines, differentiating between how hatchery fish are produced and how hatchery fish are used.

D. Guidelines on Hatchery Practices, Ecological Integration and Genetics.

Management of all hatcheries should be consistent with the life history of the cultured stock and the environmental conditions of the watershed, especially the annual temperature regime of the relevant section of native habitat represented in the stock of fish propagated. Life history strategies demonstrate the optimum course of action in the complexity of selective pressures exerted on them (Brannon, in press). Proper management, therefore, must include only measures that are consistent with those life histories, or severe impacts on the native populations should be expected. Management policy on such conventions as stock introductions (listed above), size and time of release, magnitude of release, genetic agenda, and recovery strategies are of major importance to the success of hatchery programs. Details on these issues are in the following guidelines, but it needs to be understood that in many cases where scientific principles are advocated, applied evidence is not available to demonstrate the precept. In these cases, it may be more appropriate to view the guidelines as hypotheses that need to address problems they exemplify — as safeguards against unforeseen events that could destroy the viability of the runs managers are attempting to conserve. Some theories are troublesome to practitioners because their experiences do not support the axiom. Concerns about inbreeding are an example. Many populations of salmonids are small and inbred by the nature of the environment describing their habitat. In fact, where certain traits are critical to their survival, such as an innate complex orientation pattern to reach a destination, specificity rather than diversity defines fitness. This appears contrary to the theory, but in the broader range of the species, diversity is still the key to species stability. Measures taken to maintain the diversity present, or to prevent potentially negative effects of induced inbreeding, even within naturally inbred lines, are precautions that safeguard against artificially imposing a deleterious artifact of hatchery production on a population.

Present technology is bringing into application measures that improve the quality of fry at the time of emergence and at readiness of juveniles to enter the migratory phase. Providing required nutritional needs in a form available in artificial diets were some of the first advancements in hatchery technology (Hublou, 1963), and nutritional develops have continued (Forster and Hardy, 1995).

Substrate and darkness during incubation to maximize energy efficiency for growth are now employed routinely. These conditions were found to more accurately simulate natural incubation environments and produce larger fry at emergence than open tray or basket incubators (Brannon, 1965). Other technologies are also being employed, and their appearance in the list only reaffirms the importance placed on them.

Guideline 1. Technology should be developed and used to more closely resemble natural incubation and rearing conditions in salmonid hatchery propagation.

In developing hatchery technology, hatchery programs should work toward the goal of providing environments that resemble natural conditions during artificial propagation. These may include:

- Incubation in substrate and darkness;
- Incubation at lower densities;
- Rearing at lower densities;

- Rearing with shade cover available;
- Exposure to in-pond, natural-like habitat;
- Rearing in variable, higher velocity habitat;
- Non-demand food distribution during rearing;
- Exposure to predator training;
- Minimize fish-human interaction;
- Acclimation ponds at release sites;
- Volitional emigration from release sites.

Rationale: Lower rearing densities, minimum exposure to humans, and shade cover over raceways enhances fish quality and maintains a behavior more similar to that of wild fish. Also, volitional migration when the fish are ready to begin their journey to sea is a technology practiced at some hatcheries, promoting natural transit behavior and less impact on the carrying capacity of the receiving stream or other water body. These are positive advancements in hatchery production operations that are encouraged to continue. Other practices need research on potential indirect effects. For example, although accelerated rearing can easily overcome any size deficiency of the fry experienced at the time of emergence, what isn't known are the potential impacts accelerated rearing will have on the normal biological development from embryo to fingerling, or the impact that large hatchery fish have on their wild counterparts.

Guideline 2. Hatchery facilities need to be designed and engineered to represent natural incubation and rearing habitat, simulating incubation and rearing experiences complementary with expectations of wild fish in natural habitat.

Rationale: Hatchery technology in the Columbia basin has relied primarily on standard tray incubation and concrete raceway technology based on engineering designs that emphasize efficiency and convenience for fish culture operations. Qualities associated with natural habitat have not been incorporated in such designs, and fish reared in standard concrete raceways learn behavior conducive to those situations, and out of harmony with what they will experience when released into natural conditions. Comparatively poor survival success of hatchery fish is attributed in part to such experiences atypical of natural conditions. Technology needs to design facilities that utilize engineered earthen stream channels that represent natural habitat with cover, glides and pools, woody debris and flow patterns mimicking natural habitat. Incubation and rearing could take place in the same channel facility, at densities appropriate to encourage natural feed (supplemented with formulated diets) and provide learning opportunities under simulated natural conditions. Training would include exposure to size variability among other species that share the habitat, and limited exposure to predation.

Guideline 3. New hatchery technology for improving fish quality and performance needs to have a plan for implementation and review at all hatchery sites, where appropriate, to assure its application.

Rationale: Assuring that technological advances in hatchery propagation are part of hatchery operational plans is critical to the implementation of changes meant to improve the quality and performance of hatchery fish in the natural environment. Often such implementation occurs only among those hatcheries where a willingness to make changes exists, given that information on new technology is even transmitted. It is important that technological advancements are first verified and the mechanism through which such technology enhances quality or performance is well understood. Then there needs to be a process for implementing the technology, with accountability for its installation and review to make it as routine as feed delivery, assuring its application and evaluation.

Guideline 4. To mimic natural populations, anadromous hatchery production strategy should target natural population parameters in size and timing among emigrating anadromous juveniles to synchronize with environmental selective forces shaping natural population structure.

Rationale: Hatchery programs have tended to concentrate on large-size fish at the time of release, as well as varying the timing of release, to facilitate higher return success. Although such rationale is understandable from the standpoint of improving hatchery fish survival, such practices introduce atypical migrants that create an alteration in the natural continuity of events around which population strategies have evolved. With the exception of fall chinook that normally show variation in migratory distribution patterns, such practices with other anadromous salmonids are believed to have negative effects on fitness of wild fish, and may perturb population structure to the disadvantage of natural populations. Based on interpretations of population structure and life history patterns (Brannon, in press), avoiding atypical size and time at migration among hatchery fish is desirable, even with the immediate disadvantage it may have on hatchery return success. The point is that hatcheries should focus on mimicking the natural environmental selective forces within the target watershed so hatchery-produced emigrating juveniles exhibit the same size distributions as juveniles from the natural population.

Guideline 5. To mimic natural populations, resident hatchery production strategy should target population parameters in size and release timing of hatchery-produced resident juveniles to correspond with adequate food availability and favorable prey to maximize their post-stocking growth and survival.

Rationale: Post-stocking mortality of a wide array of resident fish species could be reduced by implementing release strategies that match released fry or fingerlings with periods of adequate production and availability of planktonic and invertebrate food items. Attention to vulnerability of stocked resident fish fry or fingerlings as prey, and abundance and behaviors of potential predators in receiving waters can also significantly improve initial post-stocking survival.

Guideline 6. Supplementation hatchery policy should utilize ambient natal stream habitat temperatures to reinforce genetic compatibility with local environments and provide the linkage between stock and habitat that is responsible for population structure of stocks from which hatchery fish are generated.

Rationale: Temperature is a crucial factor affecting adult salmonid return timing and spawning (Brannon, 1987), and is an important factor affecting the length of time juveniles spend in stream residence before migrating to sea. This fundamental influence has formed the framework around the evolution of salmonid population structure. Temperature demonstrates its pivotal effect on the evolution of life history forms through temporal influences on egg incubation and juvenile growth as the basis for differentiation of adult timing and juvenile residence behavior, respectively. It is argued, therefore, that temperature is one of the most critical environmental factors affecting life history forms peculiar to their respective stream system. Temperature is the environmental parameter motivating the evolution of stock predispositions selectively reinforced over time to represent genetically distinct units. Temperature regimes during early life history are typically altered from the natural pattern by hatchery use of ground water for incubation. Hatchery management policy should adhere to using the ambient temperature regime of their natal environments to maintain the compatibility of hatchery fish with the natural system and the effectiveness of hatchery contribution to the natural spawning population. In some cases, wild fish spawn on spring-fed reaches of streams, and the appropriate incubation temperatures in those situations would be incubation substrate temperatures. However, when it comes to the rearing phase where the growth rate is determined by temperature (Brett et al, 1969), it is the daily ambient mean temperature that is important to follow.

Guideline 7. Salmonid hatchery incubation and rearing experiences should use the natal stream water source whenever possible to enhance homestream recognition.

Rationale: Another factor associated with the natal habitat and homing accuracy is the homestream odor profile that provides the fingerprint ultimately identified with the homestream spawning and incubation site. Hatchery programs not only use ground water for incubation, but hatcheries are usually away from the natal environment to which local stocks have adapted. The assumption is that by planting the fish in the proper location, hatchery fish will home to that stream on return. While this is true, imprinting is sequential (Brannon and Quinn 1990; Quinn et al. 1990), and the incubation environment is the first odor cue on which alevins imprint and the ultimate identity sought by returning fish (Brannon 1982). Strays are common in some hatchery populations and lack of having imprinted during the incubation phase is suggested as being responsible for higher stray rates. To assure the continuity between hatchery fish genetics and local stream habitat, the water sources closely linked with the natal environment are most desirable. This guideline is most difficult to incorporate with present hatcheries because the capital structure and water system have been established without those priorities. New facilities, however, should be located on sites with access to appropriate water sources.

Guideline 8. Hatchery release strategies need to follow standards that accommodate reasonable numerical limits determined by the carrying capacity of the receiving stream to accommodate residence needs of non-migrating members of the release population.

Rationale: Standards should include impact considerations on the wild fish residing in the system, and should be based on life history requirements of the cultured stock. Hatchery releases of cultured fish into receiving streams occur under the assumption that the river is used primarily as a migratory conduit to the estuary. This is true for only those fish (smolts) at emigration readiness. Fish not ready to migrate will take up transitional residence in the stream, causing the potential negative interactions with wild fish present. Care should be taken to limit release numbers consistent with the estimated rearing capacity of the system to minimize impacts on wild fish. Moreover, the practice of releasing fish to make space for other broods should be discontinued. Release of hatchery fish must fit a schedule consistent with life history requirements of the natural population from which the brood lot was derived.

Guideline 9. Hatchery programs should dedicate significant effort in developing small facilitates designed for specific stream sites where supplementation and enhancement

objectives are sought, using local stocks and ambient water in the facilities designed around engineered habitat to simulate the natural stream, whenever possible.

Rationale: Hatcheries are most often developed around the concept of a central facility from which fish are outplanted to many other streams or acclimation ponds, not always using native stocks in each instance. The rationale is usually related to the major capital expenditures for hatcheries under the old hatchery concept. It is much more desirable to locate smaller, stream-specific operations to maintain stock identity with the particular stream targeted. Nothing larger than a station capacity of 100,000 eggs or 25,000 fingerlings would be required on smaller tributary systems. This would require no more than a rearing channel to accommodate such small inventories, but small numbers in natural-like habitat is the ideal for supplementation of native salmonids. Even fry releases can be a feasible option to consider under these circumstances associated with the natural habitat, when conditions for supplementation can call for such limited, and perhaps temporary, artificial application. Again, this hypothesis is impossible with present facilities located where they are and with capital commitments in water and concrete. However, with new artificial production facilities, part-time stations of this nature would address both the biological and ecological requirements that future operations must satisfy.

Guideline 10. Genetic and breeding protocols consistent with local stock structure need to be developed and faithfully adhered to as a mechanism to minimize potential negative hatchery effects on wild populations and to maximize the positive benefits that hatcheries can contribute to the recovery and maintenance of salmonids in the Columbia ecosystem.

Rationale: As an integral component in a complex ecological system, salmonid stocks have evolved with their environments. Spawning time, emergence timing, juvenile distribution, marine orientation and distribution are not random, but rather occur in specific patterns of time and space for each population (Brannon 1984), and include behavior that evolved under historical abundance constraints in natural populations. The appropriate seed stock is key to producing viable, healthy fish for the respective system. Given the ecosystem concept for management protocol in the Columbia Basin, population genetics and the natural environment salmonid stocks have evolved under have to become blueprints in hatchery programming. Differences between the genetics of wild stocks and hatchery fish (Ryman and Sthl, 1980; Allendorf and Utter, 1979) are considered by the SRT as a major source of poor hatchery fish performance in the wild. Development and adherence to strict genetic guidelines and breeding protocols consistent with local population structure is essential for effective hatchery contribution to wild production and maintenance of local genetic diversity.

Guideline 11. Hatchery propagation should use large breeding populations to minimize inbreeding effects and maintain what genetic diversity is present within the population.

Rationale: One of the potential negative effects of artificial production is that relatively small breeding populations are involved in hatchery programs. Even when 100,000 fingerlings are scheduled for supplementation, that number represents a little over 25 females for brood stock, and a relatively limited representation of the gene pool. In the Idaho captive rearing project where juveniles are intercepted and reared to maturity as a means to avoid demographic risks of cohort extinction, only enough parr are captured to provide 20 spawners for each population, which is even a smaller representation of the gene pool. The risks in using small breeding populations are loss of diversity and magnifying the effect of deleterious genes. Hatchery survival can increase the contribution of the artificially propagated fish out of proportion with number, with the result that over time the hatchery population will become increasingly more represented among the natural spawners. The issue is not just inbreeding, because many healthy natural populations are very site- specific in unique environments and represent inbred lines. The risk is that hatchery production can accelerate the potential harmful effects of inbreeding by involving only a small portion of the returning adults in the artificial breeding population. To avoid these negative effects of hatchery production, a large number of spawners should be included in the breeding protocol. When the run is relatively small, this may require live spawning, and removing only a portion of the eggs from each female and subsequently releasing the fish to continue spawning naturally.

Guideline 12. Hatchery supplementation programs should avoid using strays in breeding operations with returning fish.

Rationale: In situations where strays constitute a substantial proportion of hatchery return populations, care should be taken to avoid inter-stock hybridization because of the loss of adaptive traits in the resulting progeny. Reisenbichler (1998) demonstrated examples of reduced fitness from hybridization. Stock hybridization breaks down genetic homeostasis and disrupts co-adaptive gene complexes, which lowers the fitness of the local stock. A policy needs to be developed to minimize the contribution of strays to the local hatchery stock. In the situation where a hatchery is supplementing a native population, inter-stock hybridization should be avoided to prevent loss of adaptive fitness.

Guideline 13. Restoration of extirpated populations should follow genetic guidelines to maximize the potential for re-establishing self-sustaining populations. Once initiated, subsequent effort must concentrate on allowing selection to work by discontinuing introductions.

Rationale: When undertaking restoration projects where populations have been extirpated, restoration strategies need to be given careful consideration and reference to genetic guidelines. Where neighboring populations represent appropriate characteristics, stock transfer may be the best strategy. When suitable stocks are not available, or when information is insufficient with which to match a donor stock, then inter-stock hybridization may be an alternative. Inter-stock hybridization breaks down co-adapted gene complexes and releases genetic variability on which selection can work. Restoration can use different genetic-based approaches, depending on the situation, but the characteristics of the donor stock(s) are critical. The key is to follow through with the strategy selected and allow sufficient time for the founders to be selectively established by avoiding continued introductions in the target stream.

Guideline 14. Germ plasm repositories should be developed to preserve genetic diversity for application in future recovery and restoration projects in the basin, and to maintain a gene bank to reinforce diversity among small inbred natural populations.

Rationale: One of the most important considerations in the Columbia Basin fisheries management plan is to preserve the existing genetic diversity. Diversity is inherent to the stability of the species. The various systems, with their component population networks, are the sanctuaries of variability. Recovery and enhancement of natural production in the basin will not be a rapid process, and in the meantime further loss of diversity may occur, with some populations becoming extinct. It is critical, therefore, to launch an immediate program to preserve germ plasm by collecting and cryopreserving milt from all naturally spawning populations that can be reached. The technology is available and currently is being employed with some ESA-listed salmonid stocks. This effort needs to be expanded and given greater priority. Germ plasm should be collected from each population on more than one broodyear to develop as complete a repository as possible. The availability of germ plasm for future use in maintenance of diversity or restoration of extirpated runs will be invaluable in the long-term ecological framework of the managed river.

Guideline 15. The physical and genetic status of all natural populations of anadromous and resident fishes need to be understood and routinely reviewed as the basis of management planning for artificial production.

Rationale: Knowing the status of the endemic stock where hatchery fish are involved is imperative under the ecological framework of fisheries management. Information should include life history, population structure and the habitat utilized. This knowledge must include, in addition to the traditional numerical status of the run, details on its population structure, distribution patterns, size and timing of migration, and the level of genetic specificity and diversity within the population. The habitat status associated with the population must also be known, including the area available, the condition of the habitat, new areas that can be developed, and the carrying capacity. This information is essential to the management of all native anadromous and resident species in the Basin, which will require ecological expertise at the programmatic and hatchery levels.

E. Guidelines on Research and Monitoring

Good management is the key to successful integration of hatcheries into a functioning and dynamic ecosystem. Research to improve artificial production, the extent of its application, and its limitations is basic to the effective management of hatcheries in the basin. In this regard, monitoring is also a critical element in the management process. Knowing what is successful and what must change is impossible without appropriate monitoring programs.

Guideline 16. An in-hatchery fish monitoring program needs to be developed on performance of juveniles under culture, including genetic assessment to ascertain if breeding protocol is maintaining wild stock genotypic characteristics.

Rationale: The NPPC needs to design a scientifically valid monitoring program for the basin hatcheries. Special attention should be paid to the collection of valid data that applies to routine assessment of juvenile performance in the hatchery incubation and rearing phase, up to the point of release. Genetic monitoring of the stock inventory would include descriptive evaluation at first feeding and at release time to assess if hatchery propagation is altering genotypes from that of the wild population.

Guideline 17. A hatchery fish monitoring program needs to be developed on performance from release to return, including information on survival success, interception distribution, behavior, and genotypic changes experienced from selection between release and return.

Rationale: The NPPC needs to design a scientifically valid monitoring program for hatchery fish performance after release from the culture facilities. In addition to return success, attention should be paid to relative interception distribution (tag analysis) of hatchery fish to compare performance parameters with native fish. Special attention should also be given to descriptive genetic assessment at time of return to determine if genotypes surviving are representative of genotypes released, and compatible with the native stock. With the advent of the PIT tag system, opportunities to gather more specific information exists. Significant insights can be gained on straying, migratory route and timing that are key to honing hatchery programs.

Guideline 18. A study is required to determine cost of monitoring hatchery performance and sources of funding.

Rationale: A study should be undertaken to consider how much monitoring programs will cost and what reallocation of effort in the production programs would be required to fund adequate monitoring efforts where additional funds cannot be secured.

Guideline 19. Regular performance audits of artificial production objectives should be undertaken, and where they are not successful, research should be initiated to resolve the problem.

Rationale: Routine audits of hatchery production objectives should be established (for example, every five years) to determine if they are achieving their objectives. In those cases where programs or hatcheries are not showing any production benefit, they should be re-prioritized to research-only until the problems can be resolved. In some cases, research may disclose that the objectives are not attainable. In those situations, emphasis can then be redirected, programs changed, or discontinued.

Guideline 20. The NPPC should appoint an independent peer review panel to develop a basinwide artificial production program plan to meet the ecological framework goals for hatchery management of anadromous and resident species.

Rationale: With the development of the broad ecological framework in the basin placing emphasis on hatchery management in the arena of conservation fisheries and ecosystem function, it will be necessary for practitioners and fisheries scientists to work together in developing the appropriate hatchery program plans to achieve the ecosystem goal. Problems that have prevented hatcheries from achieving their goals, or insights on what may be impossible to achieve in the ecosystem approach at the hatchery level, cannot be ascertained without major contribution from hatchery managers experienced in the system. Also, the inherent conflict between the concept of ecosystem management and the concept of management for harvest mitigation has to be resolved within the ecosystem framework. Those resolutions, and the development of the hatchery program plan addressing specific actions needed to achieve the goal, are essential elements early in the planning process. The responsibility will require appointment of an independent peer review panel that can give careful and appropriate consideration, through solicitation of agency, tribal and public interests, to past management experiences.

Given the new management emphasis on wild stocks, special consideration must be given to the possibility that some of the maladaptive traits developed by hatchery fish in hatcheries could be expressed even more deleteriously when those fish attempt to spawn naturally (in a supplementation program) or when they interact genetically (as strays) with natural spawning populations, or as they interact with natural stocks ecologically throughout the post-release portion of the life cycle. While these possible risks are in some sense the most alarming, they are also the most poorly documented, and the quantitative strength of the underlying forces are not well understood. Therefore, a large research and monitoring effort needs to be directed at these questions of genetic and ecological effects of hatchery fish on naturally spawning stocks. The results of these studies are needed to lay to rest some of the fears about worst-case scenarios, and they are also needed to teach us how to modify hatchery management to achieve the most positive kinds of interactions with wild stocks.

