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Mainstem/Systemwide Province Artificial Production Program Summary

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Northwest Power Planning Council

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Table of Contents

Table of Figures

Table of Tables

I. PROGRAM DESCRIPTION

Opportunities to significantly increase production of naturally produced salmonid populations through improvements in natural habitats may be somewhat limited due to the lack of suitable fish habitat remaining in the Columbia Basin. The lack of adequate habitat coupled with competing societal demands has forced the region to look for alternative methods to augment fish populations. For many years, artificial production of juvenile fish for release has been used to help mitigate for the loss of important spawning, rearing, and migration corridor areas. Fish hatcheries and other artificial production programs have made an important contribution to the basin by sustaining or increasing regional harvest opportunities and have provided for the maintenance or reintroduction of some naturally produced salmonid populations. However, while artificial production can be used as an important tool to increase juvenile and adult fish, it may carry inherent risks to naturally spawning populations. Critical regional issues are whether artificial production can increase the number of adults for harvest opportunities and continued propagation while still protecting or enhancing naturally spawning populations and whether artificial propagation can enlarge existing naturally spawning populations. Human development has changed freshwater and estuarine habitats in the Columbia River Basin, reducing opportunities for natural populations to exist and migrate normally.

The primary purpose of the Mainstem and Systemwide Artificial Production Program is to improve existing artificial production activities and ensure that artificial production programs will protect or enhance naturally spawning populations. The Northwest Power Planning Council (Council) 2000 Fish and Wildlife Program (Program) outlines the general approach of how artificial production should be utilized in the basin. The Program states that, "artificial production actions must have an experimental, adaptive management design. This design will allow the region to evaluate benefits, address scientific uncertainties, and improve hatchery survival while minimizing the impact on, and if possible, benefiting fish that spawn naturally." It further discusses artificial production strategies within certain limits imposed by habitat condition and improvement, and in reference to subbasin plans. The Program protects listed and mixed-stock fisheries by limiting adverse effects and supporting effective harvest of hatchery fish. It is one of four important documents prepared in 2000 by regional salmon recovery groups that contain recommendations for hatchery reforms: Program, Federal Caucus Conservation of Columbia Basin Fish Final Basinwide Salmon Recovery Strategy (formerly known as the All-H Paper), Federal Columbia River Power System Biological Opinion (FCRPS Biological Opinion), and the Governors' Plan. The documents have common recommendations that are found in the Artificial Production Review (APR), as well as additional strategies that may be applied to reforming artificial production to meet Program goals.

The scope of the Council's program is represented by a basinwide approach to artificial production reform which was developed by the APR process completed in November 1999. The APR process developed a comprehensive set of artificial production policies and recommendations for the basin involving anadromous and resident fish. The Council adopted the policies and recommendations produced by the APR and incorporated them into the Program.

In summary, the policies are:

- The purpose and use of artificial production must be considered in the context of the ecological environment in which it will be used.
- Artificial production must be implemented within an experimental, adaptive management design that includes an aggressive program to evaluate the risks and benefits and address scientific uncertainties.
- 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.
- 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.
- 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.
- The entities authorizing or managing an 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.
- Decisions on the use of the artificial production tool needs to be made in the context of fish and wildlife goals, objectives, and strategies at the subbasin and province levels.
- Appropriate risk management needs to be maintained in using the tool of artificial propagation.
- 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.
- Federal and other legal mandates and obligations for fish protection, mitigation, and enhancement must be fully addressed.

The APR report also made recommendations on how to best implement artificial production reform in the basin. The first phase of a basinwide artificial production reform effort is now underway. The Council has initiated a process to evaluate all artificial production facilities and programs within the Columbia Basin. This evaluation will attempt to answer fundamental questions as to whether the artificial production program is meeting its stated purposes, legal mandates, and operational goals; whether the program is affecting naturally spawning populations; and finally, in today's context, does this program still make sense. The evaluations will help determine whether a current artificial production program should maintain, alter, or shut down current operations. Also, because it is a basinwide evaluation of all hatcheries, the evaluation will assist the region to understand the scope and projected cost of needed hatchery reforms in the Columbia Basin. The program/facility evaluations will also provide valuable information to subbasin planning processes and regional Endangered Species Act (ESA) recovery planning. During evaluations, data types, storage methods, and metadata associated with the information gathered will be reviewed to propose standardized data gathering, archiving and metadata for future work as recommended in the Review of Databases Funded through the Program (Council Document ISRP 2000-3). Common data definitions and identification of data in a spatial and temporal context will aid distributed access systems for basin-wide monitoring and evaluation of hatchery and wild populations.

The formation of the Council's Artificial Production Advisory Committee (APAC) is called for under the 2000 Fish and Wildlife Program. The primary purpose of the committee is to advise the Council on how best to achieve a regional perspective and unified approach to artificial production reform in the Columbia River Basin. The membership of APAC includes representatives from the fish agencies, tribes, utilities, environmental organizations and universities. The first meeting of the APAC occurred in July 2001. The committee's first assignment from the Council was to initiate a review of the purposes and operations of all artificial production programs in the basin.

Over a period of several months, APAC has helped to develop the workplan and deliverables for the artificial production Facility/Program Review and Evaluation (FPRE). The FPRE is currently underway and has several objectives:

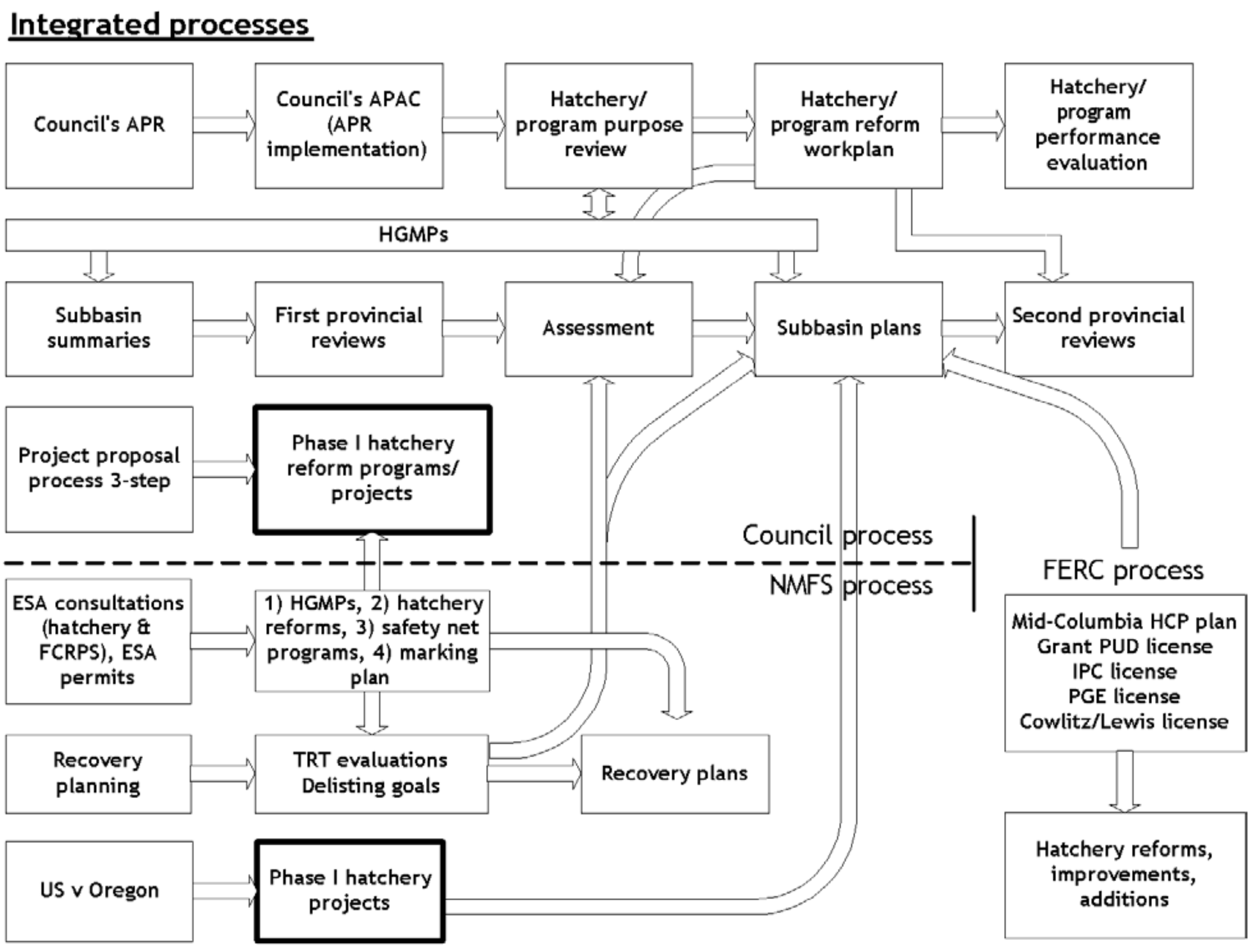
- Determine program consistency with legal, policy, and scientific criteria.
- Determine program alignment with mandate, purpose, and operations.
- Inform the sub-basin planning process about the extent and appropriateness of artificial production programs within sub-basin waters.
- Determine the state and progress of hatchery reform in the Columbia River Basin.
- Estimate the funding requirements for hatchery reform.
- Create a central database of critical artificial production information to monitor reform, inform fisheries managers, support other regulatory and planning processes, and analyze future production/harvest strategies and scenarios.
- Determine if the production program optimally contributes to current fishery management objectives and priorities.