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Appendix

Regional scientific questions on artificial production addressed in this report:

1. What are the ecological impacts of artificial production in the Columbia River Basin?

General
- o What are the positive biological/ecological contributions of artificial production in the Columbia River?
- o What are the negative biological/ecological impacts of artificial production in the Columbia River?
- o Does it not make sense to alter stock composition in hatcheries based on ocean conditions?

Fitness
- o Can hatcheries be used to rebuild wild, native salmonid populations and maintain their genetic and life history attributes, their fitness and the evolutionary capacity of the populations?
- o Are hatchery salmonids less fit for survival in the natural freshwater and ocean environments? If they are, what are the changes that must be made in the hatchery operation to make hatchery fish as fit as wild fish?
- o Is there a differential survival between hatchery and wild salmonids throughout their life cycle stages? Is there a differential survival rate for hatchery and wild fish as they encounter the human changes in the system? For example, do wild and hatchery fish survive dam passage, barging and predation at different rates? If they do, then should the agencies and tribes in their management programs acknowledge this differential survival rate?
- o Where have hatchery stocks caused the decline or extinction of wild stocks? Where have hatcheries enhanced the restoration of a wild stock?
- o Can the biological diversity, fitness and productivity of a wild, native salmonid population be maintained with a hatchery?
- o Do hatchery programs exist in the Columbia Basin or the region that have been shown to do a good job supporting biological diversity, genetic and life history attributes, fitness and productivity of the native population they interact with? Can they serve as a model for the basin and region?
- o Should a coordinated gene flow management policy be developed to control stray hatchery fish in the basin?

Disease
- o Are hatchery disease treatment programs likely to create resistant pathogens that could pose a health risk to wild salmonids? What should be done to eliminate or manage this risk?

2. What is scientific context for the use of artificial production in the Columbia Basin?
- o What are the major research questions associated with artificial production?
- o How does the existing level of scientific uncertainty affect the use and management of artificial production?
- o What are the priority research questions that need to be answered to integrate hatchery and wild production so that there is no loss of fitness and productivity in either the hatchery or wild populations?
- o What is the historic relationship between natural production and harvest?

3. How has artificial production performed relative to its management goals?

General
- o How effective has artificial production been relative to stated objectives in the Columbia River?

Harvest
- o How does artificial production affect harvest regimes and vice versa? What has been the affect of this relationship on natural production?
- o How do we mitigate fisheries with the least impact on wild fish?
- o As the proportion of hatchery fish increases and harvests are targeted on them, a mixed stock harvest problem is created where the wild, native population is exposed to high harvest rates. In this way the hatchery program fuels the harvest management program and wild fish are overharvested. What are your recommendations for reducing or terminating this problem? Can hatchery fish be used as a buffer to protect wild fish or is this a rationalization to justify not making changes in fishery management?
- o If harvest rates are constrained by natural production, then how can we alter hatcheries to meet compensation goals?

Mitigation
- o Can hatcheries be used to double the runs and, at the same time, maintain the biological diversity, fitness and productivity of the individual subbasin populations? Or is there a conflict between these two goals set forth by the fish agencies and tribes through the Power Planning Council? What are your recommendations for resolving this conflict, if it exists?
- o Mitigation has been carried out in such a way that the effect is the replacement of wild, native salmonids with hatchery fish. Is this effective mitigation? Have the mitigation agreements and goals been met in each relevant case in the Columbia? If hatchery mitigation is not working, what should it be replaced with that would protect wild populations?
- o Given that hatcheries are a necessary tool to mitigate for lost natural production, where does is make most sense, (i.e. most effective in production and cost) to locate production facilities?
- o Have mitigation hatcheries been successful in replacing numerical losses in the basin? Have they been successful in replacing the biological diversity and fitness of the wild, native runs that were lost?

4. What is the scientific basis for the use of supplementation?

- o What is the potential, and what are the associated risks, for artificial production to augment or supplement natural production in a biologically sound and sustainable manner?
- o What are the hatchery protocols needed to prevent a hatchery population from diverging from the wild donor population?
- o Can it be assumed that a hatchery population derived from a wild donor population will not diverge from the donor population in genetic, life history traits, and fitness?
- o How should a hatchery program be operated when reintroducing a salmonid population into a stream where the species has gone extinct if the goal is to promote a healthy, self-reproducing new population?
- o Does hatchery supplementation of wild salmonids work? Is there evidence in the scientific literature that shows hatchery supplementation is able to maintain the biological diversity, abundance, distribution, productivity and fitness of the

original wild, native population? If not, should the region continue to fund new hatchery supplementation projects?

- Can these wild native populations be recovered using supplementation where wild brood stocks are used in the hatchery program?
- Can hatchery supplementation increase the numbers of fish while maintaining the productivity (fitness) of the affected population over time?
- Should hatchery and wild salmonids be integrated so that they function as single reproductive unit within a subbasin? Or should the two be kept separate, including the separation of spawning time to reduce crossbreeding between hatchery and wild fish?

5. *What is the application to residence fish?*

Appendix 2

Artificial Production Programs and Policy Developments in the Columbia River Basin

This appendix contains a description of the major anadromous and resident fish artificial production programs in the Columbia basin, not only the federally funded programs but also separate hatchery programs associated with FERC-licensed dams and state fish and wildlife agencies. In addition, the appendix includes a description of the extensive scientific and policy developments concerning artificial production that the basin has seen since the 1980s, as well as a look forward to the planning and implementation that can be vehicles for further production policy reform. Following the narrative description is a table listing the major programs and facilities and certain relevant information about these programs and facilities (Attachment 1).

Federal and non-federal artificial production programs in the Columbia River Basin

The program descriptions are compiled from a number of sources. Another recent (and relatively comprehensive) compilation of information about production programs and facilities in the basin is the recent Biological Opinion on artificial production in the Columbia basin produced by the National Marine Fisheries Service and the Biological Assessments produced by the various agencies in preparation for the Biological Opinion. For a list of relevant documents concerning artificial production in the Columbia basin, *see* the bibliography in Appendix 5.

Federally funded anadromous fish production programs

Mitchell Act hatcheries. Twenty-five hatchery facilities funded by Congress under the Mitchell Act (also known as the Columbia River Fishery Development Program) are the heart of federally funded artificial production in the basin. Begun in the 1930s and 40s, and pursued ever since without a change in the basic legal authorization, the Mitchell Act called for the “conservation of the fishery resources of the Columbia River” through “one or more salmon cultural stations” and by other means. The majority of the funds spent under the Mitchell Act have been used to mitigate for the salmon and steelhead losses that occurred throughout the river by developing hatchery production in the lower Columbia. Mitchell Act facilities are largely concentrated in the lower Columbia below Bonneville Dam (16 facilities) or in the Bonneville Dam pool area (7 facilities). Two facilities are located in the mid-Columbia area upstream of the confluence with the Snake River. The Mitchell Act program is administered by the National Marine Fisheries Service, although the facilities are primarily managed and operated by cooperating agencies, primarily the Oregon Department of Fish and Wildlife, the Washington Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service.

Releases from Mitchell Act facilities represent a large portion of all smolts released in the Columbia River Basin — estimated at one time to be approximately three-quarters of the total numbers produced and more than one-half of the total weight of all Columbia River Basin hatchery releases. The proportion of Mitchell Act releases to total basin releases is no longer quite that large, although Mitchell Act production is still far higher than all other programs —

proposed release plans for 1999 show Mitchell Act releases of approximately 60 million anadromous juveniles out of a total of 142.5 million projected for the basin as a whole, or 42 percent. Of those 60 million juveniles, more than half will be fall chinook, with the rest spring chinook, coho, steelhead, chum and sea-run cutthroat trout. Release of 60 million represent a reduction over the last decade of Mitchell Act production, which once ranged as high as approximately 100 million juveniles per year. Cutbacks in Congressional appropriations have been largely responsible for the reduction in total production.

Production to preserve lower-river and ocean harvest opportunities has been the main focus of the Mitchell Act program, a source of bitterness to some of the lower river treaty tribes, whose usual and accustomed fishing sites lie above Bonneville Dam. The effort in the 1980s and 1990s to develop and fund new production programs above Bonneville Dam as part of the Council's Columbia River Basin fish and wildlife program has been, in large part, an effort on the part of the tribes and their state co-managers to address the fact that the Mitchell Act program provided mitigation in the lower river for impacts that affected people in the upper river as well. Also, as a result of production agreements negotiated as part of the *U.S. v. Oregon* harvest litigation and embodied in the Columbia River Fish Management Plan, the federal, state and tribal governments have cooperated in recent years in limited movements of Mitchell Act fish upriver for release, such as the release of fall chinook and coho from Mitchell Act facilities in the Yakima River.

Mitchell Act funding comes from Congressional appropriations without reimbursement by Bonneville. Funding for some of the efforts to re-program Mitchell Act releases upriver have made their way into the fish and wildlife projects funded by Bonneville to implement the Council's fish and wildlife program. Mitchell Act facilities abandoned in recent years due to reductions in Congressional appropriations have also found their way into the Council's program, such as the adaptation of the Gnat Creek hatchery by the Oregon Department of Fish and Wildlife to produce fish for a terminal fisheries project in Young's Bay under the Council's program.

In the recent Biological Opinion issued by the National Marine Fisheries Service, the Fisheries Service concluded that hatchery operations in the lower river, including the operations of Mitchell Act facilities, are likely to jeopardize the continued existence of listed lower Columbia River steelhead. The Biological Opinion identified two main problems that led to this conclusion — releases of hatchery steelhead into natural production areas that result in predation and competition with listed steelhead juveniles and, especially, the continued use of non-endemic steelhead stocks in the production facilities in the lower river, which has the potential to affect listed steelhead through genetic introgression. The Fisheries Service identified a set of reasonable and prudent alternatives to avoid jeopardy (and additional conservation recommendations), focused primarily on transitions to locally-adapted stocks, an end to releases of non-endemic stocks, management of hatchery adult stray rates to less than 5 percent of the annual natural population size, and restrictions on the size of juvenile releases to minimize predation and competition.

At the same time the Fisheries Service issued the Biological Opinion, it also decided to add to the endangered species list lower Columbia chinook and upper Willamette spring chinook and steelhead. The Fisheries Service will thus have to revise its Biological Opinion on the production programs to take into account the effects on these newly listed fish.

For a more detailed discussion of current Mitchell Act production numbers and plans, see the *Biological Assessment for Mitchell Act Operations, 1999*, and *Mitchell Act Information Packet 1999*, prepared by the National Marine Fisheries Service, Columbia River Fisheries Development Program Office, Portland Oregon.

Grand Coulee mitigation — Leavenworth complex. The U.S. Bureau of Reclamation completed construction of Grand Coulee Dam in 1941, blocking the migration of salmon beyond that point on the mainstem of the Columbia River. In mitigation of the losses, the Bureau implemented a plan developed by the Washington fishery agency to trap adult salmon at Rock Island Dam on the mid-Columbia and transport them to a hatchery constructed on the Wenatchee River at Leavenworth for artificial propagation, the smolts to be planted in the Wenatchee, Methow, Entiat and Okanogan rivers. The Entiat and Winthrop hatchery facilities, on the Entiat and Methow rivers, are satellite facilities of the Leavenworth Hatchery. The Fish and Wildlife Service operates the Leavenworth complex, funded through Bureau appropriations and reimbursed by Bonneville. Production plans in 1999 call for releases of more than 2 million spring chinook, as well as 100,000 summer steelhead from the Winthrop hatchery.

The Biological Opinion recently released by the National Marine Fisheries Service analyzed the effects of Leavenworth complex production on listed upper Columbia steelhead. Chinook and steelhead in the mid-Columbia region are now listed or proposed for listing.

John Day Dam mitigation. Congress authorized construction of the John Day Dam as part of the Flood Control Act of 1950. Construction and operation of the dam resulted in the loss of spawning grounds for what was then estimated as 30,000 adult fall chinook salmon. Mitigation has been provided by the Bonneville Fish Hatchery in Oregon under a cooperative agreement between the Corps and the State of Oregon, and by the Spring Creek National Fish Hatchery in Washington. Bonneville Fish Hatchery was originally built in 1909 by the State of Oregon and has undergone major renovations funded by the Mitchell Act, John Day mitigation and the State of Oregon. The U.S. Army Corps of Engineers, under John Day mitigation, funds 45 percent of the operation and maintenance of the Bonneville Hatchery and the Mitchell Act funds 55 percent. The Spring Creek Hatchery, originally a Mitchell Act hatchery, also has been renovated and modernized. The Corps and the Mitchell Act each fund 50 percent of the operation and maintenance of the Spring Creek Hatchery.

Spring Creek Hatchery is a huge producer of fall chinook, with a production goal of 15 million tule fall chinook and 1999 projected releases of 10.7 million. The Bonneville Hatchery produces fall chinook, spring chinook, coho, and winter and summer steelhead for release locally and in other areas (e.g., fall chinook for the Umatilla River and steelhead for the Clackamas River program). The Bonneville facility is also used as part of the Grande Ronde River Endemic Spring Chinook Captive Broodstock Program, described briefly below.

Lower Snake River Compensation Plan. In the Water Resources Development Act of 1976, Congress authorized funding for a program to mitigate for fish and wildlife losses caused by construction and operation of the four lower Snake River hydroelectric projects (Lower Granite, Little Goose, Lower Monumental and Ice Harbor dams), known as the Lower Snake River Compensation Plan (LSRCP). The Corps of Engineers built ten hatcheries and sixteen satellite facilities for adult trapping and juvenile acclimation facilities between 1980 and 1998 on or for the lower Snake, Salmon, Clearwater, Walla Walla, Grande Ronde, Imnaha, Tucannon, Touchet and Walla Walla subbasins, at a cost over $170 million via Congressional appropriations later reimbursed by Bonneville. (Kooskia Hatchery on the Clearwater, which first began operations in 1969, is not technically part of the LSRCP, but it is operated by the Fish and Wildlife Service as a satellite of Dworshak Hatchery spring chinook production under the LSRCP.)

The U.S. Fish and Wildlife Service funds and administers the operation, maintenance and evaluation of LSRCP hatcheries and related facilities, using Congressional appropriations also reimbursed by Bonneville. Hatcheries and satellite facilities are operated by the Fish and Wildlife Service and by cooperating agencies, primarily the three state agencies, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, and Washington Department of Fish and Wildlife. Three recently completed fall chinook facilities on the Snake and Clearwater rivers (Pittsburg Landing, Big Canyon, Capt. John's Rapids), although part of the LSRCP program, have operations and evaluation costs directly funded by Bonneville under the Council's fish and wildlife program. All three facilities are operated by the Nez Perce Tribe in conjunction with the Washington Department of Fish and Wildlife. The Confederated Tribes of the Umatilla Indian Reservation and Shoshone-Bannock Tribes also participate as cooperators in operation and management decisions, and all cooperators except the Shoshone-Bannock Tribes receive funds to conduct monitoring and evaluation studies.

The purpose of the LSRCP has been to replace lost salmon, steelhead and trout fishing opportunities, with management goals focused on replacing the loss of returning adult steelhead and salmon, rather than on releasing a given number of smolts. The adult return goals have been based on estimates of salmon and steelhead adult returns to the Snake River Basin in the years prior to the construction of the four lower Snake River dams — adult returns of 18,300 fall chinook, 58,700 spring and summer chinook, and 55,100 steelhead to and above the area of the dams. The production release goals for spring, summer and fall chinook and steelhead (as well as rainbow trout) are in the range of 10-15 million juveniles per year, although broodstock collection problems and other factors limit the ability to meet these goals. Production estimates for 1999 are closer to 10 million juveniles. No sockeye or coho are produced under the LSRCP authorizing legislation, even though these fish existed in the river and its tributaries prior to construction of the dams.

With the exception of fall chinook in the lower Snake River mainstem and steelhead in Idaho, production target have been met. Meanwhile, naturally spawning salmon and steelhead runs in the Snake have declined to the point of endangered species listings. As an indication of the decline, one of the key issues for the LSRCP is whether these facilities can be transformed to be of use in supplementation efforts or even in conservation/captive propagation efforts while addressing productivity limitations.

In its recent Biological Opinion, the National Marine Fisheries Service concluded that hatchery operations in the Snake, including LSRCP operations, are not likely to jeopardize the continued existence of listed Snake spring/summer chinook, fall chinook or sockeye. The Fisheries Service did conclude, however, the production was likely to jeopardize the continued existence of listed Snake steelhead and lower Columbia River steelhead. The problems identified were the same as in the lower Columbia — release strategies for hatchery steelhead that result in predation and competition with listed steelhead juveniles and, especially, the continued use of non-endemic steelhead stocks in the production facilities, which has the potential to affect listed steelhead through genetic introgression. The reasonable and prudent alternatives identified to avoid jeopardy were also similar (as were relevant conservation recommendations) — transitions to locally adapted stocks, an end to releases of non-endemic stocks, management of hatchery adult stray rates to less than 5 percent of the annual natural population size, restrictions on the size of juvenile releases and other strategies to minimize predation and competition. The same concerns about non-endemic stocks, stray rates and release strategies were present with regard to impacts on listed spring/summer and fall chinook, but the Fisheries Service concluded that recent developments to address these concerns made a jeopardy finding unnecessary.[25]

Dworshak Dam mitigation. Separate from the LSRCP is a production program to mitigate for steelhead and resident trout losses caused by the construction of Dworshak Dam, blocking the North Fork Clearwater River in Idaho. For this purpose, the Corps of Engineers funded the construction of the Dworshak National Fish Hatchery and the USFWS receives funds via the Corps to operate the facility, all reimbursed by Bonneville (the Dworshak hatchery also produces spring chinook as part of the LSRCP). The primary goal of fishery mitigation at Dworshak has been to preserve artificially the North Fork steelhead run, as the dam completely blocked the North Fork, a mitigation goal set at returning 20,000 adult steelhead to the Clearwater River. Production goals are to release approximately 1.2 million smolts at the hatchery and another 1.1 million in Clearwater tributaries. Adult steelhead returns to the hatchery have ranged from 1,988 to 43,942 since 1972, and the goal of 20,000 fish has been attained in eight of 25 years of operation. Dworshak steelhead operations were included in the Snake River steelhead production operations that the National Marine Fisheries Service concluded were likely to jeopardize continued existence of the listed Snake River steelhead. However, the Clearwater B-steelhead reared at the Dworshak hatchery are included in the steelhead ESU under ESA but are classified as non-essential for recovery. This classification is because of the North Fork Clearwater habitat of the B-steelhead is no longer available as a result of the construction of Dworshak Dam, and the hatchery has maintained an adequate number to maintain gene pool.

Warm Springs National Fish Hatchery. Authorized in 1966 and operational by 1978, the Warm Springs hatchery is located on the Warm Springs River in Oregon and funded and operated by the U.S. Fish and Wildlife Service. (This is one of the few federally funded anadromous production facilities in the basin outside of the Mitchell Act facilities that are not directly or by reimbursement funded by Bonneville.) The hatchery, projected in 1999 to release 750,000 spring chinook into the Warm Springs River, has suffered from an inadequate water supply and fish health problems.

Willamette River mitigation. Congress authorized the Corps of Engineers to build a number of dams on tributaries of the Willamette, blocking or causing serious damage to anadromous and resident fish runs. These include Cougar and Blue River dams on the McKenzie River, Detroit and Big Cliff dams on the North Santiam River, Green Peter and Foster Dams on the South Santiam, and Lookout Point and Dexter Dams on the Middle Fork of the

[25] For details on the status of the LSRCP program, see the publication of the papers from the *Lower Snake River Compensation Plan Status Review Symposium, 1998*, hosted by the Fish and Wildlife Service, and the *Independent Scientific Review Panel; Review of the BPA Reimbursable Account Programs in the Columbia River Basin, 1999*.

Willamette. Anadromous fish mitigation is provided by the Leaburg, McKenzie, Marion Forks, South Santiam, and Willamette hatcheries, producing over 5 million spring chinook and steelhead smolts for release at various sites in the Willamette Basin. The Oregon Department of Fish and Wildlife operates the hatcheries under a cooperative agreement with the Corps, and the Corps provides a majority of the funding while the State of Oregon also provides a substantial portion of the funds. The Corps funded portion is reimbursed by the Bonneville Power Administration.

The Biological Opinion recently released by the National Marine Fisheries Service did not implicate these Willamette mitigation hatcheries in the jeopardy conclusion on lower Columbia steelhead. However, the Fisheries Service just listed the wild spring chinook and steelhead runs in the Willamette, as well as lower Columbia chinook, and the Biological Opinion will have to be revised to analyze the effects of hatchery production in the Willamette on these runs.

Northwest Power Act/Council's fish and wildlife program. The most recent attempt to adapt artificial production techniques to the changing needs in the basin has been through the Council's fish and wildlife program. The Northwest Power Act requires the Council to develop a Columbia River Basin Fish and Wildlife Program consisting of measures to protect, mitigate and enhance fish and wildlife affected by the construction, operation and management of hydroelectric facilities in the basin. The basin's tribes and state fish and wildlife agencies, often acting in various combinations of co-managers, have used the Council's fish and wildlife program to provide mitigation for hydropower effects in part by developing and obtaining funding for new artificial production programs in the subbasins above Bonneville Dam, to increase harvest opportunities and as part of an experimental attempt to supplement naturally spawning populations. The Council's fish and wildlife program conceives of this effort as a coordinated habitat restoration/production program in which artificial production efforts are supposed to be tied to habitat improvements. The purpose is to increase natural production capacity by introducing fish from the artificial production facilities. All Council program projects are funded by Bonneville. These efforts have included the following:

Hood River Production Project: The Hood River production project is a joint program of the Confederated Tribes of the Warm Springs Reservation of Oregon to rebuild spring chinook and steelhead populations in the Hood River through hatchery and acclimation facilities on that river and through use of production facilities already developed in the Deschutes River. Releases projected for 1999 include 125,000 spring chinook, 30,000 summer steelhead and 60,000 winter steelhead.

Yakima/Klickitat Fisheries Project: This is a Yakama Nation/Washington Department of Fish and Wildlife project whose main goal is to rebuild salmon runs in the Yakima River, which dropped from historic levels estimated as high as 900,000 adult fish per year to fewer than 5,000, as well as to increase populations in the Klickitat and other streams important to the Yakama Nation. The main focus has been the multi-million-dollar Cle Elum Supplementation and Research Facility and associated acclimation facilities, intended to be a large-scale test of spring chinook supplementation, with projected releases of spring chinook juveniles of up to 810,000. The National Marine Fisheries Service produced a Biological Opinion in 1996 on proposed 1997-2001 Cle Elum spring chinook operations. The Yakama Nation has also begun or is planning fall chinook and coho production in the Yakima, Klickitat and other streams, in part using fish from Mitchell Act hatcheries. Significant funding for habitat work in the Yakima associated with the supplementation effort has also come from the Council's program and other sources.

Umatilla Hatchery complex: Hatchery propagation in the Umatilla River is funded under the Council's fish and wildlife program as part of a coordinated habitat restoration/flow improvement/production effort to restore spring chinook, fall chinook, coho salmon and summer steelhead populations in the Umatilla subbasin. Salmon runs in the Umatilla have been gone since as far back as 1920, and the steelhead were at very low numbers when the program began. The Umatilla hatchery and six satellite facilities provide juvenile acclimation/release and adult holding/spawning. ODFW operates the hatchery, and the Confederated Tribes of the Umatilla Indian Reservation operate the satellite facilities. Additional facilities are proposed, including a juvenile coho and fall chinook acclimation/release facility, and a hatchery on the South Fork Walla Walla River that would, in part, produce spring chinook smolts for release at satellite facilities in the Umatilla subbasin. Projected production for 1999 includes 810,000 spring chinook, 3.162 million fall chinook, 1.5 million coho, and 150,000 steelhead.

Northeast Oregon Production Facilities, Grande Ronde and Imnaha subbasins: As part of what is called the Northeast Oregon Hatchery (NEOH) program, the Oregon Department of Fish and Wildlife, the Umatilla Tribes, and the Nez Perce Tribes have been planning and implementing supplementation programs for spring chinook and steelhead in the Grande Ronde and Imnaha subbasins, also the scene of Lower Snake River Compensation Plan production. The Grande Ronde spring chinook runs declined so severely that the Grande Ronde production initiative project has transformed into a captive propagation effort — facilities at the Bonneville Hatchery and elsewhere have been constructed or adapted so that spring chinook can be reared in captivity for later release into the Grand Ronde basin. The Grande Ronde has also been a Model Watershed under the Council's fish and wildlife program, the scene of significant funding for watershed planning and rehabilitation activities to accompany natural and artificial production efforts.

Northeast Oregon Production Facilities, Walla Walla River: Planning is under way to develop production and acclimation facilities to be used to help restore extirpated spring chinook and enhance the depressed steelhead populations in the Walla Walla, an effort led by the Umatilla Tribes, in conjunction with the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife. The project in concept also includes stream habitat/watershed enhancement, structural fish passage improvement and enhanced instream flow.

Salmon River Supplementation: The Council's program funds a number of supplementation studies and activities by the Idaho Department of Fish and Game, the Nez Perce Tribe, the Shoshone-Bannock Tribes and the Fish and Wildlife Service to evaluate whether artificial production can be used to boost the rapidly declining, listed spring/summer chinook and steelhead populations in the Salmon basin. Most of the projects are small-scale research, monitoring and evaluation efforts. The supplementation efforts in the Salmon overlap with the LSRCP production, and as the LSRCP facilities and efforts begin to transform in part in the direction of supplementation and conservation, some of the LSRCP costs and activities are coming into the Council's program. And as in the Grande Ronde, in part the effort has transformed into a conservation/captive propagation program, in which spring chinook are or will be reared in captivity for later release into the Salmon basin. The Salmon is also the basin where, in the summer of 1991, the Shoshone-Bannock Tribes, Idaho Fish and Game, the National Marine Fisheries Service and others initiated an emergency captive broodstock program to try to prevent Snake River sockeye in Redfish Lake from extinction.

Nez Perce Tribal Hatchery/Clearwater River: The Council's fish and wildlife program calls for the Nez Perce Tribe to develop a number of small-scale production facilities under the umbrella of a single program for fall and spring chinook supplementation in the Clearwater River. The multi-million-dollar project is in the final design stage and is nearly ready for review and approval as to whether it will shift into construction and production. The Nez Perce Tribal Hatchery as planned will consist of two central incubation and rearing facilities, and six satellite rearing facilities. Maximum production goals are 768,000 spring chinook and nearly 3 million fall chinook juveniles, although initial production will be far below the maximum. The National Marine Fisheries Service completed a Biological Opinion in 1997 for Nez Perce Tribal Hatchery operations in 1998-2002. The Nez Perce Tribe is also working on a project to restore coho to the Clearwater, with initial funding provided by the Bureau of Indian Affairs for the release of approximately 1 million coho juveniles, taken from lower Columbia hatcheries and reared at existing facilities in the Clearwater. The Clearwater River has also been a focus watershed for habitat improvements under the Council's program, which links habitat improvements to artificial production.

Select Area Fisheries Evaluations (SAFE): This is a terminal fisheries project in the lower Columbia River (Young's Bay and other sites) included in the Council's program, funded by Bonneville and operated by the Clatsop Economic Development Council and the Oregon Department of Fish and Wildlife to produce fall chinook, coho and spring chinook. Projected releases in 1999 total nearly 3 million juveniles. The National Marine Fisheries Service produced a Biological Opinion on the SAFE program in 1998.

Federally funded resident fish production

Many of the federal programs have significant resident fish production components as well, including the Lower Snake River Compensation Plan, Dworshak hatchery mitigation, Willamette River mitigation, and especially the Council's fish and wildlife program. Focused both on rivers affected by hydropower operations and on the reservoirs created by dam construction, these programs include the production of various types of trout for the purpose of supporting fisheries and, in some cases, to try to supplement naturally spawning production; kokanee production efforts; bass production in some reservoirs; investigations throughout the basin about using artificial production techniques to help preserve and rebuild white sturgeon populations, and more. Here too we find questions about the efficacy of this production, such as raised by the kokanee production efforts in Flathead Lake and Lake Pend Oreille, and significant concerns about impacts of artificial production and the introduction of non-native species on native stocks, including listed species such as bull trout.

Examples of these resident fish production programs include:

Colville Tribal Fish Hatchery. The Colville Tribal Fish Hatchery Project involves the production of 22,679-kg (50,000 lbs.) of resident fish that include brook trout, rainbow trout and lahontan cutthroat trout. All fish are released into reservation waters, including boundary waters, in an effort to provide a successful subsistence/recreational fishery for Colville Tribal members as well as a successful non-member sport fishery as partial mitigation for anadromous fish losses above Chief Joseph and Grand Coulee Dams.

Lake Roosevelt Rainbow Trout Net Pens. The Lake Roosevelt Rainbow Trout Net Pens Project enhances the Lake Roosevelt fishery by rearing up to 500,000 Rainbow Trout annually. The effort uses up to 42 volunteers to build, maintain and operate 34 net pens on the reservoir. The goal is to provide up to 190,000 harvested adult rainbow trout annually. This program is monitored by the Lake Roosevelt monitors and strategies are worked out with the Lake Roosevelt Hatchery Technical Committee. The Lake Roosevelt Trout Net Pens Project is part of the Spokane Tribal Hatchery and is operated in conjunction with the Washington Department of Fish and Wildlife's Sherman Creek Hatchery, and with management recommendations from the Lake Roosevelt Monitoring/Data Collection Program.

Kootenai River White Sturgeon and Conservation Aquaculture Study. This is an adaptive management effort to use artificial production techniques to assist the ESA-listed Kootenai River white sturgeon.

Hatcheries associated with FERC-licensed hydropower projects

In addition to federally funded production programs, privately owned and public electric utilities produce millions more fish as mitigation for the impacts of their FERC-licensed dams. While these facilities are funded by the utilities, with minor exceptions they are all operated by state fish and wildlife agencies. A partial list includes production facilities funded by:

- Idaho Power Company (the Oxbow, Rapid River, Niagara Springs and Pahsimeroi hatchery complexes in the Snake and its Salmon River tributary, operated by the Idaho Department of Fish and Game and producing spring and fall chinook and steelhead, mitigating for the impact of Hells Canyon Complex);
- PacifiCorp (Lewis and Speelyai hatcheries produce spring chinook and coho salmon and the hatchery below Merwin Dam produces steelhead, sea-run cutthroat trout and rainbow trout, all to mitigate the impact of the dam. The hatcheries are operated by the Washington Department of Fish and Wildlife);
- Portland General Electric (helps fund production of spring chinook and steelhead at the Clackamas Hatchery in mitigation for the Little Sandy Dam and Clackamas River projects and spring chinook and steelhead at the Round Butte Hatchery in mitigation for the Round Butte and Pelton projects on the Deschutes River. The City of Portland, NMFS and State of Oregon also fund fish production at the Clackamas Hatchery.)
- Washington Water Power (helped to fund the Cabinet Gorge Kokanee Hatchery, producing kokanee for Lake Pend Oreille, and funds rainbow trout stocking in the Spokane River in mitigation for its Spokane project);
- Douglas County PUD (hatchery facility producing steelhead, spring chinook, and sockeye in the mid-Columbia region and in the Methow tributary, for Wells Dam mitigation);

- Chelan County PUD (hatchery production of coho, yearling chinook and steelhead as Rocky Reach Dam mitigation, and kokanee production as Lake Chelan project mitigation);
- Grant County PUD (Priest Rapids Hatchery and spawning channel production of fall chinook as mitigation for Priest Rapids and Wanapum dams);
- City of Portland (helps fund production of spring chinook and steelhead at the Clackamas Hatchery to mitigate for its Bull Run projects. The Clackamas Hatchery is also funded by PGE, NMFS and the State of Oregon.);
- Cowlitz County PUD (sharing the cost of some of the PacifiCorp production, as mitigation for a power plant it owns at the outlet of Swift Reservoir);
- Tacoma Public Utilities (funding hatchery producing spring and fall chinook, coho, steelhead, sea-run cutthroat trout and resident trout, in mitigation for Mayfield and Mossyrock dams on the lower Cowlitz River).

Because of the potential these programs have to adversely affect listed fish populations, the National Marine Fisheries Service analyzed them in its recent Biological Opinion (as part of the non-federal production activities by the state fish and wildlife agencies), implicated certain of these programs in the steelhead jeopardy findings, prescribed conditions on incidental take statements to protect listed steelhead and chinook populations, and suggested additional conservation recommendations.

Production facilities operated by state fish and wildlife agencies that are not federally financed or associated with FERC-licensed project mitigation

The state fish and wildlife agencies operate many of the federally financed production facilities, under all the programs (Mitchell Act, Lower Snake River Compensation Plan, Corps' mitigation hatcheries, Council's fish and wildlife program). They also operate most of the production facilities associated with FERC-licensed projects. But the state agencies also operate hatcheries in the basin that are not federally funded or linked to FERC-licensed projects, projects funded by the states themselves and developed primarily to address declining fisheries. As with the FERC-licensed hatcheries, because of the potential these programs have to adversely affect listed fish populations, the National Marine Fisheries Service analyzed them in its recent Biological Opinion, implicated some of these programs in the steelhead jeopardy findings, prescribed conditions on incidental take statements to protect steelhead and chinook populations, and suggested additional conservation recommendations.

Examples of these types of facilities and programs include three funded by the State of Oregon and operated by the Oregon Department of Fish and Wildlife:

- Roaring River Hatchery (producing summer steelhead for release into the North Santiam River);
- Oak Springs Hatchery (steelhead and resident trout production at a facility on the Deschutes River, producing various stocks for release in the Clackamas, Hood, Santiam, Sandy and other rivers — a hatchery implicated in the problems associated with the use of non-endemic steelhead stocks that pass into natural production areas and with the release of juvenile hatchery steelhead that compete with listed steelhead,

but also in the forefront of steelhead production programs that are trying to match production stocks and techniques to naturally spawning populations in some areas);

- Clatsop Economic Development Council and other lower Columbia production (Oregon funds coho and fall chinook production activities for Young's Bay and other areas in the lower river to supplement the Mitchell Act and Bonneville-funded programs).

Artificial production policies and activities in transition since the 1980s

As noted in the text, the last decade has seen myriad efforts to review Columbia basin production policies and activities and to try to reform them. Many of these efforts were initiated and funded through the Council's fish and wildlife program. The critical issues in these studies have included how to improve the survival of hatchery fish, whether and how production activities can play a role in providing significant and widely spread harvest opportunities throughout the basin, and whether we can do these things while we also act to protect and rebuild naturally spawning and wild runs in as many river reaches as possible.

Several factors converged in the mid- to late-1980s to begin the transition in production policy. These need to be highlighted here, as the same factors will continue to play a significant role in the continuing transition of artificial production activities and policy. One source for change came out of the *United States v. Oregon* harvest litigation in federal court. State/federal/tribal agreements on production policy within the *U.S. v. Oregon* framework, in conjunction with the Council's fish and wildlife program, became the driving vehicle for two of the critical issues forcing a change in existing production policy — to widen the harvest opportunities provided by artificial production and to attempt to use artificial production techniques to try to rebuild naturally sustaining populations. *U.S. v. Oregon* began as and remains primarily a forum for resolving disputes over in-river harvest allocation. But production activities became part of the considerations as the state, federal and tribal parties recognized that treaty fishing rights could also be supported by increasing the numbers of fish upriver, above Bonneville Dam. After a series of yearly and five-year allocation agreements or decisions, in 1988 the parties to the litigation developed, and the court approved, the Columbia River Fish Management Plan. The goal of the Management Plan was "to rebuild weak runs to full productivity and fairly share the harvest of upper river runs." In the area of production, the Management Plan called for "agreed-to production-oriented actions to achieve the goal of rebuilding upriver anadromous runs," so as to "assure that rebuilding and harvest allocation objectives are achieved concurrent with restoration of the runs." One part of this commitment was the hypothesis, favored especially by the tribes over the last decade, that artificial production could be used to supplement natural production if combined with habitat improvements, and thus rebuild naturally spawning upriver runs.

The Management Plan contemplated that the main vehicle for this effort was to be the development by the fish and wildlife managers of subbasin-by-subbasin harvest and production plans for the tributaries above Bonneville. This led to an extensive subbasin planning effort that became part of the Council's 1987 fish and wildlife program amendment process. The co-managers developed draft subbasin plans, but the effort eventually ran afoul of developing Endangered Species Act concerns, as described below, and never reached the intended conclusion of subbasin plans formally adopted into the Council's program. Pending the development of a comprehensive set of subbasin plans, the Management Plan also included a list of specific production objectives and actions utilizing artificial propagation to be undertaken during the Plan's tenure. Many of these production actions were already in master planning as part of the Council's fish and wildlife program (e.g., the plans for an experimental supplementation production program in the Yakima basin). Following the adoption of the Management Plan, most of the conflicts, disputes and agreements regarding production that have been part of the *U. S. v. Oregon* process have involved specific disputes concerning the use of hatchery fish to supplement natural production. In general, the production agreements under the Management Plan moved into the Council's program to become the core of the production planning and activities now funded under that program.

A third factor forcing change in existing production policy has been concern over the adverse impact of hatchery production on wild fish. These issues were not absent during the development of the Management Plan and the Council program's production initiatives, but the driving vehicle for forcing this issue squarely into the core of hatchery policy has been the Endangered Species Act listings. The listings began in the Snake basin at the turn of the decade and have now spread to the whole basin — now affecting both the lower river home of the main harvest mitigation production and the upper basin areas that are the site of the reprogramming and supplementation efforts. ESA consultations have forced hatchery managers to evaluate and reach conclusions as to whether existing or proposed production programs jeopardize the continued existence of listed stocks through health impacts, competition and other ecological interactions, genetic impacts, and other considerations. Thus existing hatchery programs, especially in the Snake (e.g., the Lower Snake River Compensation Plan activities) came under this type of review. The review of existing programs began in the Snake basin (e.g., the Lower Snake River Compensation Plan activities), but has increased and will only increase and broaden further with the recent additional listings. The LSRCP program staff has worked very closely with NMFS staffs in developing production criteria and suggested changes to reduce or eliminate risks of these programs to listed species. Coming under even greater scrutiny have been the tribal/state proposals to use new artificial production initiatives to try to help rebuild weak naturally spawning populations. The critical fish population demographics that caused some to turn to artificial production techniques as part of the rebuilding solution caused others to worry greatly that new artificial production efforts could fatally undermine the incredibly vulnerable wild populations.

The wild fish considerations embodied in the ESA listings were the major factor preventing the subbasin planning process from coming to a conclusion, as the co-managers could not agree in a number of basins how much risk to accept in planning for new production. Planning work on specific supplementation proposals also slowed to a crawl, as the agencies and tribes worked to address the wild fish and ESA concerns, dampen the extent of the risk presented by each project, and provide greater assurances that artificial production could be a boost and not a hindrance to natural production.

The logjam partially broke in the mid-1990s, as federal agency ESA review finally cleared a number of supplementation initiatives to proceed under the Council's program as high-priority experiments. Ironically, at the same time NMFS and others began to investigate using the most intrusive of artificial production techniques — captive broodstock — to try to save or conserve populations on the verge of extinction, including Snake River sockeye and spring chinook in the Grande Ronde and Salmon river tributaries of the Snake.

Policy and operational review and reform through the Council's fish and wildlife program

All of the federal and non-federal production programs in the basin, including Mitchell Act and the Lower Snake River Compensation Plan program have, to varying degrees in recent years tried to come to terms with these four factors — how to reform operations and policies to improve hatchery fish survival, broaden harvest opportunities, protect wild populations, and if possible assist in rebuilding naturally spawning populations. But the Council's Columbia River Basin fish and wildlife program has attempted to embody all the factors, probably because it is the most recent and is the result of policy recommendations developed by the agencies and tribes over the last 15 years while grappling with these very questions. The program's twin goals are to "double the runs" (i.e., increase abundance for increased harvest opportunities) while protecting biological diversity. New artificial production initiatives are one of the key activities identified in the Council's program for increasing the numbers for harvest, moving those harvest opportunities upriver, *and*, if connected with habitat restoration, rebuilding dwindling or extirpated naturally spawning populations in the tributaries while being consistent with policies to protect wild fish — thus, if all goes well, protecting and increasing biological diversity. The program's production and habitat provisions represent confidence in the possibility of an intertwined habitat and production effort that can protect and increase natural production partly through a wide array of small- and not so small-scale supplementation experiments.