In general, the FPRE will provide valuable information on how best to implement artificial production reform at a programmatic, subbasin and regional basis for listed and unlisted resident and anadromous fish.

It is intended that the FPRE will be fully integrated with the Hatchery and Genetic Management Plan (HGMP). Unlike the FPRE process, HGMPs focus primarily on individual artificial production programs. An HGMP is a comprehensive and detailed plan that describes the facilities, operations, benefits, risks, performance, and evaluation of artificial production programs (by species, by sub-basin). An HGMP is a tool used by National Marine Fisheries Service (NMFS) and U.S. Fish & Wildlife Service (USFWS) pursuant to the ESA to assess impacts of artificial production programs on listed species in (a) issuance of section 10 permits, (b) conduct of section 7 consultations, and (c) assessments conducted under NMFS' 4(d) Rules. The HGMP was also created to serve as a common template and source of information for (i) local and regional fish production and management planning, (ii) sub-basin planning, (iii) recovery planning, (iv) scientific review of production programs, and (v) hatchery performance reviews. The Council will use HGMPs as a tool to help ensure implementation of its hatchery reform policies. NMFS/USFWS will use HGMPs as their primary tool for regulating production programs and integrating them into recovery plans pursuant to the ESA.

Figure 1 below graphically illustrates the integrated hatchery reform effort of the Council's Program and the major processes involved including fish recovery with NMFS and USFWS and the Federal Energy Regulatory Commission (FERC) hatchery mitigation effort. It should be noted that these integrated processes all provide input into the subbasin plans in terms of the goals, objectives and strategies to achieve recovery of listed fish and protection, mitigation and enhancement of non-listed fish. The fiscal allocation required to implement the subbasin plans in so far as hatcheries are proposed as a management strategy will be thoroughly reviewed in the Provincial Project Review process (second round) to begin in Fiscal Year 2003.

Figure 1. Integrated Hatchery Reform and Mitigation Efforts



II. PROGRAM ACCOMPLISHMENTS

A. What have we collectively learned regarding the use of artificial propagation as a management strategy?

Pacific salmon are unique among species under ESA protection in having large-scale hatchery programs that co-occur in time and space with listed natural populations. Modern production hatcheries are so instrumental in supplying salmonids to the common property resource that it is almost impossible to separate management of the fisheries from management of the hatcheries. The Pacific salmon are also different from other organisms in that they have a very lengthy and diverse migration pattern which passes through intercepting fisheries controlled by several nations in addition to several states and Indian Tribes. Over five billion hatchery-reared juveniles are released annually into the Pacific Ocean from Pacific Rim hatcheries. On the Columbia River alone, nearly 150 hatchery facilities produce approximately 130 million fish, which provide up to 80% of the fish in key fisheries. Advancements in culture technologies (e.g., nutrition and health care) have allowed hatcheries to successfully rear juvenile life stages of all species of Pacific salmon. However, despite the great success of production hatcheries, the final decades of the twentieth century have seen the emergence of a different philosophy behind salmon resource management. Although the production capabilities of hatcheries and their sustainable fisheries contributions are well established, a newly defined role for conservation purposes is less clear.

Concerns about impacts on listed salmon species resulting from production hatchery programs constitute a major uncertainty for salmon management in the next decade. Hatchery fish may differ from wild fish in a number of important genetic, physiological, nutritional, behavioral, ecological, and health and life history parameters. The magnitude of differences and the generation effect can vary greatly. For instance, in extreme cases of domestication and importation of extraneous genetic material, the genetics of the hatchery stock may be rendered severely maladapted for survival in any other environment than artificial for certain life stages. Likewise, the morphology, behavior, and health of hatchery fish may be altered to the point that the hatchery fish have extreme loss of fitness for the natural environment. While such cases of extreme differentiation between hatchery and wild fish have only been documented in a few cases where hatchery intervention has been prolonged and poorly executed, less extreme differences between hatchery and wild fish are often noted.

It is commonly accepted that hatchery fish are less reproductively fit than native wild fish in a natural environment, but it is not clear if those differences are biologically meaningful. There is some evidence that hatchery juveniles are known to be more aggressive than wild fish, prefer higher social densities, have lowered territorial fidelity and predator responses, and have lowered post release survival. This is possibly an environmental difference rather than a genetic one perhaps influenced more by rearing-related factors than a fundamental wild versus hatchery difference. The potential impacts of hatcheries on wild populations are commonly acknowledged as 1) decreasing abundance by mining spawners from natural populations; 2) decreasing abundance or distribution by competition, predation, or disease; 3) decreasing fitness through domestication selection, increasing inbreeding, or by introducing alleles that are deleterious compared to local alleles; 4) reducing genetic and/or life history diversity of the population; and 5) masking the relative abundance of natural populations on spawning grounds.

The magnitude of impacts of production hatcheries is poorly understood. However, a few recent studies have suggested that such impacts may be significant. This uncertainty is summed up by Brannon et al. (1998) (http://www.nwppc.org/98-33.htm) (Part I., Section VI.):

> "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, which demonstrates the mechanisms that theory is based on, 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 on interaction with hatchery fish, as well as even the poor success of hatchery fish on hatchery practices, such evidence, at best, is indirect and neglectful of the other major environmental perturbances in the system. The task of making linkages is a formidable one, but necessary in the fair resolution of hatchery assessment."

Overall, the largest immediate risk may be in production of fish with lowered physiological and behavioral development that are ecologically unsuited to the post release environment (Flagg et al. 2000a), or demonstrate poor reproductive success.

Hatcheries also can have a number of potential benefits. It is clear that sustainable fisheries for salmon and steelhead in the 21st century will depend on a level of hatchery production. Even under optimistic scenarios, natural populations cannot be expected to satisfy commercial, sport, and tribal harvest goals; therefore, hatchery fish will play an important role in supporting salmon abundance into the foreseeable future, including meeting mitigation and compensation objectives. For wild stock supplementation, hatcheries may be the quickest means to increase or maintain abundance of wild populations, ameliorate survival bottlenecks, minimize inbreeding effects by maintaining or increasing effective population size, increase or maintain fitness by replacing deleterious alleles that have become fixed in local populations, and speed recovery efforts through captive broodstocks.

The conditions and operation of the hatchery tend to dictate the expression of potential differences between the hatchery fish and their wild counterparts yet environmental perturbances may ultimately affect success. The balance to understanding the proper use of hatcheries will be in properly evaluating risks and benefits. These will differ depending on the different production-to-conservation roles the hatchery may undertake.

Initial, antiquated, production hatchery methodology probably had a more severe impact on fitness characteristics than present methodologies. Beginning in the late 1900s, reforms were championed to mitigate the effects of hatcheries on wild fish. The range of reforms to existing hatcheries primarily included development of new, local broodstocks and eliminating non-local broodstocks, adopting genetically appropriate mating protocols, implementing improved rearing protocols, improving disease management, managing the number of hatchery fish allowed to spawn naturally, constructing acclimation facilities to improve survival and homing, constructing broodstock collection facilities, marking hatchery fish to distinguish them from natural-origin fish, and developing hatchery and genetic management plans to comprehensively guide operations and monitoring and evaluation programs.

Supplementation strategies by which hatcheries are used to produce fish from wild stocks that are reintroduced into the natural environment to become naturally spawning wild fish are a relatively recent development and one about which there is both controversy and uncertainty. Supplementation projects generally utilize production hatchery rearing methods with juvenile releases normally occurring at acclimation sites to provide homing to target areas. Supplementation has the potential benefits of reducing short-term risk of extinction, speeding recovery if limiting factors are removed/reduced, reseeding vacant habitat, and increasing harvest opportunity. These benefits remain at risk if limiting factors, leading to the need to boost natural production, are not addressed. To date little information is available regarding the performance of supplemented fish and their progeny in the natural environment. However, interspecies interactions will occur with non-target fish species. When supplementation is used, it should be regarded as experimental and carried out within an adaptive management framework.

The listing of salmonid stocks under ESA generated an active conservation role for hatcheries that is expressed in the 2000 FCRPS Biological Opinion. The goals of a modern conservation hatchery incorporate wild broodstock, gene pool preservation and population recovery. Captive broodstock rearing of salmon to adulthood in protective culture may also be used to provide gametes for recovery actions a strategy proposed in the Basinwide Salmon Recovery Strategy. However, intensive genetic oversight is provided in all cases to ensure sourcing, rearing, and mating protocols to protect genetic integrity. For these programs, juvenile rearing should be conducted in a manner to minimize domestication and mimic natural life history parameters to the extent possible. For instance, fish may be reared in habitats enriched with cover, structure, and substrate; provided currents for orientation; fed to enhance coloration, fin quality, size and condition factor and conditioned to avoid predators. Conservation hatcheries should, if practical, aim to release juveniles at a size range that equals the size distribution of the wild population and with a volitional outmigration pattern, unless the environment is adverse to juvenile survival under that rearing and release strategy. When supplementation is used, it should be regarded as experimental and carried out within an adaptive management framework.

Conservation hatcheries should function in ways that reflect the latest scientific information and conservation practices to maintain genetic diversity and natural behavior and to reduce the short-term risk of extinction (Flagg et al. 1999, 2000b). Exact application of the conservation hatchery strategies outlined above will depend on physical and management limitations of individual hatcheries. Conservation hatchery concepts have not been in operation long enough to be fully developed or tested. However, initial information indicates rearing more wild-like fish under conservation strategies may increase normal behavioral and ecological interactions and increase survival.

Monitoring, evaluation, and assessment of artificial production is a necessary component of the Mainstem/Systemwide Artificial Production Program: 1) to report progress, to assess reform measures, and determine consistency with the APR (Program), 2) as a first step in the design of reforms (FCRPS Biological Opinion), and 3) to determine the purpose of each hatchery in supporting fish recovery and harvest (Governors' Plan).

B. What are the critical biological questions that remain unanswered or are under the process of being answered by the currently funded projects?

Research to address effects of hatcheries has been identified as high priority by various regional groups and expert panels. The Basinwide Salmon Recovery Strategy reflects recommendations from other documents and cites the potential risks of interactions between wild and hatchery fish. Several specific strategies are recommended for hatcheries including: 1) use of local broodstocks (and elimination of inappropriate broodstocks), 2) minimizing straying, 3) HGMPs, 4) captive brood stock, and 5) conservation hatcheries.

The 2000 FCRPS Biological Opinion - ESA Section 7 Consultation addresses actions to be taken related to objectives for location specific impacts to listed species. Almost all actions proposed might affect artificial production reform because the listed species are anadromous and at some point in their history encounter hatchery fish, or other listed stocks in the FCRPS. Some sections provide detailed information regarding hatcheries, life history information, and population trends and risks that apply directly to the Mainstem/Systemwide Artificial Production Program. Section 4 gives explicit proposed actions for salmon and steelhead that are population specific. Artificial production program projects will need to consider each of the following in the project design: 1) historical records of the geographic and spatial distribution of original local stock, 2) the life history of local stocks; 3) how current habitat and hydrology will affect the outcome of the project (critical uncertainties); 4) the influence and risks of their hatchery stocks on wild/naturally spawning stocks; and 5) populations trends and risks that will provide an evaluation of the success of the project action. Section 5 looks at judicial uses of artificial production that will not adversely affect the environmental baseline of areas of critical habitat for wild stocks. Hatchery fish may interact with wild fish in all the critical areas including: 1) juvenile rearing areas, 2) juvenile migration corridors, 3) areas for growth and development to adulthood, 4) adult migration corridors, and spawning areas. Effects of the artificial production program should be addressed for each critical area, and the effects of cyclical changes in natural conditions should be considered in monitoring and evaluation objectives for each project. Section 6 provides guidance for analytical methods to evaluate effects at specific sites in the hydrosystem. Hydropower operations will contribute to the outcome of all artificial production projects when released fish use the mainstem migrational corridor. Each artificial production project will describe the biological requirements of the hatchery fish over the complete life cycle, to help in the analysis of the effects of FCRPS operations on project outcome. Artificial production projects will reference, coordinate and cooperate with state, tribal, local, and private actions (Section 7). Estimates of the effect of transportation actions will need to be included in the critical uncertainties for the project (Section 8). Section 9 discusses Reasonable and Prudent Alternatives and is the most important in the 2000 FCRPS Biological Opinion regarding artificial production. Many hatcheries provide off-site mitigation, and under section 9.4.2.7 and section 9.6.4, broad goals for artificial production measures are outlined: to reduce and eliminate adverse genetic, ecological, and management effects on natural populations while retaining and enhancing hatcheries contributions to achieve conservation, recovery and mitigation. Reform measure actions for artificial production are more explicit (section 9.6.4.2) and can be built directly into the Mainstem/systemwide Artificial Production Program. A research, monitoring and evaluation plan, including data management, is outlined in 9.6.5 and should serve as a template for evaluating artificial production project performance. Analysis of effects of the FCRPS on egg-to-smolt survival, as well as other life stages, is mandated in section 9.7. Hatcheries typically release juveniles at the smolt stage, and the artificial production program project should require descriptions of how it affects survival at the egg-to-smolt, and each of the subsequent life stages, as a measure of critical uncertainties associated with the project.

The Governors' Plan recommends changes in hatchery management practices and reviews of individual hatcheries to support hatchery reform. Several strategies not found in the other documents are outlined: 1) development of a regional supplementation plan, 2) wild fish refuges, and 3) marking programs to facilitate terminal and selective hatchery fish harvest programs.

Measuring, quantifying, and evaluating genetic and ecological consequences of hatchery fish on wild populations are the primary obstacles to assessing the conservation and sustainable fisheries roles of hatcheries. At present, there is evidence that hatchery programs can have both positive and negative effects on natural populations, but low inferential power hinders our ability to predict the nature or magnitude of these effects that will occur in any specific situation. Despite the over 100 years of hatchery research and technology development, there is a dearth of empirical evidence and quantifiable data on genetic and ecological effects. Key issues regarding hatcheries and natural populations must be resolved. These issues can be framed in terms of four questions:

1. ***Can hatchery and natural production be successfully integrated to conserve natural population vigor and structure and allow sustainable fisheries?***

2. ***Is it possible to minimize impacts to wild fish from releases of hatchery fish for harvest augmentation?***

3. ***Is it possible to produce juvenile fish from conservation hatcheries that can contribute to increased natural productivity and aid in recovery of listed populations?***

4. ***How quickly do the negative effects of artificial propagation accumulate and how quickly are they reversed by natural selection?***

As noted, hatchery programs for conservation are viewed as adaptive and experimental. The key questions can be subdivided into seven smaller questions that are addressable as hypotheses that are experimentally testable.

1. **What is the relative fitness of hatchery fish when they spawn in the wild?** In order to draw the most fundamental conclusions about wild stocks (are they self-sustaining or declining due to relative impacts of hatchery fish) we must know the relative fitness of hatchery fish that spawn in the wild. At present, information bounds relative fitness as "*somewhere between 20% and 80%*". Without better information, it is difficult to assess relative effects of hatchery fish versus other environmental or management effects. Not all natural populations are even affected by hatcheries which help to act as controls to tease out common environmental or management effects. A second reason we must evaluate the relative fitness of hatchery fish is that this parameter determines the longer-term evolutionary impact of hatchery strays on wild populations, which leads to the next question.

2. **To what extent does hatchery production undermine local adaptation in a manner that threatens the long-term viability of salmonids?** The answer could be "not at all", or the answer could be that the combination of hatchery strays and small population sizes is depleting local adaptation to such an extent that we are risking salmon population viability in

the face of dramatic climate change. That is to say if the hatchery fitness is high (question 1) then the answer to this question can be "substantial". This question is much broader than a hatchery issue, requires a general understanding of the role of local adaptation in salmon populations, and will help define rational recovery goals and strategies (how many and which populations to protect).