The individual planning efforts that have accompanied the specific, individual production initiatives in the Council's program have yielded an extensive body of analysis about the problems and opportunities presented by the interaction of artificial and natural production. So has the ESA/wild fish analyses and Biological Opinions that the federal agencies and others have had to produce, beginning with a genetic review by various federal agencies involved in production programs and a genetics "team" established under the Council's program that produced a set of guidelines for artificial production intended to protect wild populations from adverse genetic impacts. (Attachment 3 is a list of the major policy and scientific documents produced in the last ten years.) But given the nature of the Council's program, in which all of the specific production initiatives are predicated on a conceptual foundation of experimenting with artificial production to assist rebuilding of naturally spawning populations, the Council, the federal and state agencies, and the tribes realized the need in the early 1990s for a more systematic approach to analyzing these issues. If supplementation proposals under the fish and wildlife program were to proceed in the face of ESA listings and increasing concerns for impacts on wild fish, what was needed was a systematic review of the dilemma and a set of guidelines for proceeding that, in theory at least, could increase to an acceptable level the chance that artificial production techniques could benefit natural production without undue harm to existing wild populations.

Out of these considerations came the Regional Assessment of Supplementation Project (RASP), a multi-year, multi-agency analytical effort called for by the Council's program and funded by Bonneville. The final report in 1992, produced by agency personnel and subject to independent scientific review, provided a background description of the supplementation concept; a discussion of the elements of supplementation theory and the uncertainties inherent in the supplementation experiment; model planning guidelines, objectives, actions and performance standards for supplementation initiatives; and a plan for regional coordination of research, monitoring and evaluation of supplementation actions. It was partly on the basis of the generally well received RASP effort, and the revision of individual supplementation initiatives to be consistent with the RASP guidelines, that the National Marine Fisheries Service (and others) agreed in 1996 that a number of supplementation initiatives in the Council's program could proceed to implementation.[26]

The RASP guidelines applied only to the new supplementation initiatives, representing just a tiny fraction of the artificial production activities in the basin. So, the Council's program also recognized the need for a broader review of production policies and activities across the basin, to see whether and how production programs and individual hatcheries could be evaluated and reformed in a systematic way to deal with the critical factors now at play in the basin. This was the genesis for the formation of the inter-agency Integrated Hatchery Operations Team (IHOT), funded by Bonneville under the Council's program. The Council's program called on the fishery managers "and other experts as needed," "in consultation with appropriate specialists in genetics," to develop "basinwide guidelines to minimize genetic and ecological impacts of hatchery fish on wild and naturally spawning stocks." In the development of these guidelines, IHOT was to include "approaches to basinwide coordination of hatchery production" to reduce impacts, and monitoring and evaluation of hatchery and wild stock interactions. IHOT was to review existing production policies and then develop and update "regionally integrated policies for management and operation of all existing and future hatcheries in the basin," — policies to "be monitored for consistency with the goal of increasing sustained production while maintaining genetic resources."

The program specified that policies developed by IHOT had to include elements addressing fish health, genetics, ecological interactions, hatchery performance standards, and regional hatchery coordination, with standards specified in the program for each element. Moreover, the program called for IHOT to submit a plan to the Council for implementing these policies and to plan and oversee independent audits of hatchery performance for consistency with guidelines and policies developed by IHOT.[27] The program's charge to IHOT strikingly resembles the Senate committee's directive to the Council to "conduct a thorough review" of production programs in the basin, to draw on the assistance of the state and federal agencies and tribes in conducting this review, and to recommend "a coordinated policy" for the future operation of hatcheries and "how to obtain such a coordinated policy."

Pursuant to the program's charge, by late 1994 IHOT produced *Policies and Procedures for Columbia Basin Anadromous Salmonid Hatcheries*, containing policy elements, performance standards, performance measures, and evaluation guidelines. The policies covered the areas specified in the program, including policies on regional hatchery coordination, hatchery performance standards, fish health, ecological interactions and genetics. IHOT also produced operations plans for anadromous fish production facilities in Idaho, Washington and Oregon, and set in motion independent audits of most all of the anadromous fish hatcheries in the basin, using performance measures developed in the policy document. *See A Summary of Hatchery Evaluation Reports (NPPC, July 1998).* The audits describe deficiencies in hatchery operations when measured against the performance standards and recommend improvements to address these deficiencies. The extent of the improvements recommended is daunting, and the audit recommendations mostly sit and await further consideration by policymakers. The IHOT

[26] *See Supplementation in the Columbia Basin, Final Report, Bonneville Project No. 85-62, 1992.*

[27] *Columbia River Basin Fish and Wildlife Program, Section 7.2A, 7.2B.*

policies and audits focused mostly on reforming practices in the hatcheries and in release techniques, with the aim to improve the survival of the hatchery releases and to try to avoid harmful immediate interactions. Deciding whether to undertake some of the improvements recommended will require further consideration of broader interactions, of what we really want artificial production facilities to do, and what priorities we have for limited funds.

As the new production activities in the Council's fish and wildlife program moved from planning into construction and implementation, Bonneville's direct fish and wildlife expenditures to implement the program have increased, as has the proportion of that budget spent on artificial production. Partly out of lingering concern for the possible effects, and the high costs, of these state and tribal programs, Congress amended the Northwest Power Act in 1996 to add independent science review, public review, and Council recommendations into Bonneville's decisions on fish and wildlife project funding. In the first two years of the new funding review process, the Independent Scientific Review Panel created by the amendment has deferred significant recommendations on the artificial production initiatives in the fish and wildlife program pending the completion of the Artificial Production Review. But the Panel believes supplementation should be conducted in small-scale experiments and is uneasy with the extent to which these experiments have grown in number and size under the program. The Panel's recommendations for project funding in Fiscal Year 2000 revisited the debates over these newest production efforts in the basin.

Vehicles for implementing developments in production policy — annual funding reviews and Endangered Species Act reviews

The funding review process that began with the Council's fish and wildlife program, described just above, is and will be one of the two main vehicles for implementing operational reforms in production policy. Recent conference committee language from Congress has extended the independent scientific/public/Council review procedure to all of the Bonneville fish and wildlife budget. The review process thus encompasses all of the federally funded production programs in the basin except the Mitchell Act programs (and a few stray facilities, such as the Warm Springs Hatchery). If we have the political will, production programs can be held to a rigorous set of performance standards as a prerequisite to funding, standards designed to improve survival, protect wild runs, and help rebuild naturally spawning populations, with compliance evaluated in part by independent technical panels — while making funds available to assure that the facilities the region desires can in fact be revised to meet the standards. For the purposes of providing a coordinated and consistent review of production programs against a set of standards, Congress and the region should consider incorporating the Mitchell Act programs (and the other exceptions) into the same funding review process.[28]

As demonstrated recently, Endangered Species Act review by means of biological opinions and incidental take reviews is another existing tool for realizing reforms in production actions, especially for one of the areas of concern — minimizing impacts to wild fish populations. The ESA reviews apply to all the major production programs in the basin, whether part of the funding review process described above and whether federal or not, allowing for a consistent and coordinated application of standards across the basin. And because we now have listings of different types of anadromous and resident fish in every part of the basin, program

[28] *See* the implementation recommendations in Part III of this report.

reviews to evaluate impacts to listed fish are really surrogates for the general issue of impacts to all naturally spawning populations. Because it is essentially impossible to operate a production program in the face of a "jeopardy" opinion, or without an incidental take permit, the biological opinions and permits have real power for implementing needed changes or at least for preventing likely harmful operations. They carry no funding to make changes happen, but they do provide leverage and priorities in deciding on funding.

Since 1995 the National Marine Fisheries Service has issued a dozen Biological Opinions on specific artificial production proposals and on artificial production programs in the aggregate, culminating in the March 1999 Biological Opinion on Artificial Propagation in the Columbia River that reviewed all federal and major non-federal salmon and steelhead production programs for impacts to the six types of fish then listed and that declared a jeopardy situation for the first time. The nearly simultaneous listing of five more species in the basin will require a further elaboration of the ESA analysis in a revised Biological Opinion. Moreover, in order to prepare itself for these biological reviews, the Fisheries Service has had to develop a number of useful technical memoranda, policy statements, and artificial propagation and genetics guidelines — another spur to wider policy reform.

Forums for revisiting decisions on whether, when, where and why to use the artificial production tool — including the Columbia River Fish Management Plan renegotiations, Council fish and wildlife program amendment process, multi-species recovery planning under the ESA, and the Multi-Species Framework analytical process.

The annual funding reviews and the ESA reviews of artificial production are and will be most useful in achieving changes in hatchery practices. They are not the best policymaking vehicles for deciding whether we want hatcheries to begin with, and where and for what purpose. As noted in the text, what the region needs are medium-term to long-term decisions and agreements at the basinwide *and* the subbasin or subregional (or ecological province) levels on what we want to accomplish in terms of fish and wildlife recovery in the basin as a whole and in each subbasin or subregion, and what strategies seem most promising for rebuilding naturally sustaining populations to healthy, harvestable levels — decisions and agreements based in the best available scientific knowledge of how river ecosystems function and how fish and wildlife populations survive and interact. Part of that decisionmaking process will have to include decisions on whether and how to use the artificial production tool in each subbasin as part of these strategies. Only when these larger questions are revisited and determined for some period of time can we definitively decide how best to invest our funds to reform hatchery practices.

The planning process described above is exactly what the system and subbasin planning process of the late 1980s was intended to achieve. That process foundered because of significantly changing circumstances (especially the first ESA listings) right as the process and the draft subbasin plans were nearing completion. The need still exists, and the time may be ripe to return to the task.

There are three planning processes underway or soon to be initiated that could be vehicles for making these larger determinations and for how artificial production should fit within a broader recovery framework. The challenge will be to make sure that these processes do in fact engage the right questions *and* that the processes work in concert, not at cross purposes.

The first is the renegotiation of the Columbia River Fish Management Plan under the auspices of the federal district court as part of the *U.S. v. Oregon* harvest litigation. The Management Plan expired at the end of 1998, although the court extended the application of the plan. The federal, state and tribal participants continue to negotiate toward a revised set of population rebuilding objectives based in part on an understanding of a revised set of production objectives and expectations.

The first Management Plan agreement led directly to a Council fish and wildlife program amendment process and the system and subbasin planning process. The renegotiated agreement could do the same. The Council will begin a program amendment process in December 1999, following completion of the Multi-Species Framework Project. The amendment rulemaking is the second possible vehicle for revisiting the basic decisions about the use of hatcheries. A plausible outcome of that program amendment process could be a policy and biological framework, for the system as a whole and at least down to the ecological province level, on recovery goals and objectives, including decisions (or criteria to guide decisions) on whether, where, why and how to use the artificial production tool to try achieve these objectives. If completed and appropriately structured, the product of the Management Plan negotiations could once again feed as a recommendation into the program amendment process. But the dynamics are different than in the mid-1980s, with ever-growing ESA concerns, a fish and wildlife budget agreement, independent science review procedures for implementing the program, and especially a growing scientific and policy emphasis on ecological processes and not technological processes to rebuild fish and wildlife populations. The Management Plan renegotiations cannot take place in a vacuum — the negotiations and the results have to be sensitive to and coordinated with these other elements. The fish and wildlife program has its own limitations, especially the too-narrow focus on hydropower system mitigation in a basin with a multi-faceted problem, and the Council's lack of direct implementation authority. A fish and wildlife program amendment process that is not well coordinated with the other planning processes risks being irrelevant.

The third possible vehicle for addressing these larger questions about the use of artificial production could be multi-species recovery planning for the Columbia River Basin under the Endangered Species Act. The National Marine Fisheries Service is focused at present on producing Biological Opinions that focus on particular actions that may threaten the existence of listed fish. But given the magnitude of the ESA problem after the most recent set of listings, the potential exists for taking a systemwide planning approach to recovery that could integrate a host of elements, decide on recovery objectives and approaches, and evaluate the use of the artificial production tool to meet these objectives. Like the other planning processes, ESA recovery planning has peculiarities and limitations, including a defined approach to recovery of self-sustaining population numbers that may be far too low to be relevant to what people want out of fish populations in the basin, and a focus on the weakest stocks when real systemwide recovery may depend on building from protected strong stocks. Thus ESA recovery planning without coordination and shared analysis with the other planning process is also just as likely to be largely irrelevant or to get cross-ways with the other planning processes and the identified needs in the basin.

To bring these planning process into a shared analytical and substantive focus, based on the best available thinking in ecological science, the Council recommends linking them all to the Multi-Species Framework process. The Framework process grew out of recent reviews of Columbia basin fish and wildlife activities that highlighted the need for a fish and wildlife restoration effort based upon a framework of fundamental ecological principles, with the river (and relevant parts of the Pacific Ocean) understood as a system of interacting biological and physical components (the ecosystem). The Council joined with the other entities in the basin precisely to provide a coordinated and unified biological and social-economic analysis that will help decisionmakers define for more than the short-term a set of goals, ecological objectives and strategies for fish and wildlife recovery in the basin as a whole and at finer levels of geographic scale. Part of that analytical process will include, it is hoped, evaluating the efficacy of artificial production techniques in helping to meet broader defined recovery goals and objectives, which will in turn allow for informed decisions on whether and how to incorporate the use of the artificial production tool into basin and sub-basin objectives. The Council considers its final report on the Artificial Production Review to be consistent with and a contribution to the Multi-Species Framework process.

Attachment 1 (Tables): Artificial Production Programs In the Columbia River Basin

Glossary of Table Data

CODE	NAME
IDFG	Idaho Fish and Game
USFWS	United States Fish and Wildlife Service
IPC	Idaho Power Company
BPA	Bonneville Power Administration
FH	Fish Hatchery
NMFS	National Marine Fisheries Service
COE	Corps of Engineers
BR	Bureau of Reclamation
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
NPT	Nez Perce Tribe
YIN	Yakama Indian Nation
NFH	National Fish Hatchery
SCTS	Salmon Culture Technology Center
ODFW	Oregon Department of Fish and Wildlife
STEP	Salmon and Trout Enhancement Program
CEDC	Clatsop Economic Development Council
PGE	Portland General Electric
LSRCP	Lower Snake River Compensation Plan
WDFW	Washington Department of Fish and Wildlife
MDFWP	Montana Department of Fish, Wildlife, and Parks
SBT	Shoshone Bannock Tribe
SPC	Shoshone Paiute
STOI	Spokane Tribe of Indians
CCT	Confederated Colville Tribes
PUD	Public Utility District
WWP	Washington Water Power
DJ	Dingle-Johnson
PPL	Pacific Power and Light
OMSI	Oregon Museum of Science and Industry
URB	Upriver Brights

Resident Species Codes

CODE	NAME
AG	Arctic Grayling
BG	Bluegill Sunfish
BLC	Bear Lake Cutthroat Trout
BR	Brown Trout
BRC	Bear River Cutthroat Trout
BT	Brook Trout
BUT	Bull Trout
CC	Channel Catfish
CT	Cutthroat Trout
GT	Golden Trout
KK	Kokanee Salmon
KT	Kamloops Trout
LB	Large Mouth Bass
LCT	Lahontan Cutthroat Trout
LT	Lake Trout
M	Mackinaw
RB	Rainbow Trout
RBT	Redband Trout
S	Splake
SRCT	Snake River Cutthroat Trout
TM	Tiger Muskellunge
W	Walleye
WCT	Westslope Cutthroat Trout
WSG	White Sturgeon
YCT	Yellowstone Cutthroat Trout

Idaho Department of Fish and Wildlife

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Clearwater FH (Clearwater)	IDFG	USFWS	Steelhead	Dworshak Natl. Fish Hatchery	Dworshak Natl. Fish Hatchery	Dworshak/ Clearwater FH	Clearwater FH	Clearwater River Drainage	
	IDFG	USFWS	Spring Chinook	Powell, Crooked River, Red River	Powell, Crooked River, Red River	Clearwater FH	Clearwater FH	Clearwater River Drainage	
Eagle FH (Boise)	IDFG	BPA	Sockeye	Redfish Lake Creek/Sawtooth FH	Sawtooth FH/Eagle FH	Eagle FH	Sawtooth FH/Eagle FH	Sawtooth Basin Lakes	Research Hatchery
	IDFG	BPA	Spring Chinook	Salmon River Tributaries	None (captive rearing only)	None (captive rearing only)	Eagle FH	Upper Salmon River Drainage	
Sawtooth FH (Salmon)	IDFG	USFWS	Spring Chinook	Sawtooth FH/East Fork Satellite	Sawtooth FH/East Fork Satellite	Sawtooth FH	Sawtooth FH	Salmon River Drainage	
	IDFG	USFWS	Steelhead	Sawtooth FH/East Fork Satellite	Sawtooth FH/East Fork Satellite	Sawtooth FH	Sawtooth FH	Salmon River Drainage	
	IDFG	USFWS	Steelhead	East Fork Satellite/Squaw Creek Pond	East Fork Satellite	Sawtooth FH	Sawtooth FH	East Fork Satellite/Squaw Creek Pond	
Magic Valley FH (Salmon)	IDFG	USFWS	Steelhead	Sawtooth FH/ Pahsimeroi FH	Sawtooth FH/ Pahsimeroi FH	Sawtooth FH	Magic Valley FH	Salmon River Drainage	
McCall FH (Payette)	IDFG	USFWS	Summer Chinook	South Fork Satellite	South Fork Satellite	McCall FH	McCall FH	South Fork Salmon River Drainage	
Pahsimeroi FH (Salmon)	IDFG	IPC	Steelhead	Pahsimeroi FH	Pahsimeroi FH	Sawtooth FH	Magic Valley FH/ Hagerman NFH	Salmon River Drainage	
			Summer Chinook	Pahsimeroi FH	Pahsimeroi FH	Sawtooth FH	Sawtooth FH/ Pahsimeroi FH	Pahsimeroi FH	
Niagara Springs FH (Salmon)	IDFG	IPC	Steelhead	Pahsimeroi FH	Pahsimeroi	Sawtooth FH	Niagara Springs FH	Salmon River Drainage	
Oxbow FH (Lower Snake Mainstem)	IDFG	IPC	Steelhead	Oxbow FH	Oxbow FH	Oxbow FH	Niagara Springs FH/ Magic Valley FH	Salmon River Drainage	
	IDFG	IPC	Spring Chinook	Oxbow FH	Oxbow FH/ Rapid River FH	Rapid River FH	Rapid River FH	Salmon River Drainage/ Clearwater Drainage	
Rapid River FH (Salmon)	IDFG	IPC	Spring Chinook	Rapid River FH	Rapid River FH	Rapid River FH/ Clearwater FH	Rapid River FH/ Clearwater FH	Salmon River, Snake River, Clearwater River Drainage	
	IDFG	IPC	Steelhead	Rapid River FH	None	None	None	Salmon River Drainage (adult releases)	

Oregon Department of Fish and Wildlife

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Big Creek FH	ODFW	*NMFS*	Fall Chinook	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	Released at the hatchery
				Big Creek	Big Creek	Big Creek + STEP	STEP	Young's River	Transferred to STEP
				Big Creek	Big Creek	Big Creek + STEP	STEP	Clatskanie River, Scappoose Cr, Johnson Cr.	Transferred to STEP
				Big Creek	Big Creek	Various	Various	Young's Bay, Skipanon River	Transferred to high school programs
			Fall Chinook	Big Creek	Big Creek	CEDC	CEDC	Young's Bay	Transferred to CEDC
				Big Creek	Big Creek	Big Creek	Big Creek	Young's Bay	Transferred to CEDC Young's Bay Net Pens
				Big Creek	Big Creek	Big Creek	Big Creek + Klaskanine	Klaskanine River	Transferred to Klaskanine, 2 releases
			Coho	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek	2 releases on Big Creek
				Big Creek	Big Creek	CEDC	CEDC	Klaskanine River	Transferred to CEDC
				Big Creek	Big Creek	Big Creek + Abernathy	Abernathy	-	Research facility, no documented releases
				Big Creek	Big Creek	Various	Various	Young's Bay, Skipanon River	Transferred to high school facilities