3. **Can we quantify the ecological consequences of hatchery production (and proposed improvements in hatchery practices) in terms of altered survival of wild fish?** Precise information on the biology, physiology, ecology, behavior, and health of wild and hatchery stocks of salmonids in the Northwest is lacking. Specific information, particularly in terms of ecological and genetic consequences of hatchery production and rearing practices, needs to be developed to provide a template for recovery actions that will retain locally adapted characteristics of wild stocks. Fundamental changes in hatchery production policy and implementation may be necessary where listed stocks overlap hatchery operations. Development of fully successful conservation hatchery strategies requires quantification of the differences between hatchery and wild fish and an understanding of the mechanisms causing those genetic, physiological, behavioral, and phenotypic differences.

4. **Do hatchery reform measures work in the sense of yielding adequate smolt-to-adult returns of hatchery fish to support harvest and rebuild wild stocks?** Recent research has suggested that differences between hatchery fish and wild fish have the potential to be mitigated through improved husbandry. However, the hypothesis that conservation hatcheries can produce fish with reduced impacts on wild stocks needs to be tested at production scales. There are likely to be trade-offs involved in hatchery reform. For example, attempts to release more 'natural' fish may result in lower harvestable numbers than are currently possible with more intensive culture techniques. Reform of hatcheries in the manner of conservation hatcheries will fail if survival of hatchery-reared fish is so low that the end result is a decreasing population size.

5. **Can invasive husbandry technologies such as captive broodstocks be used to retain population uniqueness and aid in recovery of stocks on the verge of extinction?** Direct intervention may be the only means of maintaining some ESA-listed stocks in the short term while factors for population decline are being addressed. Essentially, captive propagation of endangered animals has been shown to decrease the acute risk of extinction from demographic and environmental hazards. Captive broodstocks have been identified as a method of choice when extreme intervention is required. Over a dozen formal captive broodstocks are currently underway for ESA-listed stocks and more are proposed. Captive broodstock programs are a form of artificial propagation where animals of wild origin are maintained in captivity throughout their life and adults or offspring are released to supplement wild populations. Because of potentially high survival in captivity, captive broodstock technology has the ability to markedly amplify endangered populations in a short time frame. Captive propagation of animals to maximize their survival and reproductive potential has won acceptance in endangered species restoration worldwide. Nonetheless, captive broodstock technology for Pacific salmon is relatively new and many uncertainties remain regarding their potential to maintain genetic integrity and provide useful population amplification.

6. **What are the appropriate trigger points to implement artificial propagation strategies?** Criteria need to be developed to determine when intervention using artificial propagation should occur. When to implement conventional-hatchery, supplementation, captive rearing, or captive broodstock approaches in hopes of recovering stocks needs to be defined. It seems that the current approach is to monitor a population until it is essentially functionally extinct and then implement a captive broodstock program in hopes of preserving some fraction of the stock's uniqueness. Developing a schedule of artificial propagation interventions based on demographic and genetic statistics for a population could provide an optimal strategy to recover specific stocks.

7. **Are there other recovery/management strategies that can be used to restore anadromous fish populations?** The current status of most of the Columbia River Basin's fish stocks is at such a depressed state that it is time for a solicitation of projects using the most innovative of approaches to artificial propagation and recovery. Essentially three artificial production strategies are used in the Columbia River Basin: conventional hatchery, captive broodstock, and supplementation. The decline of animal populations is a global issue and Columbia River salmon restoration solutions may come from experiments outside of the basin.

These critical biological questions regarding uses and impacts of artificial propagation remain largely unanswered at present. Several projects, either ongoing or new, have been submitted via the subbasin provinces to address critical questions. In addition, information regarding these questions is being derived through ongoing artificial propagation research under the Mainstem and Systemwide Province. This ongoing research includes the projects below:

1. Project 198740100 - Assessment of Smolt Condition: Biological and Environmental Interactions
2. Project 198909600 - Monitor and Evaluate Genetic Characteristics of Supplemented Salmon and Steelhead
3. Project 199005200 - Performance/Stock Productivity Impacts of Hatchery Supplementation
4. Project 199009300 - Genetic Analysis of *Oncorhynchus nerka*, (Modified to Include Chinook Salmon)
5. Project 199105500 - NATURES, Formerly Supplementation Fish Quality
6. Project 199202200 - Physiological Assessment of Wild and Hatchery Juvenile Salmonids;
   A special case should be made for project 199202200 because it is an ongoing project but was inadvertently left out of the ongoing process for FY 2002.
7. Project 199305600 - Assessment of Captive Broodstock Technology
8. Project 199606700 - Manchester Spring Chinook Broodstock
9. Project 200000700 - Infrastructure to Complete FDA Registration of Erythromycin
10. Project 200001700 - Recondition Wild Steelhead Kelts
11. Project 200104600 - Collaborative Center for Applied Fish Science

The projects 198909600, 199005200, and 199009300 are investigating important genetic aspects of stock supplementation and recovery programs in the Basin. These projects are expected to resolve a number of elements inherent in Questions 1 and 2 above.

Project 198740100 - Assessment of Smolt Condition: Biological and Environmental Interactions

Project 198740100 provides scientific support to regional hatcheries and fish management agencies by evaluating the developmental biology of juvenile salmonids to address critical questions 1, 2, 3, and 4, and indirectly 5, 6, and 7 through cooperative projects. Formerly serving the Fish Passage Center Smolt Monitoring Program, since 1996 the project has cooperated on hatchery and management projects to assess the effects of hatchery rearing, acclimation, release, and fish passage protocols on developmental biology, smolt condition, and health (Gannam and Schrock 1999, 2001; Maule et al.1996; Maule and VanderKooi 1999; Sauter et al. 2001; Schrock et al. 1998, 1999, 2000, 2001; VanderKooi and Maule 1999). The current focus is production level studies to identify the influence of a range of variables including different feeding regimens and diets, water sources, and temperature regimes on early development. The objective is to determine the physiological and immunological range of response of salmonids to environmental change during their early life stages, to provide information on optimal rearing conditions for different stocks in relation to long term survival. Results from these activities provide information for hatchery reforms to resolve critical questions 1-7. Genetic samples were collected in 2001, and will be collected in 2002 for analysis to compare hatchery fish with their local, naturally spawning counterparts in preparation for developmental studies to determine selection in the two groups under different rearing protocols. The project continues to provide technical assistance, to develop analysis methods for easy application in production level applications, and to sponsor an annual smolt workshop to facilitate information exchange about juvenile salmonid projects among a wide range of agencies and groups. The primary purpose of the project is to provide research, monitoring and evaluation capabilities to hatchery and field managers during the implementation and assessment of new methods and strategies.

Project 198909600 - Monitor and Evaluate Genetic Characteristics of Supplemented Salmon and Steelhead

Project 198909600 is a genetic monitoring program that is designed to evaluate the effects of outplanting hatchery-reared fish on natural and wild populations of spring/summer chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) in four major drainages within the Snake River Basin. In addition to publication in peer-reviewed literature and project reports (see below), findings from this study have been provided periodically to state and tribal comanagers to assist in adaptive management strategies. For example, combined allozyme and DNA results have indicated that the Dworshak Hatchery steelhead population is the most distinctive in the Snake River basin. Analysis of natural/wild populations believed to be affected by strays or outplants from Dworshak Hatchery do not show evidence of substantial genetics effects. The distinctiveness of the Dworshak stock appears to reflect its ancestry rather than being the result of genetic or demographic events subsequent to domestication. Considerable genetic diversity was found among chinook salmon populations of the Grande Ronde River basin, and estimated gene flow is on the order of 1-2 migrants per year. The ratio N_b/N is critical to evaluation of genetic risk, and this study has provided the most comprehensive data available for any salmon species on this important ratio. Most recently, DNA-typing to construct pedigrees in naturally-spawining Imnaha River steelhead has shown that naturally-produced fish achieve more than twice the reproductive success of their hatchery-reared counterparts. Because of the prominent role of hatchery supplementation in attempts to recover depressed salmon populations, and because of the wide-spread call for monitoring and evaluation of recovery actions in all the current tribal, state, and federal recovery plans, this study represents an essential element in the facilitation of informed adaptive management.

Project 199005200 - Performance/Stock Productivity Impacts of Hatchery Supplementation

The purpose of project 199005200 is to facilitate successful integration of natural and artificial production of anadromous salmonids by providing information on domestication in hatchery programs. If domestication does not occur and hatchery populations are genetically equivalent to wild populations then interbreeding of hatchery and wild fish will not undermine local adaptation. The project is a test for genetic differences in growth and survival between hatchery and wild steelhead in Idaho's Clearwater River system, and spring chinook salmon in Oregon's Warm Springs River system. The study has shown superior growth and survival for offspring of hatchery steelhead when all fish rear together in hatcheries but inferior survival for offspring of hatchery steelhead when all fish rear together in natural streams. Apparently, adaptation of a steelhead population to the hatchery program (domestication) results in reduced fitness for natural production. The study also provides compelling evidence for how such domestication occurs despite low mortality in most hatcheries: The detection rate at dams on the Snake and Columbia Rivers for the progeny from hatchery parents was 3x the detection rate for progeny from wild parents (all fish had reared together in the hatchery until release as "smolts"), suggesting intense selective mortality favoring "hatchery-type" fish within weeks after release from the hatchery.

The study shows consistent but smaller genetic differences between hatchery and wild spring chinook salmon from the Warm Springs River, Oregon. These differences occurred despite efforts in this hatchery program to prevent genetic divergence of the hatchery population; at least 10% of hatchery broodstock were wild fish in almost every year.

Project 199009300 - Genetic Analysis of *Oncorhynchus nerka*, (Modified to Include Chinook Salmon)

Project 199009300 is an ongoing investigation providing "real-time" genetic analysis of returning Redfish Lake sockeye salmon and returning Salmon River chinook salmon from their respective captive propagation programs. This research has resulted in a comprehensive mitochondrial database and genetic profile from which the immediate and long-term genetic risks to Snake River sockeye and Salmon River chinook salmon can be addressed. The present target populations are listed as federally threatened or endangered species. Moreover, genetic analyses using microsatellite loci begun in 1999 has been greatly expanded from a pilot study to provide even greater detail and a comprehensive "megadata" base. Broodstock and captive rearing programs are conducted by the National Marine Fisheries Service (BPA program # 9204000 and #9606700) and the Idaho Department of Fish and Game (BPA program # 9107200, #9700100). Our objectives are commensurate with the responsibilities and objectives of the fore mentioned agencies as well as those of the Sho-Ban Tribe (BPA program # 9107100) and the IDFG evaluation of chinook captive rearing demonstration technology (BPA program #9801002). Thus far this has led to a successful, cooperative, interdisciplinary effort toward the conservation of these threatened and endangered species. This project serves to genetically evaluate captive broodstock and captive rearing technologies as a means of conserving genetic diversity. Additionally, our general objectives are directed at resolving the origins and phylogeographic relationships of existing *O. nerka* and *O. tshawytscha* stocks in the Columbia

Basin. The project utilizes a number of non-destructive, molecular genetic approaches to define the relatedness of endangered *O. nerka* within Redfish Lake, monitor incidental take of endangered *O. nerka* in the kokanee fishery, and provide long-term comparative genetic information. This program directly monitors genetic changes through time regarding the development and implementation of both sockeye captive propagation and chinook salmon captive rearing evaluation programs. The project provides spawning matrices for both sockeye and chinook programs to minimize the loss of genetic variability and the occurrence genetic drift within those artificial propagation projects. To date changes in genetic diversity and variation within each captive chinook population has been evaluated and compared to naturally spawning counterparts. Likewise, changes which occur as the Redfish Lake sockeye population becomes "closed" (i.e. all returning adults are from the artificial production program) is also evaluated. Thus far, measurable genetic variation has remained relatively stable. Redfish lake anadromous sockeye still retain a genetic identity apart from sympatrically distributed kokanee. Moreover, kokanee do not appear to contribute to any outmigrant assemblages. The project also monitors outmigrating sockeye and chinook and evaluates the relative success of each release strategy and how those strategies effect the proportion of genetic variation observed in returning adults.

Project 199105500 - NATURES, Formerly Supplementation Fish Quality

Project 199105500 has been investigating the use of natural rearing enhancement system (NATURES) raceways as pertains to hatchery reform needs and ecological consequences identified in Questions 3 and 4. Increasingly, salmon hatcheries in the Pacific Northwest are being called upon to provide fish for restoration of endangered populations. Unfortunately, hatchery fish are often quite different in morphology, behavior, and survival than wild fish. The exact reasons for the differences between hatchery and wild fish are unknown. However, much of the apparent poor performance of hatchery fish in augmenting natural populations may be related to deficiencies in the way they are grown under conventional hatchery scenarios. NATURES project goals are to develop fish culture techniques that enable hatcheries to produce wild-like salmon with increased postrelease survival. The NATURES project has tested fish culture protocols that incorporate environmental enrichment (cover, structure, and substrate), automated underwater feeders, exercise current velocities, live food diets, and predator avoidance training.

Some combinations of NATURES variables have produced elements of wild-like fish behavior. In addition, both enriched habitat rearing and predator avoidance training have been shown to increase post release smolt survival through migratory corridors (up to 25+% and 50+%, respectively: Maynard et al. 1995, 1996a,b, 1998, 2001; Berejikian et al. 1998, 1999a,b, 2000). Juvenile steelhead reared in NATURES environments demonstrate greater competitive ability than those reared in conventional environments. However, NATURES-reared fish do not appear to have a greater competitive impact on natural fish (Berejikian et al. in press), perhaps because steelhead reared in NATURES environments exhibit aggressive and territorial behavior patterns that more closely resemble those exhibited by wild steelhead (Berejikian et al. in press). A more complete evaluation of the risks and benefits of NATURES rearing environments on competitive interactions with wild fish should include studies conducted under conditions of more natural community structure (i.e., in the presence of heterospecific competitors and natural predators).

Most NATURES variables have only been researched on a laboratory or pilot raceway level and remain to be fully tested at production level. Nonetheless, the potential wild-like characteristics and high postrelease produced by NATURES culture strategies are considered crucial components of successful hatchery reform. The high survival and wild-like attributes of NATURES salmonids can be utilized by conservation hatcheries to help restore self-sustaining runs to natural populations threatened with extinction. The high survival of NATURES fish will enable enhancement and mitigation programs to reduce the magnitude of releases while maintaining fishery and spawning recruitment goals. This reduction should immediately lessen the ecological impact these programs have on ESA listed populations. The NATURES project addresses 2000 NMFS Biological Opinion RPAs 170-173 and 184. The continued development of NATURES rearing protocols is a crucial tool for artificial production in the Columbia River Basin.

Project 199202200 - Physiological Assessment of Wild and Hatchery Juvenile Salmonids

Project 199202200 should be addressed as an ongoing investigation aimed at reducing negative impacts of hatchery salmon on wild salmon and evaluating supplementation by 1) improving the smolt quality and smolt-to-adult recovery (SAR) of fish reared in hatcheries, and 2) produce a more wild-type hatchery smolt in supplementation programs. Initially, this project examined the physiology of naturally rearing spring chinook salmon from the Yakima River, Washington, to develop a physiological template for naturally rearing fish (Beckman et al., 2000). The studies also demonstrated the influence of growth rate on smolt physiology and instream survival and migration of Yakima spring chinook salmon and found high spring growth rates associated with rapid downstream movement (Beckman et al., 1998a,b). Taken together, these studies consistently show that mimicking natural seasonal growth patterns in hatchery environments results in superior smolt development, downstream migration, and SAR (Dickhoff et al., 1995; Beckman et al., 1999). More recently a collaborative project with the WDFW and the Yakama Nation, characterized the developmental physiology of the first three generations of conventionally and semi-naturally (NATURES) reared hatchery fish at the Cle Elum Supplementation Hatchery, at remote acclimation sites, and at downstream dams during outmigration. Significant differences were found comparing wild and hatchery Yakima River spring chinook salmon. The most serious difference was an approximate 50% incidence of early maturation of Cle Elum Hatchery-reared males (1+ year-old minijacks) as compared with our estimates of <5% for wild males. Investigations need to be conducted to better quantify the incidence of precocious maturation in wild and hatchery spring chinook and develop rearing strategies for use in all supplementation programs that will allow for production of fish that have similar morphological, physiological and life-history attributes as their naturally reared cohorts.