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Winter Steelhead	Big Creek	Big Creek	Big Creek	Big Creek	Big Creek, Sandy River	Released at the hatchery in Big Creek; direct release in the Sandy R.
				Big Creek	Big Creek	Big Creek + Bonneville	Bonneville	Transferred to Bonneville H.	Reared at Bonneville for Clackamas and Sandy Rivers
				Big Creek	Big Creek	Big Creek + STEP	STEP	Fertile Valley	Transferred to STEP
				Big Creek	Big Creek	Big Creek	Big Creek	Gnat Creek	Transferred to Gnat Creek Accl.
				Big Creek	Big Creek	Big Creek	Big Creek	Klaskanine River	Transferred to Klaskanine Accl.
Sandy	ODFW	*NMFS*	Coho	Sandy	Sandy	Sandy	Sandy	Sandy River	2 releases
				Sandy	Sandy	Sandy	Sandy	Young's Bay	Transferred to CEDC Young's Bay Net Pens
				Farady Dam/ Clackamas	Sandy	Sandy	Sandy	Clackamas River	Released above River Mill Dam
Bonneville	ODFW	*NMFS, COE*	Fall Chinook	Bonneville	Bonneville	Bonneville	Bonneville	Tanner Creek	2 releases

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				Bonneville	Bonneville	Bonneville	Bonneville	Young's Bay	Transferred to CEDC Young's Bay Net Pens
				Bonneville	Bonneville	Bonneville	Bonneville	Umatilla	Transferred to Thornhollow, released in March
				Bonneville	Bonneville	Bonneville	Bonneville	Umatilla	Transferred to Thornhollow, released in April
				Bonneville	Bonneville	Bonneville	Bonneville	Columbia River, WA	Transferred to Ringold Acclimation - WDFW
				Bonneville	Bonneville	Bonneville	Bonneville	Klickitat River, WA	Transferred to Klickitat H. - WDFW
			Spring Chinook	Clackamas	Clackamas	Clackamas + Bonneville	Bonneville	Transferred to Clackamas H	Final Rearing at Clackamas H.
			Summer Steelhead	South Santiam	South Santiam	South Santiam + Bonneville	Bonneville	Clackamas River	Acclimated at Clackamas H.
			Winter Steelhead	Big Creek	Big Creek	Big Creek + Bonneville	Bonneville	Clackamas River	3 Releases, 3 acclimation sites

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Winter Steelhead	Big Creek	Big Creek	Big Creek + Bonneville	Bonneville	Sandy River	2 Releases, 2 acclimation sites
Cascade	ODFW	*NMFS*	Coho	Bonneville	Bonneville	Cascade	Cascade + Bonneville	Tanner Creek	Released at the hatchery
				Bonneville	Bonneville	Cascade	Cascade	Umatilla River	Transferred to New Accl. Site (RM 56)
				Bonneville	Bonneville	Cascade	Cascade	Yakima River	Transferred to YIN acclimation sites
Oxbow	ODFW	*NMFS*	Coho	Bonneville	Bonneville	Cascade	Upper Herman Creek	Tanner Creek	Acclimated at Bonneville H.
				Bonneville	Bonneville	Cascade	Upper Herman Creek	Young's Bay	Transferred to CEDC Young's Bay Net Pens
				Bonneville	Bonneville	Cascade	Lower Herman Cr. Ponds	Umatilla River	Transferred to New Accl. Site (RM 56)
				Bonneville	Bonneville	Cascade	Lower Herman Cr. Ponds	Young's Bay + Lower Columbia River	Transferred to CEDC Net Pens, Tongue Pt., Blind Sl., Young's Bay.
Eagle Creek NFH	USFWS	*NMFS*	Coho	Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek (Clackamas River)	Released at the hatchery
				Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek	Yakima River	Transferred to YIN acclimation sites

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek	Young's Bay	Transferred to CEDC Young's Bay Net Pens, 2 releases
			Winter Steelhead	Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek (Clackamas River)	Released at the hatchery
				Eagle Creek	Eagle Creek	Eagle Creek	Eagle Cr. + Clackamas H.	Clackamas River	Transferred to Clackamas H.
				Eagle Creek	Eagle Creek	Eagle Creek	Eagle Creek	Clackamas River	Transferred to Clackamette Cove Accl.
Clackamas	ODFW	*NMFS,* ODFW, City of Portland, PGE	Spring Chinook	Clackamas	Clackamas	Clackamas + Oxbow	Clackamas + Oxbow	Clackamas River	2 releases in the Clackamas River at the hatchery
				Clackamas	Clackamas	Clackamas + Willamette	Clackamas + Marion Forks	Clackamas River	Transferred to Cassidy Pond Acclimation
				Clackamas	Clackamas	Clackamas + Willamette	Clackamas + Marion Forks	Sandy River	Direct release
				Clackamas	Clackamas	Clackamas + Willamette	Clackamas + Marion Forks	Sandy River	Transferred to Marmot Accl.
				Clackamas	Clackamas	Clackamas + Oxbow	Clackamas + Bonneville	Clackamas	Released at the hatchery
				Clackamas	Clackamas	Clackamas + STEP		Clackamas River, Sandy River, Willamette River	Transferred to STEP

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Winter Steelhead	Farady Dam/Clackamas	Clackamas	Clackamas	Clackamas + Oak Springs	Clackamas River	Transferred to Oak Springs for final rearing
				Eagle Creek	Eagle Creek	Eagle Creek	Eagle Cr. + Clackamas H.	Clackamas River	Transferred in from Eagle Cr. NFH
Gnat Creek	ODFW	*BPA*	Spring Chinook	N/A	N/A	Gnat Creek	Gnat Creek	Columbia River, Young's Bay	Transferred to CEDC Net Pens, Tongue Pt., Blind Sl., Young's Bay.
Klaskanine	ODFW	*BPA*	Fall Chinook	Big Creek	Big Creek	Big Creek	Big Creek + Klaskanine	Klaskanine River	Released at the hatchery
Marion Forks	ODFW	ODFW/ COE	Spring Chinook	Minto Pond	Minto Pond	Marion Forks	Marion Forks	N. Fk. Santiam River	Direct Release
				Minto Pond	Minto Pond	Marion Forks	Marion Forks	N. Fk. Santiam River	Transferred to Minto Pond for Acclimation
Roaring River	ODFW	ODFW/ USFWS	Summer Steelhead	South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs + S. Santiam	N. Fk. Santiam River	Transferred to Minto Pond for Acclimation
South Santiam	ODFW	ODFW/ COE	Spring Chinook	South Santiam	South Santiam	S. Santiam + STEP		Santiam River	Transferred to STEP
				South Santiam	South Santiam	S. Santiam + Willamette	Willamette + South Santiam	S. Fk. Santiam River	Transferred to Willamette, South Santiam, 2 releases

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				South Santiam	South Santiam	S. Santiam + Willamette	Willamette + South Santiam	S. Fk. Santiam River	Transferred to Willamette, South Santiam, 2 releases
				South Santiam	South Santiam	S. Santiam + Willamette	Willamette	Mollala River	Transferred to Willamette, 2 releases
			Summer Steelhead	South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs + S. Santiam	S. Fk. Santiam River	Released at the hatchery
				South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs	Various programs	Transferred to Oak Springs, fulfills various other programs
				South Santiam	South Santiam	S. Santiam + Bonneville	S. Santiam + Bonneville	Clackamas River and Sandy River	Final Rearing at Bonneville H.
				South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs + S. Santiam	N. Fk. Santiam River	Transferred to Minto Pond Accl.
McKenzie	ODFW	ODFW/ COE	Spring Chinook	McKenzie	McKenzie	McKenzie	McKenzie	Willamette River	2 direct releases in Willamette River
				McKenzie	McKenzie	McKenzie	McKenzie	Willamette River	Transferred to Multnomah Net Pens
				McKenzie	McKenzie	McKenzie	McKenzie	Clackamas River	2 direct releases in Clackamas River

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				McKenzie	McKenzie	McKenzie	McKenzie	Clackamas River	Transferred to Clackamette Cove Net Pens
				McKenzie	McKenzie	McKenzie	McKenzie	McKenzie River	4 releases at the hatchery
				Mckenzie	McKenzie	McKenzie + Willamette	Willamette, Dex, McKenzie	McKenzie River	Transferred to Willamette, Dexter, McKenzie
				McKenzie	McKenzie	McKenzie + Willamette	Willamette	Willamette River	Transferred to OMSI Net Pens
				McKenzie	McKenzie	McKenzie + Willamette	Willamette	Willamette River	Direct release in Willamette River
Leaburg	ODFW	COE	Summer Steelhead	South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs + Leaburg	McKenzie River	Released at the hatchery
				Leaburg	South Santiam	S. Santiam + Oak Springs	Oak Springs, Leaburg, Dex	M. Fk. Willamette River	Final Rearing and release at Dexter
Willamette	ODFW	ODFW/ COE	Spring Chinook	Dexter Ponds	Dexter Ponds	Willamette	Willamette	Lookout Pt. Res., Fall Creek	Fingerling releases

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				Dexter Ponds	Dexter Ponds	STEP	Willamette + STEP	Willamette River	Transferred to STEP
				Dexter Ponds	Dexter Ponds	Gnat Creek	Tongue Pt. Net Pens	Columbia River	Transferred to Gnat Creek + CEDC
				Dexter Ponds	Dexter Ponds	Gnat Creek	Young's Bay	Columbia River	Transferred to Gnat Creek + CEDC
				Dexter Ponds	Dexter Ponds	Gnat Creek	Blind Slough	Columbia River	Transferred to Gnat Creek + CEDC
				Dexter Ponds	Dexter Ponds	Gnat Creek	Gnat Creek	Columbia River	Transferred to Gnat Creek + CEDC
				Dexter Ponds	Dexter Ponds	Willamette	Willamette + Dexter Pds.	M. Fk Willamette River	Transferred to Dexter Ponds, 3 releases
				Dexter Ponds	Dexter Ponds	Willamette	Willamette	M. Fk Willamette River	Direct release in Willamette River
			Summer Steelhead	Willamette	Willamette	Willamette	Willamette	Fall Creek	Direct Release
Oak Springs	ODFW	ODFW/ BPA	Summer Steelhead	South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs	Sandy River, Hood River	Direct Release

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
				South Santiam	South Santiam	S. Santiam + Oak Springs	Oak Springs and others	Various	Transferred to Roaring R., S. Santiam, Leaburg hatcheries
				Powerdale Fish Facility	Powerdale Fish Facility	Oak Springs	Oak Springs	W. Fk. Hood River	Acclimated at Dry Run Bridge
			Winter Steelhead	Parkdale Tribal Hatchery	Parkdale Tribal Hatchery	Oak Springs	Oak Springs	M. Fk. and E. Fk.Hood River	Acclimated at Parkdale and E.Fk. Irrigation District Ponds
Round Butte	ODFW	PGE/BPA	Spring Chinook	Parkdale Tribal Hatchery	Parkdale Tribal Hatchery	Parkdale + Round Butte	Round Butte	M. Fk. Hood River	Acclimated at Parkdale
				Parkdale Tribal Hatchery	Parkdale Tribal Hatchery	Parkdale + Round Butte	Round Butte+Pelton Ladder	W. Fk. Hood River	Acclimated at Dry Run Bridge
				Pelton Ladder	Round Butte	Round Butte	Round Butte+Pelton Ladder	Deschutes River	Transferred to Pelton Ladder
			Summer Steelhead	Pelton Ladder	Round Butte	Round Butte	Round Butte	Deschutes River + Lake Simtustus	Direct Releases
				Pelton Ladder	Round Butte	Round Butte	Round Butte	Jefferson County Sports and Rec. Catchout	Transfer to Jefferson County Sports and Rec. Catchout
Umatilla	ODFW	BPA	Fall Chinook	Three Mile Dam	Three Mile Dam	Umatilla	Umatilla	Umatilla River	Acclimated at Thornhollow

ODFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Spring Chinook	Three Mile Dam+Carson	S. Fk. Walla Walla+Carson NFH	Umatilla + Carson	Umatilla	Umatilla River	Acclimated at Imeques
			Summer Steelhead	Three Mile Dam	Minthorn Pond	Umatilla	Umatilla	Umatilla River	Acclimated at Bonifer and Minthorn ponds
Lookingglass	ODFW	LSRCP	Spring Chinook	Imnaha ponds	Lookingglass	Lookinglass	Lookingglass	Imnaha River	Acclimated at Imnaha Ponds
				Lookingglass+ Lookinglass Dam	Lookingglass	Lookingglass	Lookingglass	Lookingglass Creek	Released at the hatchery
				Upper Grand Ronde	Lookingglass	Lookingglass	Lookingglass	Upper Grand Ronde River	Acclimated at Upper Grand Ronde acclimation site
				Catherine Creek	Lookingglass	Lookingglass	Lookingglass	Catherine Creek	Acclimated at Catherine Creek site
				Lostine River	Lookingglass	Lookingglass	Lookingglass	Lostine River	Acclimated at Lostine River site
Wallowa Hatchery	ODFW	LSRCP	Summer Steelhead	Wallowa + Big Canyon	Wallowa	Wallowa + Irrigon	Irrigon	Wallowa River and Deer Creek	Acclimated at Wallowa and Big Canyon
			Summer Steelhead	Little Sheep Creek	Little Sheep Creek	Wallowa + Irrigon	Irrigon	Little Sheep Creek	Acclimated at Little Sheep Cr.

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Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Beaver Creek (Elochoman)	WDFW	Mitchell Act	Searun Cutthroat	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek	
			Winter Steelhead	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek	
			Summer Steelhead	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek	Beaver Creek/Gobar Ponds	
Chelan (Upper Mid. Col.)	WDFW	Chelan PUD	Summer Steelhead	Wells	Wells	Eastbank	Eastbank/Chelan/ Turtle Rock	Wenatchee River	
Cle Elum (Yakima)	YIN/ WDFW	BPA	Spring Chinook	Roza	Cle Elum	Cle Elum	Cle Elum	3 sites	
Cowlitz Salmon (Cowlitz)	WDFW	Tacoma Public Utilities	Fall Chinook	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
			Coho	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
			Spring Chinook	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
Cowlitz Trout (Cowlitz)	WDFW	Tacoma Public Utilities	Searun Cutthroat	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
			Summer Steelhead	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
			Winter Steelhead	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	Cowlitz River	
Eastbank (Upper Mid. Col.)	WDFW	Chelan PUD	Spring Chinook	Chiwawa Pond	Eastbank	Eastbank	Eastbank	Chiwawa	
			Summer Chinook	Wells	Wells	Wells	Eastbank	Similkameen/Carlton Ponds	
			Summer Chinook	Dryden Dam	Eastbank	Eastbank	Eastbank	Dryden Pond	
			Summer Steelhead	Dryden Dam/Wells	Eastbank/Wells	Eastbank/Wells	Eastbank/Turtle Rock	Wenatchee River	
			Sockeye	Tumwater Dam	Eastbank	Eastbank	Eastbank	Lake Wenatchee Net Pens	

WDFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Elochoman (Elochoman)	WDFW	Mitchell Act	Tule Fall Chinook	Elochoman	Elochoman	Elochoman	Elochoman	Elochoman	
			Coho	Elochoman	Elochoman	Elochoman	Elochoman	Elochoman/ Deep River Net Pens	formerly part of Kalama Falls program
Fallert Creek (Kalama)	WDFW	Mitchell Act	Spring Chinook	Kalama Falls	Kalama Falls	Kalama Falls	Fallert Creek	Fallert Creek	
		WA State	Coho	Fallert Creek	Fallert Creek	Fallert Creek	Fallert Creek	Fallert Creek	
Grays River (Grays River)	WDFW	Mitchell Act	Summer Steelhead	Beaver Creek	Beaver Creek	Beaver Creek	Grays River	Gobar Pond/ Grays River/ other tribs	
			Coho	Grays River	Grays River	Grays River	Grays River	Deep River Net Pens	
Kalama Falls (Kalama)	WDFW	Mitchell Act	Fall Chinook	Kalama Falls	Kalama Falls	Kalama Falls	Kalama Falls	Kalama Falls	
			Spring Chinook	Kalama Falls	Kalama Falls	Kalama Falls	Fallert Creek	Fallert Creek	
			Coho	Kalama Falls	Kalama Falls	Kalama Falls	Kalama Falls	Kalama Falls	
			Summer Steelhead	Skamania	Skamania	Skamania	Beaver Creek	Fallert Creek	Development of local brood
			Summer Steelhead	Kalama River	Kalama Falls	Fallert Creek	Fallert Creek	Kalama System/ Fallert Creek	
			Winter Steelhead	Beaver Creek	Beaver Creek	Fallert Creek/ Beaver Creek	Beaver Creek	Gobar Pond	Development of local brood
			Winter Steelhead	Kalama River	Kalama Falls	Kalama Falls/ Beaver Creek	Fallert Creek	Fallert Creek	
Klickitat (Klickitat)	WDFW	Mitchell Act	Spring Chinook	Klickitat	Klickitat	Klickitat (Klickitat)	Klickitat	Klickitat	URB Marking: Elochoman, Washougal, Bonneville involved
			Fall Chinook	Priest Rapids	Priest Rapids	Priest Rapids/Klickitat	Klickitat	Klickitat	

WDFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Coho	Lewis River	Lewis River	Lewis River/Klickitat	Klickitat	Klickitat	
Lewis River (Lewis)	WDFW	PacificCorp	Spring chinook	Lewis River/Merwin Dam	Speelyai	Speelyai	Speelyai/Lewis River	Lewis River	
		Mitchell Act	Coho	Lewis River/Merwin Dam	Lewis River	Lewis River	Lewis River	Lewis River	
Lyons Ferry (Lower Snake)	WDFW	LSRCP	Spring Chinook	Tucannon/Ringold	Lyons Ferry	Lyons Ferry	Lyons Ferry	Tucannon/Ringold	upriver=Pittsburg Landing, Captain Johns Rapids, Big Canyon
		Mitchell Act	Fall Chinook	Lyons Ferry/Lower Granite Dam	Lyons Ferry	Lyons Ferry	Lyons Ferry	Lyons Ferry/upriver sites (NPT)	
			Summer Steelhead	Lyons Ferry/Ringold	Lyons Ferry	Lyons Ferry	Lyons Ferry	Lyons Ferry/Ringold/other sites	
Merwin (Lewis)	WDFW	PacificCorp	Summer Steelhead	Merwin Dam	Merwin	Merwin	Merwin	Merwin	
Methow (Methow)	WDFW	Douglas PUD	Spring Chinook	Wells/trib trap sites	Methow	Methow	Methow	Methow/Chewuck/Twisp	
North Toutle (Cowlitz)	WDFW	Mitchell Act	Spring Chinook	Cowlitz Salmon	Cowlitz Salmon	Cowlitz Salmon	Cowlitz Salmon/North Toutle	North Toutle	
			Fall Chinook	North Toutle	North Toutle	North Toutle	North Toutle	North Toutle	
			Summer Steelhead	Skamania	Skamania	Skamania/Grays River	Grays River/North Toutle	North Toutle	
Priest Rapids (Upper Mid. Col.)	WDFW	Grant PUD	Fall Chinook	Priest Rapids	Priest Rapids	Priest Rapids	Priest Rapids	Priest Rapids	
Ringold Springs (Upper Mid. Col.)	WDFW	Mitchell Act	Spring Chinook	Ringold	Lyons Ferry	Lyons Ferry	Lyons Ferry/Ringold	Ringold	
			Fall Chinook	Bonneville/Priest Rapids	Bonneville/Priest Rapids	Bonneville	Bonneville	Ringold	

WDFW (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
			Summer Steelhead	Wells	Wells	Lyons Ferry	Lyons Ferry/Ringold	Ringold	
Rocky Reach (Upper Mid. Col.)	WDFW	Chelan PUD	Summer Chinook	Wells	Wells	Wells	Rocky Reach	Turtle Rock	
			Summer Steelhead	Wells	Wells	Wells/Rocky Reach	Rocky Reach	Wenatchee R	
Skamania (Washougal)	WDFW	Mitchell Act	Summer Steelhead	Skamania	Skamania	Skamania	Skamania	Skamania	
			Winter Steelhead	Skamania	Skamania	Skamania	Skamania	Skamania	
			Cutthroat Trout	Skamania	Skamania	Skamania	Skamania	Skamania	
Speelyai (Lewis)	WDFW	PacifiCorp	Spring chinook	Lewis R./Merwin Dam	Speelyai	Speelyai	Speelyai	Lewis River	
		Mitchell Act	Coho	Lewis River	Lewis River	Speelyai	Speelyai	Upper Col. Tribs	part of captive brood program
Tucannon (Tucannon)	WDFW	LSRCP	Spring Chinook	Tucannon	Lyons Ferry	Lyons Ferry	Lyons Ferry	Lyons Ferry/Curl Lake	
			Summer Steelhead	Tucannon	Tucannon	Tucannon	Tucannon	Tucannon	
Turtle Rock (Upper Mid. Col.)	WDFW	Chelan PUD	Summer Steelhead	Tumwater Dam	Eastbank	Eastbank	Eastbank/Turtle Rock	Wenatchee	
			Summer Chinook	Wells	Wells	Wells/Eastbank	Turtle Rock	Turtle Rock	
Washougal (Washougal)	WDFW	Mitchell Act	Fall chinook	Washougal	Washougal	Washougal	Washougal	Washougal	
			Coho	Washougal	Washougal	Washougal	Washougal	Washougal/Klickitat	
Wells (Upper Mid. Col.)	WDFW	Douglas PUD	Summer Chinook	Wells	Wells	Wells	Wells	Wells	
			Summer Steelhead	Wells	Wells	Wells	Wells	Wells	

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Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Abernathy SCTC (Lwr-Col Mainstem)	USFWS	USFWS	various	Abernathy SCTC	Abernathy SCTC	Abernathy SCTC	Abernathy SCTC	Abernathy SCTC, various sites according to research design	
Carson NFH (Wind)	USFWS	NMFS	Spring Chinook	Carson NFH	Carson NFH	Carson NFH	Carson NFH	Carson NFH (Wind River)	
	USFWS	NMFS	Spring Chinook	Carson NFH	Carson NFH	Carson NFH	Carson NFH	Umatilla River	Transferred to CTUIR
	USFWS	NMFS	Spring Chinook	Carson NFH	Carson NFH	Carson NFH	Big White Salmon Ponds	Big White Salmon Ponds	
Dworshak NFH (Clearwater)	USFWS	USFWS	Spring Chinook	Dworshak NFH	Dworshak NFH	Dworshak NFH	Dworshak NFH	Dworshak NFH (Clearwater River)	
	USFWS	COE	Steelhead	Dworshak NFH	Dworshak NFH	Dworshak NFH	Dworshak NFH	Dworshak NFH (Clearwater River), S.Fk. Clearwater R.	
Eagle Creek NFH (Willamette)	USFWS	NMFS	Coho	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH (Eagle Creek)	
	USFWS	NMFS	Coho	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Yakima River	Transferred to YIN
	USFWS	NMFS	Coho	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Young's Bay	Transferred to CEDC
	USFWS	NMFS	Steelhead	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH	Eagle Creek NFH (Eagle Creek)	
Entiat NFH (Entiat)	USFWS	BR	Spring Chinook	Entiat NFH	Entiat NFH	Entiat NFH	Entiat NFH	Entiat NFH (Entiat River)	
Hagerman NFH (Salmon)	USFWS	USFWS	Steelhead	Sawtooth SFH	Sawtooth SFH	Hagerman NFH	Hagerman NFH	Sawtooth SFH (Salmon River), other Salmon R sites	
Kooskia NFH (Clearwater)	USFWS	USFWS	Spring Chinook	Kooskia NFH	Dworshak NFH	Kooskia NFH	Kooskia NFH	Kooskia NFH (Clear Creek, M.Fk. Clearwater River)	
Leavenworth NFH (Wenatchee)	USFWS	BR	Spring Chinook	Leavenworth NFH	Leavenworth NFH	Leavenworth NFH	Leavenworth NFH	Leavenworth NFH (Icicle Creek-Wenatchee River)	

USFWS (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Little White Salmon NFH (Lwr-Mid Col Mainstem)	USFWS	NMFS	Spring Chinook	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH (Little White Salmon River)	
	USFWS	NMFS	Spring Chinook	Umatilla River	Umatilla River	Little White Salmon NFH	Little White Salmon NFH	Umatilla River	Transferred to CTUIR
	USFWS	NMFS	Fall Chinook	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH (L.W. Salmon R)	
	USFWS	NMFS	Fall Chinook	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Little White Salmon NFH	Yakima River	Transferred to YIN
Spring Creek NFH (Lwr-Mid Col Mainstem)	USFWS	NMFS, COE	Fall Chinook	Spring Creek NFH	Spring Creek NFH	Spring Creek NFH	Spring Creek NFH	Spring Creek NFH (mainstem Columbia River)	
Warm Springs NFH (Deschutes)	USFWS	USFWS	Spring Chinook	Warm Springs NFH	Warm Springs NFH	Warm Springs NFH	Warm Springs NFH	Warm Springs NFH (Warm Springs River-Deschutes R)	
Willard NFH (Lwr-Mid Col Mainstem)	USFWS	NMFS	Coho	Little White Salmon NFH	Little White Salmon NFH	Willard NFH	Willard NFH	Willard NFH (Little White Salmon River)	
	USFWS	NMFS	Coho	Little White Salmon NFH	Little White Salmon NFH	Willard NFH	Willard NFH	Clearwater River subbasin	Transferred to NPT
Winthrop NFH (Methow)	USFWS	BR	Spring Chinook	Wells Dam	Methow SFH	Winthrop NFH	Winthrop NFH	Winthrop NFH (Winthrop River)	
	USFWS	BR	Steelhead	Wells Dam	Wells SFH	Winthrop NFH	Winthrop NFH	Winthrop NFH (Winthrop River)	

Resident Fish Production

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Nez Perce Trout Ponds (Clearwater)	NPT	BPA	RT	Various		Various	Clearwater	Various	
Clearwater Hatchery (Clearwater)	IDFG	IDFG	RT	Various		Various	Clearwater	Various	
Cabinet Gorge Hatchery (Clark Fork)	IDFG	BPA; WPPS	KK	Various		Various	Clark Fork	Lake Pend Orielle	
Clark Fork Hatchery (Clark Fork)	IDFG	IDFG	WCT; KT; BT	Various		Clark Fork	Clark Fork	Clark Fork & Various	
Kootenai R. Hatchery (Kootenai)	Kootenai Tribe	BPA	WS	Various		Kootenai	Kootenai	Kootenai	
Murray Springs Hatchery (Kootenai)	MDFWP	MDFWP	KK; RT; CT; KT	Various		Kootenai	Kootenai	Various	
Kalispel Tribal Hatchery (Pend Orielle)	Kalispel Tribe	BPA	LB	Various		Pend Orielle	Pend Orielle	Box Canyon Res	
Sandpoint Hatchery (Pend Orielle)	IDFG	IDFG	WCT; RT	Various		Pend Orielle	Pend Orielle	Various	
Snake River Joint Cult. Fac (Upper Snake)	SBT/ SPT	BPA	RT; (YCT; RBT)*	Various		Upper Snake	Upper Snake	Upper Snake + Various	
American Falls Hatchery (Upper Snake)	IDFG	IDFG; American Falls Irrigation Dist.	RT	Various		Upper Snake	Upper Snake	Upper Snake + Various	

Resident (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Ashton Hatchery (Upper Snake)	IDFG	IDFG; Teton River Hydro-power	RT; KK	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Grace Hatchery (Upper Snake)	IDFG	IDFG	BLC; BRC; YCT; SRCT; BR; M; S; RT	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Hagerman Hatchery (Upper Snake)	IDFG	IDFG	RT; BR; KK; BT; LCT; KT	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Hayspur Hatchery (Upper Snake)	IDFG	IDFG	RT	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Mackay Hatchery (Upper Snake)	IDFG	IDFG; Ririe Reservoir; DJ	RT; SRCT; BT; BR; KK	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Nampa Hatchery (Upper Snake)	IDFG	IDFG	RT; BR; LCT	Various		Upper Snake	Upper Snake	Upper Snake + Various	
McCall Hatchery (Upper Snake)	IDFG	IDFG; LSRCP	WCT; RT	Various		Upper Snake	Upper Snake	Upper Snake + Various	
Lake Roosevelt RT Net Pens (Upper Columbia Mainstem)	STOI; others	BPA	RT	Various		Upper Columbia Mnstm	Upper Columbia Mnstm	Upper Columbia Mnstm	
Sherman Creek Hatchery (Upper Columbia Mainstem)	WDFW	BPA	KK; RT	Lake Roosevelt		Upper Columbia Mnstm	Upper Columbia Mnstm	Upper Columbia Mnstm	

Resident (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Spokane Tribal Hatchery (Upper Columbia Mainstem)	STOI	BPA	KK; RT	Lake Roosevelt		Upper Columbia Mnstm	Upper Columbia Mnstm	Upper Columbia Mnstm	
Colville Tribal Hatchery (Upper Columbia Mainstem)	CCT	BPA	RT; BT; LCT	Various		Upper Columbia Mnstm	Upper Columbia Mnstm	Upper Columbia Mnstm	
Colville Hatchery (Upper Columbia Mainstem)	WDFW	WDFW	RT; BT; CT	Various		Upper Columbia Mnstm	Upper Columbia Mnstm	Upper Columbia Mnstm	
Creston Fish Hatchery (Flathead)	USFWS	BPA	BT; WCT; KK	Various		Flathead	Flathead	Flathead Lake	
Leaburg Hatchery (Willamette)	ODFW	COE	RT; CT	Fish Lake		Willamette	Willamette	Various	
Marion Forks Hatchery (Willamette)	ODFW	COE / State	RT;CT	N/A		Willamette	Willamette	Various	
Roaring River Hatchery (Willamette)	ODFW	ODFW/USFWS	RT	Roaring River Hatchery		Willamette	Willamette	Various	
Willamette Hatchery (Trout) (Willamette)	ODFW	ODFW	RT	N/A		Willamette	Willamette	Various	
Oak Springs Hatchery (Deschutes)	ODFW	ODFW	RT	Oak Springs Hatchery		Deschutes	Deschutes	Various	
Round Butte Hatchery (Deschutes)	ODFW	PGE	KK	Paulina Lakes		Deschutes	Deschutes	Deschutes	
Fall River (Deschutes)	ODFW	ODFW/USFWS	RT; BT;CT	Crane Praire Res.		Deschutes	Deschutes	Various	

Resident (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Wizard Falls (Deschutes)	ODFW	ODFW/ USFWS	RT; BT; CT; AG; KK	Wizard Falls Hatchery		Deschutes	Deschutes	Various	
Wallowa Hatchery -Trout (Grande Ronde)	ODFW	ODFW/ USFWS	RT	N/A		Grande Ronde	Grande Ronde	Grande Ronde	
Cowlitz Trout Hatchery (Cowlitz)	WDFW	Tacoma City Lights	TM; CC	Cowlitz Reservoirs		Cowlitz	Cowlitz	Cowlitz Reservoirs	
Mossyrock Hatchery (Cowlitz)	WDFW	Tacoma City Lights	TM; CC; RT; BT; CT	Mayfield Lake		Cowlitz	Cowlitz	Mayfield Lake	
Goldendale Hatchery (Klickitat)	WDFW	WDFW	RT; BR; BT; CT	Local		Klickitat	Klickitat	Klickitat	
Chelan Hatchery (Lake Chelan)	WDFW; Chelan PUD	WDFW; Chelan PUD	RT; BT; CT; BR	various		Lake Chelan	Lake Chelan	Lake Chelan	
Eastbank Hatchery (Wenatchee)	WDFW	Chelan PUD	KK	various		Various	Wenatchee	Various	
Lyons Ferry Hatchery (Lower Snake Mainstem)	WDFW	COE	RT	various		L. Snake Mainstem	L. Snake Mainstem	L. Snake Mainstem	
Tucannon Hatchery (Tucannon)	WDFW	COE/WD FW	RT; BR	various		Various	Tucannon	Various	
Columbia Basin Hatchery (Crab Creek)	WDFW	WDFW	RT; BR; BT; TM; BG; CC; W	various		Crab Creek	Various	Various	

Resident (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Naches Hatchery (Yakima)	WDFW	WDFW	RT; BR; BT; CT; KK	various		Yakima	Yakima	Yakima	
Ringold Springs Hatchery (Lower Mid Columbia Mainstem)	WDFW	Mitchell Act/WDFW	BG; CC; LB; W	various		L. Mid Col. Mainstem	L. Mid Col. Mainstem	Various	
Ford Hatchery (Spokane)	WDFW	WDFW	RT; BR; BT; LT; KK; CT	various		Spokane	Spokane	Spokane	
Spokane Hatchery (Spokane)	WDFW	WDFW	RT; BR; BT; W	various		Spokane	Spokane	Various	
Vancouver Hatchery (Lower Columbia Mainstem)	WDFW	WDFW	BR; RT; CC	various		L. Columbia Mainstem	L. Columbia Mainstem	L. Columbia Mainstem	
Omak Hatchery (Okanagan)	WDFW	WDFW	RT; LCT; BT	various		Okanagan	Okanagan	Various	
Wells Hatchery (Upper Mid Columbia)	WDFW	Douglas Co. PUD	RT	various		Various	Upper Mid Columbia	Various	
Merwin Hatchery (Lewis)	WDFW	PP&L	RT; TM	various		Lewis	Lewis	Lewis	
Speelyai Hatchery (Lewis)	WDFW	PP&L; Cowlitz Co.PUD	KK	various		Lewis	Lewis	Lewis	
Mullan Hatchery (Coeur d'Alene)	IDFG	IDFG; Shoshone Co.; Shoshone Co. Sportsmens Assn.	RT	various		Coeur d'Alene	Coeur d'Alene	Various	

Resident (Continued)

Hatchery	Agency	Funding Source	Species	Adult Collection Site	Adult Holding / Spawning	Incubation	Rearing	Acclimation / Release	Comments
Sawtooth Hatchery (Salmon)	IDFG	IDFG (res. Fish)	RT; GT; CT; AG	various		Various	Salmon	Salmon	
Anaconda Hatchery (Flathead)	WDFWP	WDFWP	CT; WCT	various		Flathead	Flathead	Various	
Arlee Hatchery (Flathead)	WDFWP	WDFWP	RT	various		Flathead	Flathead	Flathead	

***** = *Plan for future production*

Appendix 3

Interim Standards for the Use of Captive Propagation

Interim Standards for the use of Captive Propagation Technology in Recovery of Anadromous Salmonids Listed under the Endangered Species Act[29]

Introduction

In response to a request from the Northwest Power Planning Council (NPPC), the National Marine Fisheries Service (NMFS) developed these interim guidelines for applying captive propagation technology to recovery actions for anadromous fish listed as threatened or endangered under the Endangered Species Act (ESA).

These interim standards establish protocols for determining when captive propagation could be used to preserve listed fish populations. The standards also address the circumstances under which such intervention could be phased out. These interim standards specifically address the following items:

- A protocol to evaluate the risk of extinction vs. the risk of intervention;
- An explicit linkage between releases from individual captive propagation programs and the availability of suitable habitat and/or habitat restoration activities;
- A protocol to decide the type of intervention appropriate to different populations;
- A rationale for the initiation and duration of each intervention;
- A mechanism to prioritize intervention efforts.

The NPPC also requested that the interim standards include a prioritized list of likely target populations and intervention programs to form the basis for programmatic and budgetary planning. It is not possible at this time to provide such a list, because a comprehensive Columbia River propagation plan is being developed within *U.S. v. Oregon* negotiations. However, these standards will be used to evaluate any proposed captive propagation initiatives that are developed.

Purpose

The purpose of these interim guidelines is to provide a framework for developing and evaluating captive propagation proposals. This framework reflects the current state of the science of brood stock management, but does not contain the amount of detail on fish genetics, fish health, and

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hatchery management found in other publications. These guidelines provide information on important issues, decision criteria, and management concerns to agencies that might sponsor development of new captive propagation proposals. By applying the interim guidelines, agencies will have a consistent approach to using captive propagation technology in recovering ESA listed anadromous salmonids.

Captive propagation technology refers to propagation programs that hold fish in captive facilities through most or all of a life cycle (e.g., captive rearing and captive breeding; see Flagg and Mahnken 1995). Captive propagation is an experimental measure that shows promise for recovering listed species when they are under immediate risk of becoming extinct in their natural habitat. However, it is uncertain at this time whether captive propagation technology can conserve the genetic integrity and population structure of an Evolutionarily Significant Unit (ESU) and restore anadromous fish to self-sustaining, naturally-reproducing populations in their native habitat. Currently there is not enough empirical information available to identify criteria for maintaining population structure of ESU's or for establishing critical thresholds indicating when to initiate or terminate captive propagation measures. However, the theoretical basis for use of captive propagation to recover listed fish is well documented in the references cited in these guidelines. One purpose of these interim guidelines is the systematic development and evaluation of effective captive propagation measures. As the technology evolves, managers will better understand how best to utilize captive propagation - in combination with other artificial and natural propagation techniques - in developing comprehensive recovery programs.

These interim guidelines are intended to provide a systematic way for sponsors to identify the strengths and weaknesses of their projects. Far from being a set of rigid rules, they provide flexibility to reduce risks and increase benefits of individual projects, and supply a means for displaying the rationale and justification for captive propagation measures. They reflect the current understanding of salmon biology and recognize the scientific uncertainty that exists.

These guidelines will be used to evaluate any new captive propagation initiatives proposed to the NPPC through its Fish and Wildlife Program. The NPPC will only support new captive propagation programs if they comply with these standards. Additionally, new production initiatives must satisfy the terms of NPPC's 3-Step Process. The 3-Step Process is outlined in the Draft Policy dated October 21, 1997. It includes : (1) Conceptual planning and approval, (2) preliminary design, cost estimation and environmental review and, (3) final design review. The guidelines and standards outlined in this document also describe the issues that must be addressed when applying for ESA Section 10 permits to allow directed take of listed species for captive propagation program brood stock.

Recovery

The purposes of the ESA are to provide a means whereby the ecosystems upon which listed species depend may be conserved and to provide a program for conserving listed species so that they may be brought to the point where protection under the Act is no longer necessary. The definition of "recovery" under the ESA requires self-sustaining populations of native species, naturally reproducing in their native habitat. Thus, for recovery purposes, captive propagation must ultimately seek to reestablish self-sustaining, natural populations of currently listed species. The short-term goals of a captive propagation program are to reduce the risk of extinction, preserve the genetic material of a stock of fish, or increase the abundance of an at-risk stock. Longer term recovery goals must address solutions to the factors which have caused the stock to decline and means by which the naturally producing portion of the stock, living in native habitat, will be increased. Although these guidelines contain a recommendation that captive propagation programs last for only one to three generations, in some cases the causes of the decline may take longer than three generations to resolve. This does not necessarily mean that captive propagation programs should be precluded, but the program sponsors should be aware of the program's limitations regarding recovery as it is defined under the ESA.

Captive propagation on its own will rarely, if ever, constitute a complete recovery program. The elements of a complete recovery program are outlined in "Working Guidance for Comprehensive Salmon Restoration Initiatives on the Pacific Coast" (NMFS, 1996). Sponsors of new captive propagation initiatives must also address the factors of decline that caused the population to reach the status where captive propagation is necessary. Moreover, they must coordinate artificial propagation with management in the habitat and fisheries realms.

Coordination

The interim standards described herein have been developed in consultation with regional co-managers - represented by Federal and state agencies and tribes - with the assistance of other relevant parties to ensure that they address the Endangered Species Act, tribal treaty and trust responsibilities, and other sustainable fishery management responsibilities. It is expected that these interim standards will undergo additional scientific and policy analysis through ongoing processes such as recovery planning under the ESA, the Artificial Production Review being conducted by NPPC, the *U.S. v. Oregon* arena, and others. These processes should help finalize the standards for captive propagation programs across the region. It is expected that these interim standards will be applied while the other processes proceed. Evaluating results from current captive brood stock programs will provide data essential for adjusting these standards.

Background

The NMFS policy on the relationship between artificial propagation and recovery of listed salmonids is described in Technical Memorandum NMFS-NWFSC-2, "Pacific Salmon and Artificial Propagation Under the Endangered Species Act" (Hard et al.1992). It was published shortly after the first anadromous salmonids were listed in the Columbia Basin. This document discusses the potential uses of artificial propagation technology in preserving and recovering anadromous fish populations; it also makes recommendations for selecting appropriate brood stocks and operating hatcheries in a conservation framework. Protocols for collecting and mating brood stock, as well as rearing, and release, strategies and monitoring results are further discussed in Flagg and Mahnken, 1995.