Projects 199305600 and 199606700 focus on captive broodstock technology questions identified in Question 5. These projects are ESA mandated items in the NMFS Proposed Recovery Plan for Snake River Salmon (Schmitten et al. 1995) and are called for in the 2000 Program and the NMFS 2000 FCRPS Biological Opinion. There is scientific consensus that without rapidly increasing the abundance of fish available for restocking, ESA-listed stocks of salmon may be extinct before recovery efforts can begin to help them. Captive broodstocks may be the fastest conservation hatchery method for amplifying populations of Pacific salmon.

Project 199606700 - Manchester Spring Chinook Broodstock

Project 199606700 conducts smolt-to-adult seawater safety-net rearing of ESA-listed stocks of Snake River spring/summer chinook salmon. The Project was initiated in 1996 as production component linked to Idaho (199700100) and Oregon (199801001) recovery projects for Salmon River (Lemhi River, East Fork Salmon River, and West Fork Yankee Fork) and Grande Ronde River (upper Grande Ronde River, Catherine Creek, and Lostine River) stocks. For these programs, Idaho is using a captive rearing approach that involves rearing broodstock in captivity to adulthood and releasing them back into their natal streams to spawn naturally. Oregon is using a more conventional captive broodstock approach where maturing fish are spawned and the resultant progeny released as smolts to help maintain and restore the gene pool. Fish for both states programs are sources from the local watersheds of concern and raised to smolt by the respective states. At smolting, a large percentage of the fish are transferred to the custody of NMFS for rearing from smolt to adult in seawater at the NMFS Manchester Research Station.

The NMFS Manchester Research Station has the largest complex on the west coast for protective custody rearing of ESA stocks of salmonids in seawater. Two protective culture buildings (a 400-m^2 and a 1,280-m^2 facility) house a tot al of twenty 6.1-m, six 4.1-m, and four 3.7-m circular fiberglass tanks that can be supplied with over 4,500 L/min of seawater. Seawater supplied to the tanks is pumped, filtered, and UV-sterilized to ensure the fish health. The Station is a Washington State certified quarantine facility and ozonates all seawater exiting captive broodstock rearing areas. Staff at the Station helped pioneer the use of captive broodstock technology for Pacific salmon and staff expertise helps ensure the success of rearing projects. Current smolt-to-adult survival for ESA-listed chinook captive broodstocks in protective culture at the Station normally averages greater than 50%. Generally, juvenile-to-adult rearing density in the tanks is maintained below 8 kg/m^3 during most of the culture period with loading densities ranging from 0.29 to 0.84 kg/L/min. Facilities security and systems operation are electronically monitored at all times.

The Manchester Spring chinook project supports NMFS 2000 FCRPS Biological Opinion RPAs 175, 176, 177, and 182 and is a critical component of the safety nets for these ESA-listed stocks. Maturity of the fish in captivity has resulted in more than 1,230 prespawning adults provided to Idaho and Oregon for recovery efforts (Flagg et al. 1997, 1998; McAuley et al. 2000a, b). In upcoming years, the cooperative NMFS/Idaho/Oregon broodstock program should continue to provide large numbers of animals for use in recovery efforts.

Project 199305600 - Assessment of Captive Broodstock Technology

Project 199305600 provides foundational research for the development of captive broodstock technology to aid recovery of ESA-listed stocks of Pacific salmon (Flagg and Mahnken 1995, Flagg et al. 1995, 2000c, Swanson et al. 1998, Berejikian 2001a,b). The success of this research has helped establish captive broodstock technology as a central component of conservation hatchery recovery actions for ESA-listed stocks (Flagg and Mahnken 2000). While captive broodstocks appear vital to salmonid population recovery in the Northwest, research has shown that captive broodstocks grown under current technologies are not as behaviorally or reproductively competent as wild fish (Berejikian et al. 1997, 1999b, 2000b, 2001a,b; Hard et al. 2000, Schiewe et al. 1997). The major elements of this project are designed to provide information and develop captive broodstock husbandry practices that will: 1) improve the quality of adult salmon for both reintroduction and artificial spawning, 2) improve the quality of juvenile salmon for reintroduction, 3) improve in-culture survival, and 4) identify genetic risks (i.e., inbreeding) associated with captive brood populations.

This project has produced over 25 publications in the peer-reviewed literature in areas of captive broodstock nutrition, reproductive physiology, husbandry, behavioral ecology, microbiology, and genetics. Some recent results include:

1. Initial physiological studies of maturation indicate that both body fatness and size/growth rate influence timing and age of maturation. Current research is providing physiological condition and nutrition/growth targets to help limit precocious maturation and sequence adult age maturation to maximize production of captive broodstocks.
2. Electro-olfactogram (EOG) research shows promise for development of a simple assay for olfactory imprinting, which may be used to test the effects of hatchery rearing environments on imprinting in captive broodstock progeny.
3. Fish health research indicates efficacy of new generation macrolide antibiotics and vaccines to help control Bacterial Kidney Disease (BKD) infections in captive broodstocks.
4. Controlled genetic studies on captive chinook salmon have indicated that one generation of inbreeding leads to reduced survival and growth rate expressed in early life history. Results are similar to results for many captive bred mammals and are helping develop a fuller understanding of guidelines necessary to reduce impacts of captive culture.
5. Breeding behavior and adult-to-fry reproductive success studies of captively-reared fish grown under conventional culture conditions indicate that although adults exhibit a full range of reproductive behaviors, they display inferior competitive ability compared with wild adults and produce fewer progeny. Research indicates that improved physical fitness (through exercise) and increased maturational hormone levels can enhance reproductive behavior and success. Research is continuing to develop culture strategies that maximize success of fish produced in captive broodstock programs.

All components of Project 199305600 are currently focused to identify whether performance can be improved by modifying rearing protocols and identify the underlying mechanisms responsible for deficiencies. Project 199305600 supports NMFS 2000 FCRPS Biological Opinion RPAs 175, 176, 177, 182, and 184 and is a critical component of safety net protection for ESA-listed stocks. Continued development and refinement of captive broodstock technology is necessary to provide optimal mechanisms to stabilize populations until recovery actions succeed in addressing factors for decline.

Project 200000700 - Infrastructure to Complete FDA Registration of Erythromycin

The purpose of project 200000700 is to gain FDA approval of the antibiotic erythromycin for treatment of bacterial kidney disease. Within free ranging and cultured population of Pacific salmon bacterial, viral and parasitic organisms can alter the health status of the populations, particularly in cases of stress (Wedemeyer 1997; Moffitt et al. 1998; Schreck et al. 2001). Essential to any captive broodstock or fish production system is access to therapeutic treatments or vaccines to control or prevent disease episodes. Bacterial kidney disease (BKD) caused by *Renibacterium salmoninarum* can be a significant factor affecting survival of critical stocks, and to date there is no vaccine approved and effective. The antibiotic erythromycin is especially effective in treating BKD but the approval for use has not been completed within the U S Food and Drug Administration's Center for Veterinary Medicine (Moffitt 1998). Research has been conducted for many years at the University of Idaho to define the efficacious treatments for adult and juvenile salmonids (e.g.Moffitt and Bjornn 1989; Moffitt 1992; Peters and Moffitt 1996; Moffitt and Kiryu 1999; Haukenes and Moffitt 1999; Kiryu and Moffitt 2001; Moffitt and Kiryu 2001). The use of an erythromycin injectable product based on lab and hatchery studies conducted above is available through extra-label authority of regional US veterinarians. However, use of a feed additive forms of erythromycin for juvenile production is presently available and coordinated through a basin wide INAD held and administered at the University of Idaho (Moffitt 1991; Moffitt and Haukenes 1995). This INAD has provided erythromycin for use in more than 25 Columbia Basin hatcheries/hatchery complexes managed by the states, federal government and the tribes. In 2000, nearly 140,000 lbs. of medicated erythromycin feed were used at facilities in the Columbia River basin.

The pivotal studies describing efficacy, target animal safety, residue depletion for the erythromycin feed additive have been submitted, reviewed and accepted by FDA but there remain outstanding issues regarding the environmental fate of aquaculture drugs, and the risks of increasing resistant microorganisms associated with aquaculture applications (Greenlees et al.1998; Hirsh et al 1999). The regional support for continuation of the infrastructure through this project to address these needs, and to provide additional funding to resolve these issues is critical, as FDA works in dialog to resolve these. Without support from Bonneville for the science to resolve these issues, FDA would discontinue this INAD. Furthermore, resolution of issues and solutions regarding use of erythromycin have implications for approval of other chemicals or antibiotics that will need approval in the future (Assaf et al 1999, Greenlees 1998). The pioneering work in the Pacific Northwest region will lay the framework for future solutions in this regard.