Captive Propagation Programs

For several decades, artificial propagation - usually in the form of production hatcheries - has been a prominent feature of fisheries mitigation and enhancement efforts for Pacific salmon. By using the potential of artificial propagation to circumvent the high rates of mortality in early life stages experienced in the wild managers have successfully enhanced harvests. Recently, the decline of many natural populations has prompted development of a conservation role for artificial propagation. However, the use of artificial propagation for supplementing and restoring natural populations is largely unproven and entails certain risks (Miller 1990).

Conventional production hatcheries collect eggs and sperm from natural or hatchery-produced adults, hatch and rear the resultant offspring to smolt size, and release the smolts to migrate and rear to adulthood in the ocean. This technology has been successful for some fishery mitigation and enhancement programs and, with variations, has been applied to conservation as well. In addition, situations may arise that require increased reliance on artificial propagation to facilitate the recovery of a threatened or endangered salmon population.

The most conspicuous of these situations occurs when a natural population is dangerously close to extinction. One option to consider in such a case is a captive propagation program - a special case of supplementation. A captive propagation program typically involves taking gametes or fish from the natural population, rearing them to maturity in the hatchery, and either releasing the adults to breed in the wild (the captive rearing strategy) or breeding the adults in the hatchery and releasing their progeny into the natural habitat (the captive breeding strategy). A captive propagation program thus involves rearing fish in captivity for most of the life cycle, rather than releasing them as fry or smolts as is done in a traditional salmon hatchery. The potentially high salmon survival found in protective culture affords a unique opportunity to produce large numbers of juveniles for supplementation in a single generation. If proper precautions are taken to minimize genetic change during the collection, mating, rearing, and release of fish held in captive propagation, these programs have the potential to rapidly increase the abundance of severely depleted stocks.

Sponsors of captive propagation proposals should carefully evaluate the reasons why they propose to use artificial propagation instead of first solving the problems that caused natural propagation to fail. Further, they should examine their reasons for choosing captive propagation instead of more "traditional" hatchery methods as a means of artificial propagation.

The advantages cited for captive propagation include:

- The potentially much greater spawner-to-spawner survival provided by captive propagation means that a small number of founders can provide a large number of fish for reintroduction or supplementation within one or two generations.
- It is possible to collect broodstock without substantially affecting the abundance of the remaining natural population. For example, the upper Columbia River spring chinook

programs collect eggs deposited in redds by naturally-spawning, listed fish. This allows the collection of broodstock without (in theory) any substantial reduction in the number of natural spawners.

- The ability to collect eggs or juveniles may allow for artificial propagation of populations from which adults can not be collected.

However, it should be recognized that although captive broodstock programs hold promise for some species, they are unproven as a conservation measure for Pacific salmon. Therefore, as with other types of artificial propagation for recovery purposes, captive propagation programs for conservation of Pacific salmon should be regarded as experimental. Nonetheless, captive propagation technology may be the preferred option if the imminent risk of extinction is high. If implemented as part of a recovery plan, a captive propagation program should be integrated with other measures such as habitat protection and restoration that are intended to address population viability (Povilitis 1990).

Captive broodstock may be collected from the natural habitat as adults, as deposited eggs, or as juveniles. The choice of life stage to collect affects how much natural selection occurs in the broodstock sample before it is established in the hatchery and may also affect the degree to which the sample is representative. The later the life stage, the greater the opportunity for natural selection to occur and, consequently, the more closely the resulting broodstock is likely to resemble the natural spawning population. However, among the potential disadvantages of collecting older life stages for use as broodstock are difficulties in acclimating older juveniles to the hatchery environment and, if adults are used, prespawning (holding) mortality. Any losses that alter the broodstock's original genetic composition may reduce the efficacy of supplementation in rebuilding the natural population or increase the risk of adversely affecting natural populations.

The guidelines for conventional artificial propagation recommended by Hard et al. (1992) regarding broodstock collection and mating, rearing and release strategies, and monitoring may be even more critical to the success of a captive propagation program. The thrust of the guidelines is to avoid selecting for undesirable traits in the hatchery environment and to preserve characteristics that are suitable for survival in the natural environment. If enough adults are produced in a captive propagation program, it may be desirable to allow some of the captive adults to spawn in the wild — thus allowing their offspring to undergo natural selection. In a captive program, selection pressures can be minimized if mortality during captivity is low. If selection caused by mortality in captivity is minimized, the main genetic consequences to be assessed are the consequences associated with broodstock sampling, mating, and progeny release strategies and the effects of enhancing particular genotypes (Ryman and Laikre 1991). Note that this latter effect does not occur if the entire population is enhanced through artificial propagation.

Of paramount importance for a threatened or endangered species is protecting the fish in captive propagation from catastrophic loss or high mortality. This is especially true if all natural gametes have been removed from the wild to establish a captive propagation program. Consequently, the broodstock gametes should be divided between at least two independent facilities, if funding allows. Because the normal anadromous fish life cycle includes rearing in the ocean, at least a portion of the captive population should be reared in saltwater. Broodstock should be isolated from all other fish and kept under security with safeguards against environmental perturbation (including equipment failure). Because a release strategy is the pivotal last element in a recovery attempt involving captive propagation, release timing should be based on the behavior of any remaining natural fish, or on knowledge of the life-history characteristics of the natural fish if none are present.

Finally, captive propagation programs must be regarded as temporary conservation measures that should be placed in the context of an overall recovery plan which addresses all factors causing population decline. For the purposes of recovery under the ESA, a captive broodstock program should, if possible, be limited to one complete life cycle, at which time the progeny of these broodstock would be released into the wild. Whether such a program should be extended beyond a single generation will depend on the performance of the fish in captivity and the wild, the viability of the natural component being supplemented, and the success of measures taken to address other factors of decline.

Initiation of Captive Propagation Programs

Managers who plan to sponsor a captive propagation program should proceed through the following steps:

1. Consider the alternatives to captive propagation and review the guidelines presented in the following sections of this document.
2. Evaluate the status of the population targeted for captive propagation and goals of the proposed program design using the decision issues listed in Table 1.
3. Shape the program proposal using the operational standards outlined in Table 2.
4. Develop a detailed captive propagation plan following the outline in Table 3.
5. Evaluate the proposal against the hazards and benefits listed in Tables 4 and 5.

By completing this process, managers will be able to provide documentation that the proposal is justified, that it is consistent with the ESA, that risks are manageable, and that success is likely. This process will also generate documentation to show that the proposal is coordinated with other management goals and priorities and is feasible in terms of facilities and budgets.

Captive Propagation Guidelines

The use of captive propagation technology is appropriate only when the population's risk of extinction (or other substantial harm) is greater than the risks of using artificial propagation.

Key issues are:

- The consequences of not doing anything or of only pursuing other recovery options.
- Size of the project relative to the natural population.

- Number and origin of fish collected for broodstock each generation.
- Rearing strategies to produce wild-like fish.
- Release of fish that assures survival and successful integration with the natural component of the population.
- The criteria for project success.
- Spreading risks by utilizing a variety of recovery strategies when multiple populations within an ESU are at risk (i.e. all at-risk populations within an ESU should not necessarily be artificially propagated as part of a recovery effort).

Table 1 summarizes the important decision points that must be considered when proposing the use of captive propagation technology for recovery of anadromous salmonids listed under the ESA.

Table 1. Decision Standards for Using Captive Propagation Technology to Recover Listed Anadromous Salmonids.

Issue	Guidelines
Population Status	1. Population is at a high risk of extinction in the immediate future. For example: - Population is at very low abundance (e.g. < 50 fish a year) OR - Population is at low abundance and declining OR - Population is at moderate abundance and declining precipitously OR - Little or no natural production predicted for at least a full generation. 2. Population is of very low abundance relative to available habitat and production potential, and short-term supplementation is deemed necessary to accelerate natural recovery.
Importance of population	The population targeted for captive propagation is important, relative to other populations because: -Unique genetic qualities. -Unique adaptations to specific habitats (e.g. adaptations in run timing, migration distance, and behavior). -Low likelihood of successful natural recolonization from other populations in the event of extinction. -High potential productivity, or unique social, economic or cultural value.

Scale of Project	1. Total captive production should be based on the number of fish needed to : a. Prevent extinction. b. Adequately represent genetic variation for life history traits of the wild population. c. Minimize genetic change during captivity. d. Reestablish the fish in the wild. 2. Duration should be as short as possible (one to three generations)
Measures of Success	1. Successful programs will: a. Substantially reduce risk of extinction. b. Cause minimal genetic change in comparison with the original source population. c. Reintroduce fish that are phenotypically similar to wild fish of the same age in development, morphology, physiological state, and behavior. d. Increase the number of fish reproducing successfully in the wild.
Changing or Terminating Program	1. If risk of immediate extinction lessens because causes of decline are corrected, terminate or phase into a conventional supplementation program. 2. If program increases numbers of successful natural spawners, increase the proportion allowed to spawn naturally. 3. If substantial progress has not been made toward recovery at the end of three complete generations and no progress has been made toward correcting the causes of decline, reevaluate program. 4. If negative effects of captive propagation appear, the program should be altered or terminated.

If after reviewing the decision standards outlined in Table 1 managers come to the conclusion that captive propagation is an appropriate technology to apply to recovery, the operational standards summarized in Table 2 will be applied to proposed captive propagation programs.

Table 2. Operational Standards for Using Captive Propagation Technology to Recover of ESA-Listed Anadromous Salmonids

Issue	Guidelines
Choice of Brood stock	1. If all remaining individuals of the population of wild fish targeted for recovery are not incorporated in the captive broodstock, develop a broodstock selection protocol to ensure that the genetic and life history variability of the target population is reflected in the captive broodstock. 2. Continual infusion of wild fish into successive year classes of the broodstock may slow domestication of captive propagated fish.
Captive Brood Stock Spawning	1. Spawn all available adults. 2. Retrieve all possible eggs from mature females, either by multiple live spawnings or through careful attention to ripeness and handling. 3. Use spawning protocols that maximize the effective genetic population size: a. Factorial or (with greater numbers of parents) single-pair matings. b. Cryopreserved sperm(Benefits of using cryopreserved sperm should be weighed against potential for loss of viability, especially when the number of eggs is low). c. Induced spawning.
Rearing of Fish	1. As much as possible, mimic wild rearing conditions (light, cover, substrate, flow, temperature, densities) for fish to be released in the wild. 2. Facilities for freshwater rearing should have pathogen- and predator-free water supplies. 3. Fish being transferred to seawater for rearing or release should be handled so as not to compromise their ability to adapt to seawater. 4. Seawater-based rearing facilities should minimize the effects of storms, harmful phytoplankton, predation, poaching, and disease. 5. Managers should consider equalizing the contribution of all parents to the next generation to maximize effective population size and reduce artificial selection in the captive environment.

Release of Fish	1. Release fish at a life stage and size where their probability of survival to adulthood is greatest. 2. Acclimate fish to locations in the watershed where they are intended to return. 3. Design release strategies to integrate fish from captive propagation programs with wild fish at the same life history stage, if any remain in the natural system. 4. When fish are likely to remain in the release area (for example pre-smolts or residuals), disperse the releases. 5. Use release protocols that minimize stress caused by handling, transportation, or new surroundings. 6. Minimize negative interactions with other species in the watershed.
Management of Returning Adults	1. If the program meets all other guidelines, there is no general restriction on the proportion of hatchery fish of this stock on the spawning grounds of the population targeted for recovery for the first three generations. Individual projects may limit the proportion of hatchery fish spawning naturally depending on the details specific to the project. 2. Non-ESU hatchery fish from other programs should not exceed natural levels of straying between the populations in question, or constitute more than approximately one percent of total abundance if natural rates of straying are not known.
Other Disposition of Fish	If captive propagation programs produce more fish than are needed for future brood stock or release into the wild, the extra fish will be disposed of in a manner that is agreeable to the co-managers and that does not jeopardize the project or other recovery efforts.
Monitoring and Evaluation	1. Monitoring and evaluation of fish in captive propagation will include (at a minimum): a. Survival at life history stages up to adulthood. b. Viability of gametes produced in captivity. c. Behavior, morphology, and viability and reproductive success of offspring produced in captivity. 2. Monitoring and evaluation of offspring released to the wild will include: a. Survival and migration success. b. Ability to return to hatchery or natural spawning areas. c. Ability to successfully produce offspring in the wild.

Development of a Captive Propagation Program

A proposal to initiate captive propagation measures must have clear goals and objectives articulated in a Captive Propagation Operation Plan. The plan is expected to address the issues above and display how risks will be contained and evaluated. Coordination with ecosystem restoration activities and fisheries management is critical. The process for evaluating goals and objectives must be tied to proposed project duration. Captive propagation operation plans should follow the outline provided in Table 3.

Table 3. Outline of a Captive Propagation Operation Plan

Captive Propagation Program Description	1. Name of Program. 2. Stock and species to be propagated. 3. Names of the accountable organization and individuals. 4. Location of program and extent of target area. 5. Program goals. 6. Expected duration of program.
Relationship of Program to Other Management Objectives	1. Relationship to habitat protection and recovery strategies: a. Major factors inhibiting natural production. b. Description of habitat protection and recovery efforts. c. Expected benefits of and time frame for habitat restoration efforts. 2. Ecological interaction with other species: a. Consideration of interactions with other wild and hatchery salmonids that will affect or be affected by releases from the proposed program. b. Description of the interactions among the proposed program and introduced and native non-salmonid species. 3. Relationship to fisheries and harvest objectives for other species: a. Description of fisheries that might incidentally harvest these fish. b. Expected harvest impacts. c. Expected escapements.
Origin and Identity of Brood Stock	1. Guidelines for using the stock in the program. 2. Operating protocols to implement guidelines. 3. Data to support protocols: a. History of brood stock. b. Annual brood stock size and sex ratio. c. Genetic and ecological differences between this stock and other stocks. d. Description of special traits or other reasons for choosing this stock. 4. Facilities available for isolating and maintaining the captive program.

	5. Personnel accountable for developing and operating the captive propagation program.
Brood Stock Collection	1. Operating protocols: a. Number of each sex to be collected and maintained in captive propagation. b. Kind of fish collected (life stage, special characteristics). c. Description of sampling design. d. Method of identifying target population if more than one stock exists. 2. Data to support protocols: a. Distribution of target population over time and space. b. Biological information (fecundity, sex ratios).
Mating	1. Operating protocols: a. Number of each sex to be mated. b. Method for choosing spawners. c. Fertilization scheme. 2. Facilities.
Rearing	1. Operating protocols: a. How will the incubation and rearing environment be different from or similar to natural rearing? b. How will family groups be separated and their contributions equalized? 2. Data to support protocols. 3. Facilities.
Release	1. Operating protocols: a. Number, size and life stage at release. b. Date, location, and number per location of release. c. Release technique (direct, acclimation, volitional). d. Tags and marks. 2. Data to support protocols. 3. Facilities and equipment.
Monitoring and Evaluation	1. Biological and propagation parameters monitored: a. Survival at different life stages. b. Age at maturity, sex ratios, fecundity, viability of gametes. c. Genetic, morphological, meristic, and behavioral similarity to donor population. d. Survival of progeny in wild. e. Contribution to natural spawning and success of progeny. f. Incidental harvest in fisheries. 2. Evaluation and feedback mechanism. 3. Restoring a naturally-reproducing component of the population:

	a. Progress in habitat restoration. b. Use of habitat by fish from captive propagation program. c. Success in natural reproduction.

Benefit-Risk Assessment

The potential benefits of captive propagation technology applied to anadromous salmonids are : A rapid increase in the total abundance of the target population, preservation of the genetic material in a population threatened with extinction, and lowering the risk of extinction. With a recovery target of naturally self-sustaining populations of indigenous fish in natural habitats, the long-term benefit of captive propagation should be to provide more natural spawners and more naturally-produced recruits to the population once the ecosystem has recovered.

Sponsors of some captive propagation measures may be motivated by the cultural, social, or economic benefits of preserving and restoring the target population. This document does not attempt to evaluate or compare the non-biological values assigned by project sponsors. However, those values will undoubtedly be assessed by project sponsors and will influence choices and priorities when proposals are submitted.

A systematic risk-benefit analysis provides a means to consider the unique characteristics of each proposal and deal with scientific uncertainty in a way that a strictly regulatory approach to standards would not allow. Table 4 summarizes the benefits expected from captive propagation technology applied to recovery of listed anadromous salmonids.

Table 4. Summary of Benefits Attributed to Captive Propagation Technology

Benefit	**Evaluation criteria**
Increase Total Abundance of the Target Population	Spawner:Spawner replacement ratio is higher for captive propagation program than for fish remaining in natural habitat.
Preserve the Target Population	Genetic, morphological, meristic, and behavioral characteristics of fish in captive propagation reflect the natural population.
Increase Number of Natural-origin Recruits	The product of the spawner:spawner replacement rate in the captive program and the relative success of captive-produced fish spawning in the wild to natural fish exceeds 1.0 and there is sufficient current habitat capacity to allow the population to increase in abundance.

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The hazards of placing anadromous salmonids in captive propagation programs are primarily those associated with very small population size compounded by the influence of an artificial environment. The measures outlined above provide guidelines for avoiding or managing these hazards. The hazards of applying captive propagation technology to recovering listed anadromous salmonids are summarized in Table 5.

Table 5. Summary of Hazards Related to Captive Propagation Technology

Hazard	**Risk Evaluation**
Negative Effects Associated with Small Population Size	Probability of : 1. Inbreeding depression. 2. Loss of within-population genetic variability. 3. Accumulation of deleterious mutations.
Negative Effects of Propagation in an Artificial Environment	1.Domestication: Probability of adaptation to the captive propagation environment at the expense of adaptation to the natural environment. 2. Catastrophic loss due to disease outbreaks or facility failure.
Loss of Diversity Among Populations	Broodstock can be effectively collected from targeted population without substantial mixing with non-targeted, genetically distinct populations.

In developing a proposal to use captive propagation for conserving listed anadromous fish, sponsors must proceed through the decision points outlined in the sections above. In developing a hatchery operation plan, sponsors must provide documentation showing how each of the issues can be managed or reduced. More elaborate risk-benefit analysis systems are being developed in several other anadromous fish forums including the Puget Sound Comprehensive Chinook Management Plan. Experience gained in risk-benefit analysis will be used to adjust these captive rearing technology standards.

Prioritizing Captive Propagation Proposals

Petitions seeking to list anadromous salmonids in the western United States have identified hundreds of populations of the seven species of anadromous salmonids under NMFS' purview that may be at risk. The NMFS has aggregated those populations into approximately 50 Evolutionarily Significant Units (ESUs) based on genetic relationships, life history and biological similarities, and geographic associations. Approximately 15 of the ESUs have been listed, 12 are proposed for listing and eight remain candidates for consideration. Of the 17 ESUs in the Columbia River Basin, two are listed as endangered, five are listed as threatened, and six are proposed for listing.

Within each listed ESU there are usually many spawning populations. In many cases there is a wide range in the health and outlook for recovery among these populations. State, Federal, and tribal management plans identify different populations of anadromous salmonids that are managed in artificial or natural propagation programs. Documents such as the Washington Department of Fish and Wildlife's "Salmon and Steelhead Stock Identification" (SASSI) can serve as a basis for identifying stocks. It is recognized that there is considerable uncertainty regarding the degree to which identified populations are reproductively isolated. Also, it is uncertain to what degree some actually isolated populations may be identified as single populations. There are ongoing debates as to the occurrence and the importance of stock structure in many areas of anadromous fish management. The degree to which populations are separated or aggregated, and the rationale and justification for any classification will be included in captive propagation proposals.

There are currently several long-term planning processes underway in the Columbia Basin. Negotiations are proceeding for a new Columbia River Fishery Management Plan (CRFMP) which will include artificial propagation goals for each sub-basin in the Columbia River Basin that the plan addresses. The CRFMP will contain prioritized plans for harvest, as well as production, that will be negotiated by the state, Federal, and tribal co-managers under the legal mandates of *US v. OR*. The list of hatchery programs and stocks, and the coordination of CRFMP with ESA will provide a prioritized list of potential captive propagation programs in the area impacted by the court order. This area closely corresponds with the area covered by the NPPC Fish and Wildlife Program.

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GLOSSARY

Artificial Propagation - Any assistance provided by human technology to animal reproduction. In the context of Pacific salmon, this assistance may include, but is not limited to, spawning and rearing in hatcheries, stock transfers, creation of spawning habitat, egg bank programs, captive broodstock programs and cryopreservation of gametes

Broodstock - Adult fish used to propagate subsequent generations of fish

Captive broodstock program - A form of artificial propagation involving the collection of individual fish (or gametes) from a population of wild origin and rearing these individuals in captivity throughout their lives to produce offspring for the purpose of supplementing wild populations.

Captive Propagation - Artificial propagation programs which hold fish in captive facilities through most or all of a life cycle.

Captive Rearing - A variation of the Captive broodstock strategy wherein fish of wild origin are raised to maturity and released to spawn naturally with wild fish.

Cryopreservation - Preservation of gametes at very low temperature (e.g., use of liquid nitrogen to freeze sperm for later propagative use).

Domestication - Selection for traits that favor survival in an artificial environment and reduce survival in natural environments.

Evolutionarily Significant Unit (ESU) - NMFS' definition of a distinct population segment for Pacific salmon (the smallest biological unit considered to be a "species" under the Endangered Species Act). A population will be considered an ESU if : (1) it is substantially reproductively isolated from other conspecific units, and (2) it represents an important component in the evolutionary legacy of the species.

Fitness - An individual's contribution, relative to other individuals, to the breeding population in the next generation. Measures of an individual's reproductive success such as its survival, fertility, and age at reproduction are typically used as measures of fitness. The fitness of a group of individuals (e.g., a population) may be defined as the group's ability to maintain itself in its environment. Fitness is therefore a composite measure of individual reproductive success.

Hatchery - An artificial propagation facility designed to produce fish for harvest or spawning escapement. A conservation hatchery differs from a production hatchery in that it specifically seeks to supplement or restore naturally spawning populations.

Hatchery fish - A fish that has spent some of its life cycle in an artificial environment and whose parents were spawned in an artificial environment.

Hatchery Population - A population of fish that depends on spawning, incubation, hatching, or rearing in a hatchery or other artificial propagation facility.

Hazard - An undesirable event that an artificial propagation program is attempting to avoid.

Listed species/listed population/listed evolutionarily significant unit (ESU) - For pacific salmon, any ESU that has been determined to be threatened or endangered under Section 4 of the Endangered Species Act.

Native population - A population of fish that has not been substantially impacted by genetic interactions with non-native populations, or by other factors, that persists in all or part of its original range. In limited cases a native population may also exist outside its original range (e.g. in a captive broodstock program).

Natural fish - A fish that has spent essentially all of its life-cycle in the wild and whose parents spawned in the wild.

Population - A group of organisms of the same species that breed in the same place and time and whose progeny tend to return and breed in approximately the same place and time, exhibiting reproductive continuity from generation to generation.

Recovery/restoration - The reestablishment of a threatened or endangered species to a self-sustaining level in its natural ecosystem (i.e., to the point where the protective measures of the Endangered Species Act are no longer necessary).

Recovery program - A strategy for conserving and restoring a threatened or endangered species. An Endangered Species Act recovery plan refers to a plan prepared under section 4(f) of the Act and approved by the Secretary, including: (1) A description of site-specific management actions necessary for recovery; (2) objective, measurable criteria that can be used as a basis for removing the species from threatened or endangered status; and (3) estimates of the time and cost required to implement recovery. (For Pacific salmon, "Secretary" refers to the Secretary of Commerce.)

Risk - The probability of a hazard occurring.

Self-sustaining population - A population that perpetuates itself, in the absence of (or despite) human intervention, without chronic decline, in its natural ecosystem. A self-sustaining population maint0ains itself above the threshold for listing under the Endangered Species Act. In this document, the terms "self-sustaining" and "viable" are used interchangeably.

Stock transfer - Transfer of fish from one location to another. This includes any fish originating outside the geographical boundary of an ESU and transferred into it, any fish transferred out of an ESU's range or between areas occupied by different ESUs, or any fish transferred into vacant habitat.

Stray - An individual that breeds in a population other than that of its parents.

Supplementation - The use of artificial propagation to reestablish or increase the abundance of naturally reproducing populations (c.f. recovery/restoration)

Wild populations - fish that have maintained successful natural reproduction with little or no supplementation from hatcheries.

Appendix 4

Hatchery and Genetic Management Plan (HGMP) Template

A multi-agency group first developed the HGMP concept as a planning tool to address anadromous fish in the *U.S. v Washington* litigation. The National Marine Fisheries Service is in the process of modifying the HGMP template for use in recovery efforts for listed salmon species under the ESA. The U.S. Fish and Wildlife Service is considering using the HGMP template, modified as necessary, to address the needs for recovery of resident fish species listed under the ESA. The Council and other participants in the Artificial Production Review are also reviewing and modifying the draft HGMP template so that it can be used to obtain the kind of information needed from artificial production programs throughout the Columbia Basin to be able to implement the production reforms described in this report. The intent is to modify the HGMP template so that it addresses both resident and anadromous fish and is complementary to the performance standards and associated indicators.

Following is the current draft of the HGMP (version 4) that was available when this report was being finalized. As described it will be modified to reflect the needs of the Columbia Basin.

WORKING DRAFT

Hatchery and Genetic Management Plan (HGMP) Template

The purpose of this hatchery and genetic management plan (HGMP) template is to provide a single source of hatchery information for comprehensive planning by federal, state, and tribal managers, and for permitting needs under the Endangered Species Act (ESA). The information should be the best scientific and commercial information available, as it will help determine if hatchery programs are likely to meet their goals and ESA obligations.

INSTRUCTIONS:

A) If you are a hatchery manager filing out this template, solicit the assistance of staff in your organization or co-manager staff who are familiar with relevant ESU-wide hatchery plans or regional strategic plans, citation of which may replace information requested herein. These staff persons are familiar with the scientific basis for hatchery planning, and can explain why certain information is requested or not needed, and help provide definitions and answers.

If your ESU has an ESU-wide hatchery plan approved by the co-managers and the National Marine Fisheries Service (NMFS), you will be asked to follow the strategies, standards, and guidelines in the ESU hatchery plan, and explain and justify any inconsistencies.

B) If this template is being compiled to determine incidental take from propagation of species not listed under ESA, only certain parts of this template will need to be filled. (See A above)

C) If the population of this template is one which has been transferred from another hatchery, or will be transferred to another hatchery or facility, list all hatcheries and facilities which will handle the population from spawning through adult return, and describe the role of each. (See Section 1.4 below.)

D) Use one template per stock of fish, but avoid duplication by filling out one complete template, and referring to it where information is the same for another population.

E) When take (under the broad definition of ESA) of a listed species is expected in the hatchery operation, provide a numerical estimate. Take needs to be quantified under ESA.

F) Attach or cite (where commonly available) relevant reports that describe the hatchery operation and impacts on the listed species or its critical habitat (See Section 12). Include any Environmental Impact Statements, Environmental Assessments, Biological Assessments, or other analysis or plans that provide pertinent background information to facilitate evaluation of

the HGMP. Where appropriate, use these citations to provide additional support of critical information entered into this HGMP.
G) This template is provided on a computer floppy disk or in an electronic file so the information can be filled out electronically. The template text is in bold type (Have not done this yet, but will - DP). To enter information, use non-bold 12 point font size.

SECTION 1. GENERAL PROGRAM DESCRIPTION

1.1) Name of Program

1.2) Population (or stock) and species
state common and scientific names

1.3) Responsible organization and individual:
Name(and title):
Organization
Address:
Telephone:
Fax:
Email:

Other organizations involved, and extent of involvement in the program:

1.4) Location(s) of hatchery and associated facilities:
Include state and basin, regional mark processing center code, and sufficient information for GIS entry. See Instruction C above and use this section to provide information.

1.5) Type of program:
Select one from Integrated Recovery; Integrated Harvest; Isolated Recovery; Isolated Harvest. See Instruction A. (Note: Will add a page of definitions to template to cover terms such as these.)

1.6) Purpose (Goal) of program:
This is a one sentence statement of the goal of the program, consistent with your answer to section 1.5   Example: The goal of this program is to aid in the conservation and recovery of chinook salmon in Deer Creek.

1.7) Specific performance objective(s) of program
Objectives are designed to achieve the program goal, and are generally measurable, realistic, and time specific. Example: The goal of this program will be achieved by (1) using supplementation to increase by five folds the number of natural spawners in Deer Creek, by year 2012; (2)....; (3)....

1.8) List of Performance Indicators designated by "benefits" and "risks"

(Note: This section and section10 (monitoring and evaluation) are being rewritten for compatibility with current work on performance indicators in the Columbia River basin, and in the Hood Canal Summer Chum Hatchery Plan.)

Performance indicators determine the degree that program objectives have been achieved, and provide the specific parameters to be monitored and evaluated.

Separate indicators into two categories of "benefits" and "risks" the hatchery program will provide to the listed species. Where possible, use indicator list already compiled in ESU-wide hatchery plan or other strategic plans.

Some indicators examples are (1) adult:adult replacement rates of program fish; (2) trends in spawning abundance in Deer Creek measured by natural return rates and egg-to-smolt survivals; (3) predation on other species by program fish as measured by stomach content analyses; (4) genetic effects on other populations by program fish as measured by stray rates; (5) etc.

1.9) Expected size of program

Specify expected releases, adult fish harvested, and escapement goals. For existing program, provide additional historic data for three generations, or for the number of years of available and dependable information.

1.10) Date program started or is expected to start:

1.11) Expected duration of program:

1.12) Watersheds targeted by program:

Provide sufficient information for GIS entry.

SECTION 2. RELATIONSHIP OF PROGRAM TO OTHER MANAGEMENT OBJECTIVES

2.1) List all existing cooperative agreements, memoranda of understanding, memoranda of agreement, or other management plans or court orders under which program operates. Indicate whether this HGMP is consistent with these plans and commitments, and explain any discrepancies.

2.2) Status of natural populations in target area.

For "integrated" programs (i.e., supplementation programs or other programs that involve close integration with a specific natural population), identify the natural population targeted for integration.

2.2.1) Geographic and temporal spawning distribution.

2.2.2) Annual spawning abundance for as many years as available.

2.2.3) Progeny-to-parent ratios, survival data by life-stage, or other measures of productivity for as many brood years as available.

2.2.4) Annual proportions of hatchery and natural fish on natural spawning grounds for as many years as possible.

2.2.5) Status of natural population relative to critical and viable population thresholds. *See Instruction A.*

2.3) Relationship to harvest objectives

Include past harvest rates and expected future harvest rates on fish propagated by the program and on natural populations in the target area. Explain whether artificial production and harvest management have been integrated to provide as many benefits and as few biological risks as possible to the listed species.

2.4) Relationship to habitat protection and recovery strategies.

Describe the major factors inhibiting natural production (if known), such as habitat protection efforts with expected natural production benefits over the short-term and long-term.

2.5) Ecological interactions

Describe salmonid and non-salmonid fishes or other species that could (1) negatively impact program; (2) be negatively impacted by program; (3) positively impact program; and (4) be positively impacted by program. Give careful considerations to the unlisted but listable indigenous species.

SECTION 3. WATER SOURCE

Provide a quantitative and narrative description of the water source (spring, well, surface, etc.), water quality profile, and any differences between hatchery water and water used by the naturally spawning population.

SECTION 4. FACILITIES

Provide descriptions of the physical plants listed in this section, and three additional sets of information.

> One, for programs that directly take listed fish for use as brood stock, provide detailed information on catastrophe management, including safeguards against equipment failure, water loss, flooding, disease transmission, or other events that could lead to a high mortality of listed fish.
>
> Two, describe any instance where construction or operation of the physical plant results in destruction or adverse modification of critical habitat designated for the listed species.
>
> Three, describe any inconsistencies with standards and guidelines provided in any ESU-wide hatchery plan approved by the co-managers and NMFS.

4.1) Brood stock collection

4.2) Spawning

4.3) Incubation

4.4) Rearing

4.5) Acclimation/release

4.6) Other

SECTION 5. ORIGIN AND IDENTITY OF BROOD STOCK

5.1) Source

> *List all sources of brood stock for the program. Be specific (e.g., natural spawners from Bear Creek, fish returning to the Loon Creek Hatchery trap, etc.)*

5.2) Supporting information

> 5.2.1) History
>
> *Provide a brief narrative history of the brood stock sources. For natural populations, specify its status relative to critical and viable population thresholds (use section 2.2.5 if*

appropriate). For existing hatchery stocks, include information on how and when they were founded, and sources of brood stock since founding. If stock crosses, list stock of each sex.

5.2.2) Annual size
Include past brood stock sizes as well as proposed future sizes. Specify number of each sex, or total number and sex ratio, if known. For natural population brood stocks, explain how their use will affect their population status relative to critical and viable thresholds.

5.2.3) Past and proposed level of natural fish in brood stock.
If using an existing hatchery stock, include specific information on how many natural fish were incorporated into the brood stock annually.

5.2.4) Genetic or ecological differences
Describe any known genotypic, phenotypic, or behavioral differences between proposed hatchery stocks and natural stocks in the target area.

5.2.5) Reasons for choosing
Describe any special traits or characteristics for which brood stock was selected.

5.3) Unknowns
Identify areas where a lack of data leads to uncertainties about the choice of brood stock.

SECTION 6. BROOD STOCK COLLECTION

Describe any inconsistencies with standards and guidelines provided in any ESU-wide hatchery plan approved by the co-managers and NMFS.

6.1) Prioritized goals
List in order of priority the general goals for brood stock collection. Refer to sections 1.5 and 1.6.

6.2) Supporting information

6.2.1) Proposed number of each sex.

6.2.2) Life-history stage to be collected (e.g., eggs, adults, etc.)

6.2.3) Collection or sampling design
Include information on the location, time, and method of capture. Describe capture efficiency and measures to reduce sources of bias that could lead to a non-representative sample of the desired brood stock source. Also, describe the method of capture (e.g. weir trap, beach seine, etc.) and quantify as take handling, behavior modification, stress, or mortality of listed fish.

6.2.4) Identity
Describe method for identifying (a) target population if more than one population may be present; and (b) hatchery origin fish from naturally spawned fish.

6.2.5) Holding

Describe procedures for holding fish, especially if captured unripe or as juveniles. Quantify as take trapping, holding, stress or mortality of listed fish.

6.2.6) Disposition of carcasses

Include information for spawned and unspawned carcasses, sale or other disposal methods, and use for stream reseeding.

6.3) Unknowns

Identify any data gaps that lead to uncertainties about brood stock collection.

SECTION 7. MATING

Use standards and guidelines provided in any ESU-wide hatchery plan, or other regionally accepted protocols (e.g. IHOT) approved by the co-managers and NMFS. Explain and justify any deviations.

7.1) Selection method

Specify how spawners are chosen, e.g. randomly over whole run, randomly from ripe fish on a certain day, selectively chosen, prioritized based on hatchery or natural origin, etc.

7.2) Males

Specify expected use of backup males and repeat spawners.

7.3) Fertilization

Describe fertilization scheme, such as equal sex ratios and 1:1 individual matings; equal sex ratios and pooled gametes; or some other. Explain any fish health procedures used for disease prevention.

7.4) Cryopreserved gametes

If used, describe number of donors, year of collection, number of times donors were used in the past, and expected and observed fertility.

7.5) Unknowns

Identify any data gaps that lead to uncertainty in mating protocols.

SECTION 8. REARING AND INCUBATION

(Note: The information requested in this section is under evaluation to determine if additional standardization is needed to assure relevancy and utility.)

Provide current and previous goals and data. Include historic data for three generations or for years dependable data are available. Use standards and guidelines provided in any ESU-wide hatchery plan, or other regionally accepted protocols (e.g. IHOT) approved by the co-managers and NMFS. Explain and justify any deviations.

INCUBATION:

8.1) Number of eggs taken and survival objective to ponding

8.2) Loading density

Include description of the incubator(refer to Section 4.4). Also, provide measurement of egg size.

8.3) Influent and effluent gas concentration

(Dissolved Oxygen, and any other parameters monitored)

8.4) Ponding

Describe degree of button up, cumulative temperature units, and mean length and weight (and distribution around the mean) at ponding. State dates of ponding, and whether swim up and ponding are volitional or forced.

8.5) Fish Health monitoring

Describe any diseases, yolk-sac malformation, and mortality.

REARING:

8.6) Number of fish ponded and survival objective to release

8.7) Density and loading.

Include a description of the rearing containers, such as start tanks, circulation, circulating ponds, flow through, etc. Refer to section 4.4.

8.8) Influent and effluent gas concentrations

(oxygen, carbon dioxide, total gas pressure)

8.9) Length, weight, and condition factor.

8.10) Growth rate, energy reserves

(hepatosomatic index - liver weight/body weight) and body moisture content as an estimate of body fat concentration.

8.11) Food type and amount fed, and estimates of feed conversion efficiency.

8.12) Health and disease monitoring.

8.13) Smolt development indices, if applicable

(e.g. gill ATPase activity).

8.14) Use of "natural" rearing methods.

8.15) Unknowns

Describe data gaps that lead to uncertainty in the incubation and rearing protocols.

SECTION 9. RELEASE

Provide current and previous goals and data. Include historic data for three generations or for years dependable data are available. Also, describe any inconsistencies with standards and guidelines provided in any ESU-wide hatchery plan approved by the co-managers and NMFS.

9.1) Life history stage, size, and age at release.

Give averages with distribution.

9.2) Life history stage, size and age of natural fish of same species in release area at time of release.

9.3) Dates of release and release protocols.

Specify whether release is volitional or forced.

9.4) Location(s) or release.

Provide specifications to allow GIS entry.

9.5) Acclimation procedures.

9.6) Number of fish released

9.7) Marks used to identify hatchery adults.

9.8) Unknowns

Describe data gaps that lead to uncertainty in the release protocols.

SECTION 10. MONITORING AND EVALUATION OF PERFORMANCE INDICATORS

(Note: This section and Section 1.8 are being rewritten for compatibility with current work on performance indicators in the Columbia River basin, and in the Hood Canal Summer Chum Hatchery Plan.)

This section describes how the benefit or risk performance indicators listed in Section 1.8 will be monitored and evaluated, including whether funding, staffing, and other support logistics are available or committed to allow full implementation.

The items below should be incorporated into the performance indicator list and the attendant monitoring and evaluation program.

10.1) Marking

Describe types of mark(s) and the proportion of the program releases that will be marked. Include any marking of wild fish for comparative analysis.

10.2) Genetic data

Provide available and relevant genetic baseline information.

10.3) Survival and fecundity

Provide data on goals and past performances.

10.3.1) Average fecundity

10.3.2) Survival

a) Collection to spawning
b) Green eggs to eyed eggs
c) Eyed eggs to release
d) Release to adult, to include contribution to
    (I) harvest
    (ii) hatchery brood stock
    (iii) natural spawning10.4) Monitoring of performance indicators in Section 1.8

The following are examples.

10.4.1) Proportions of hatchery spawners in natural populations in target area (list all populations or spawning areas that are monitored).

10.4.2) Ecological interactions between program fish and natural fish (same and other species) in target area.

10.4.3) Disease control in the hatchery, and potential effects on natural populations.

10.4.4) Behavior (migration, spawning, etc.) of program fish.

10.4.5) Homing or straying rates for program fish.

10.4.6) Gene flow from program fish into natural populations.

10.5) Unknowns or uncertainties identified in Sections 5 through 9

10.6) Other relevant monitoring projects

SECTION 11. RESEARCH

(Note: This section is being reviewed against Section 10 requirements and will be edited as needed.)

Provide the following information for any research programs conducted in association with the HGMP. Correlate with research described in any ESU hatchery plan approved by the co-managers and NMFS.

11.1) Objective or purpose
Need for data; benefit or effect on wild population; broad significance of project.

11.2) Cooperating and funding agencies

11.3) Principle investigator or project supervisor and staff

11.4) Status of stock, particularly the group affected by project

11.5) Techniques: include capture methods, drugs, samples collected, tags applied

11.6) Dates or time period in which research activity occurs

11.7) Care and maintenance of live fish or eggs, holding duration, transport methods

11.8) Level of take: number or range of fish handled, injured, or killed by sex, age, or size

11.9) Potential for / estimates of injury or mortality, and methods to reduce either

11.10) Alternative methods to achieve project objectives

11.11) List species similar or related to the threatened species; provide number and causes of mortality related to this research project

SECTION 12. ATTACHMENTS AND CITATIONS

Attach or cite (where commonly available) relevant reports that describe the hatchery operation and impacts on the listed species or its critical habitat. Include any EISs, EAs, Biological Assessments, or other analysis or plans that provide pertinent background information to facilitate evaluation of the HGMP.

Appendix 5

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