Project 200001700 - Recondition Wild Steelhead Kelts

The purpose of project 200001700 is to test various methods to recondition wild steelhead kelts to help increase the contribution of repeat spawners to rebuilding depleted populations. Methods developed in this study could be used basin wide to help reduce kelt passage mortality. Repeat spawning is a life history strategy that is expressed by some species from the family salmonidae. Natural rates of repeat spawning for Columbia River steelhead *Oncorhynchus mykiss* populations range from 1.6 to 17%, estimated by scale pattern analysis. Increasing this repeat spawning rate-using fish culture techniques could assist the recovery of depressed steelhead populations. Kelt reconditioning techniques were initially developed for Atlantic salmon *Salmo salar* and sea-trout *S. trutta.* The recent ESA listing of many Columbia Basin steelhead populations has prompted interest in developing reconditioning methods for local steelhead populations.

Kelts are a potential resource for helping restore wild/natural steelhead populations. In the Supplemental Biological Opinion for the Federal Columbia River Power Supply System, NMFS calls on the Corps to explore ways to safeguard kelts of ESA-listed populations that pass downstream through Snake River dams. Presently, the thousands of adult steelhead (a mixture of kelts and pre-spawners) that are removed each year from the juvenile bypass systems of Snake R. dams, are simply returned to the river, where the kelts are believed to die. In Wy-Kan-Ush-Mi Wa-Kish-Wit, the tribes have adopted goals to restore anadromous fishes by emphasizing strategies that rely on natural production.

The geographic scope of the project spans the entire Columbia River Basin. Initial studies have been conducted on the Yakima River (BPA funded) and at the lower Snake River dams (Corpss funded). In the Yakima River during the 1999-2000 return period, 512 post-spawned adult steelhead were collected at the Chandler Juvenile Evaluation Facility (Evans et al. in prep). This represented 37% (512/1,380) of the total steelhead return to the Yakima River above Prosser Dam (located at the same rkm as Chandler Juvenile Evaluation Facility). Evans and Beaty (2001) estimated that in 1999-2000 the Lower Snake River contained 7,466 wild and 7,657 hatchery-origin steelhead kelts. Thus 64% of the entire wild steelhead run that migrated through the Lower Granite Dam fishway and were counted from 1 June 1999 to 30 May 2000 returned back to the dam after spawning. Based on these findings, we suspect that the kelt life history component may represent a substantial fraction of steelhead runs in other sub-basins. Therefore, we recommend applying research to practically and safely expand steelhead populations by protecting and reconditioning kelts as well as determining the benefits and risks associated with these actions.

Project 200104600 - Collaborative Center for Applied Fish Science

Project 200104600 is an ongoing effort first recommended for funding by the Council on May 26, 2001**.** The purpose of the funding to date is for planning, design, and permitting for facilities improvement and expansion at the Hagerman Fish Culture Experimental Station (HFCES), in Hagerman, Idaho. The facilities improvement involves construction and renovation of many facilities at the HFCES including building offices, increasing laboratory space for genetics, tissue culture, pathology, and water quality, renovating existing raceways, adding outdoor rearing ponds, and constructing a dormitory. In order to be cost-effective and least disruptive, this project is dovetailed with the University's planning and construction, which is anticipated to result in a cost savings of approximately 50%. This project will develop the facilities necessary to address Questions 1, 2, and 3 directly through experiments on site. Question 4 could be addressed at tribal production facilities (such as Nez Perce Tribal Hatchery and Cle Elum Hatchery) and coordinated through the Collaborative Center for Applied Fish Science (CCAFS). The CCAFS will assist the tribes and collaborators in determining key factors in management of hatchery fish and provide guidance for reform of the hatchery system, ultimately culminating in the development of population management plans including Benefit / Risk Analysis, Hatchery Operation and Genetic Monitoring Plans, and Research, Monitoring and Evaluation Plans. The CCAFS will also provide a key function in an education program for the tribes. The funding and implementation of these components will increase the probability of successful restoration of salmon in the Columbia River Basin.

These ongoing or new projects will provide specific information on a number of critical components of Questions 1-7 as outlined above. However, in order to fully address concerns for uses and effects of artificial propagation as outlined in Questions 1-7 and in documents such as the Council's APR and the NMFS 2000 FCRPS Biological Opinion, studies need to expand to include full estimates of genetic, physiological, behavioral, and ecological impacts.

C. What is the project funding to date?

Table 1 highlights sponsor requested dollars by project for the systemwide artificial production program from FY 1995 through FY2001. Cumulative total sponsor requested dollars by project are presented in Table 1 as is the grand total for all projects over the funding period FY95 to FY01. Table 1 shows that the grand total of sponsor requested dollars for all nine projects funded to date is approximately $21.7 million.

Project 199202200, Physiological Assessment and Behavioral Interaction of Wild and Hatchery Juvenile Salmonids, was inadvertently left out of the FY 2002 ongoing projects. This project should be added to Table 1 for a requested amount of $358,675 for FY 2002.

Table 1. Artificial Production Program Summary - Sponsor Requested Dollars by Project

Project ID	Title	Sponsor	FY95	FY96	FY97	FY98	FY99	FY00	FY01	TOTAL
198740100	Assessment of Smolt Condition: Biological and Environmental Interactions	U.S. Geological Survey, Biological Resources Division, Columbia River Research Laboratory	$302,800	$465,000	$469,000	$279,000	$231,000	$199,046	$241,300	$2,293,146
198909600	Monitor and evaluate genetic characteristics of supplemented salmon and steelhead	National Marine Fisheries Service, Conservation Biology Division	$224,000	$231,880	$250,000	$250,000	$210,500	$249,300	$249,200	$1,664,880
199005200	Performance/Stock Productivity Impacts of Hatchery Supplementation	Biological Resources Division, U.S. Geological Survey (formerly National Biological Survey)	$383,000	$300,000	$444,000	$450,000	$496,493	$495,232	$527,706	$3,096,431
199009300	Genetic Analysis of *Oncorhynchus nerka* (Modified to Include Chinook Salmon)	University of Idaho	$247,000	$310,000	$140,000	$130,000	$139,434	$144,859	$130,564	$1,241,857
199105500	N A T U R E S [Formerly Supplemental Fish Quality (Yakima)]	National Marine Fisheries Service	$290,000	$280,500	$400,000	$400,000	$500,000	$500,000	$525,000	$2,895,500
199202200	Physiological Assessment of Wild and Hatchery juvenile salmonids	National Marine Fisheries Service	$370,000	$345,000	$342,584	$349,600	$358,063	$349,589	$310,658	$2,425,494
199305600	Assessment of Captive Broodstock Technology	National Marine Fisheries Service	$500,000	$979,000	$1,000,000	$1,250,000	$1,200,000	$1,310,300	$1,400,200	$7,639,500
199606700	Manchester Spring Chinook Broodstock Project	National Marine Fisheries Service	x	$481,400	no data available	$391,000	$450,000	$500,000	$570,000	$2,392,400
200000700	Infrastructure to Complete FDA Registration of Erythromycin	University of Idaho - Fish & Wildlife Resources	x	X	x	x	x	$71,022	$71,766	$142,788
200001700	Recondition Wild Steelhead Kelts	Columbia River Inter-Tribal Fish Commission	x	X	x	x	x	$90,252	$227,982	$318,234
200104600	Collaborative Center for Applied Fish Science	Columbia River Inter-Tribal Fish Commission							$200,000	$200,000
Project sponsor request not BPA contract amount								**GRAND TOTAL**		$24,310,230

III. PROGRAM RELATIONSHIP TO USFWS/NMFS BIOLOGICAL OPINION AND THE IMPLEMENTATION PLAN

A. Biological Opinion

The Federal agencies that operate, or market power from the FCRPS, namely the Bonneville Power Administration (BPA), the U.S. Army Corps of Engineers (Corps), and the U.S. Bureau of Reclamation (BOR) (collectively the "Action Agencies"), reinitiated consultation with the NMFS and the USFWS to consider the effects of actions related to FCRPS configuration, operations, and maintenance on species listed as threatened or endangered under the ESA.

An extensive amount of artificial production of salmon and steelhead occurs in the Columbia River basin today. Many hatchery programs started decades ago specifically to replace natural production lost as a result of the FCRPS and other development, not to protect and rebuild natural populations. The original design and operation of many programs and facilities reflect scientific knowledge and policy decisions of a previous era. Traditionally, the objective of those hatchery programs was to provide harvest opportunities, a mitigation obligation that remains today. Most were never called upon to produce fish that are viable in nature. To a large degree, the programs succeeded in producing harvestable salmon and steelhead to maintain fisheries, even as natural production declined.

A number of studies and reviews of artificial production in the Columbia River basin have occurred in recent years. In general, the standards and guidelines that emerge from these reviews are aimed at improving the effectiveness of artificial production programs, minimizing deleterious impacts on natural populations, meshing hatchery production and policies with harvest objectives, and increasing accountability and efficiency in hatchery programs. Integrating hatchery and harvest policies is especially important to meeting obligations for Tribal and non-Tribal fisheries.

Nevertheless, recovery cannot be achieved simply by releasing more hatchery-produced fish in natural production areas, regardless of their ancestry or how they are produced. Hatcheries cannot provide the productive conditions necessary to restore self-sustaining populations in their natural habitats. The overarching goal of the reforms described here is to reduce or eliminate adverse genetic, ecological, and management effects of artificial production on natural production while retaining and enhancing the potential of hatcheries to contribute to basinwide objectives for conservation and recovery. The goal still includes providing fishery benefits to achieve mitigation mandates, but now must also include an increased emphasis on conservation and recovery.

In applying the ESA to listed species, NMFS focuses on biological requirements. NMFS' understanding of these requirements derives from many sources, including the general conservation literature, specific NMFS studies of salmon, as well as by others, and recommendations of the Tribes, state, and other federal fish and wildlife agencies and experts. NMFS recently published a compilation of scientific information in "Viable Salmonid Populations (VSP) and the Recovery of Evolutionarily Significant Units" (McElhany et al. 2000). This document identifies criteria and guidelines relevant to the needs of salmonid populations.

Because the difference between jeopardy and no jeopardy is seldom a bright line, the consultation process also focuses on the margin of safety that artificial production programs should achieve and the pace at which reforms must be implemented. This is an area where the Action Agencies have a substantial opportunity to contribute to the survival of listed species. To the extent that the Action Agencies contribute additional resources (i.e., resources beyond those that they are already obliged to provide to comply with hatchery biological opinions and, thus, continue to meet their mitigation responsibilities), they can satisfy survival goals within the meaning of this biological opinion.

Recent studies recommending hatchery reform include the Council's Artificial Production Review, several scientific reviews such as the NRC's Upstream Report (NRC 1996), the Council's "Return to the River Report" (ISG 1996), and others found in the literature. NMFS also has published several papers relevant to artificial production, including the Interim Policy on Artificial Propagation of Pacific Salmon under the ESA (April 5, 1993, 63 FR 17573), and the previously mentioned VSP report.

From the recent studies, a fairly extensive menu of measures has been identified, and specific actions to implement the measures have emerged. This does not imply that they are all ready to go. In fact, the process of hatchery reform involves a systematic review, program-by-program and hatchery-by-hatchery, to determine on a case-by-case basis which of the measures and actions to apply, and when and how they should be implemented. The actual implementation of these measures and actions whether they involve capital expenditures, operation and maintenance improvements, staffing, and/or other matters constitutes what is meant by artificial production reform throughout this opinion. Hatchery reform should occur within a broader context of planning in the Columbia River basin designed to clarify goals, objectives, and performance criteria of a basinwide approach for all species to improve accountability and effectiveness. This broader approach includes the development of subbasin plans for management of all species and recovery plans for listed species. They will include, among other things, a better integration of hatcheries and harvest objectives and strategies. The menu of reform measures is represented in the following list:

- Reform measures to clarify the goals, objectives, and performance criteria of hatchery programs to improve accountability and meet subbasin and recovery plan objectives.
- Reform measures to manage genetic risks to listed species and meet subbasin and recovery plan objectives.
- Reform measures to manage ecological risks to natural populations and meet subbasin and recovery plan objectives.
- Reform measures to improve hatchery effectiveness and meet subbasin and recovery plan objectives.

- Reform measures to avoid management risks associated with hatchery production and meet subbasin and recovery plan objectives.

Action 109: The Corps shall initiate an adult steelhead downstream migrant (kelt) assessment program to determine the magnitude of passage, the contribution to population diversity and growth, and potential actions to provide safe passage.

Data acquired through sampling in the Lower Granite and Little Goose Dam bypass systems during the peak fallback season of April through June 2000 were used to arrive at a preliminary estimate of 16,745 steelhead kelts present in the Lower Snake River at Lower Granite Dam during the study period (Evans and Beaty 2000). This abundance level represents 22% of the 74,440 adult steelhead counted passing Lower Granite in 1999 (Fish Passage Center 2000, counts for 1999). Theoretically, reconditioning and/or kelt downstream transportation could significantly increase the likelihood of a second spawning opportunity for many of these fish. Also, their downstream in-river survival could be increased by simply providing more effective alternative passage routes to avoid the higher mortality associated with turbine passage.

Evaluation should be conducted to review available literature and develop pilot testing regarding reconditioning of kelts. The Corps will assess and conduct a short-term holding evaluation at a project site where kelt are more abundant and initiate a kelt transportation pilot study as a possible means of reducing dam passage mortality. The Corps will evaluate kelt passage associated with the RSW at Lower Granite Dam (described in Section 9.6.1.4), which will be prototype-tested in 2001 in the contest of juvenile fish passage. The Corps will synthesize these work elements and report the magnitude of kelt passage, effects of passage on survival, and potential actions to improve survival, if deemed appropriate, to NMFS/Regional Forum by September 2003.
To facilitate the application of hatchery reforms to specific artificial production programs and projects, NMFS supports what is called a Hatchery and Genetic Management Plan (HGMP). The NMFS developed the HGMP in collaboration with other Federal agencies, states, and Tribes. It provides a standardized approach and a consistent body of relevant information about artificial production programs. An NMFS-approved HGMP contains a clear statement of the purpose and goals of the program or project and its relationship to harvest and other management goals. It comprehensively addresses facility and operational details relevant to reform measures and action items identified above. It requires that an appropriate monitoring and evaluation plan be developed and implemented for that facility or program. Research critical to the success of the project must also be identified.

NMFS considers an approved HGMP to be a necessary step in assessing artificial propagation programs. It is anticipated that HGMPs will evolve over time into more comprehensive and detailed documents as additional focus and resources are brought to bear on hatchery reform and as new information becomes available. The development of NMFS-approved HGMP is a substantial task that must be completed before many actual reforms can be implemented. Additionally, the process of hatchery reform does not end with a completed NMFS-approved HGMP. Rather, hatchery reform will be a continuing process of implementing, monitoring, evaluating, and revising the HGMPs. Priority should be assigned to circumstances that affect populations in the most critical condition. There is also an immediate need to enable differentiation between hatchery and naturally produced salmon.

Action 169: The Action Agencies shall fund the development of NMFS-approved HGMPs for implementation, including plans for monitoring and revising them as necessary as new information becomes available. HGMPs have to be completed first for the facilities and programs affecting the most at-risk species (Upper Columbia and Snake River ESUs), followed by those affecting mid-Columbia, and then the Lower Columbia ESUs. HGMPs for the entire Columbia basin hatchery programs and facilities should be completed (and approved by NMFS) by the 3-year check-in.

Action 170: Using new authorizations and appropriations and/or BPA funds as necessary and appropriate, the Corps, working with USFWS, shall oversee the design and construction of capital modifications identified as necessary in the HGMP planning process for Lower Snake River Compensation Plan anadromous fish hatchery programs. These improvements shall begin immediately after the relevant HGMPs are completed and approved by NMFS, and shall be completed as expeditiously as is feasible. BPA shall provide for the operations and maintenance costs of these reforms and shall reimburse the Federal Treasury for an appropriate share of the capital costs. The Corps shall have begun to implement reforms for programs affecting the most at-risk species by the 3-year check-in.

Action 171: BOR shall implement the reforms identified in the HGMP planning process for the Grand Coulee mitigation anadromous fish hatchery programs, immediately beginning after the completion of the relevant NMFS approved HGMPs and completing the work as expeditiously as feasible. BPA shall fund the operations and maintenance costs of the reforms and shall reimburse the Federal Treasury for an appropriate share of the capital costs. BOR shall have begun to implement reforms for programs affecting the most at-risk species by the 3-year check-in.

Action 172: The Corps shall implement the reforms identified in the HGMP planning process for the Corp's Columbia River basin mitigation anadromous fish hatchery programs, beginning immediately after the relevant HGMPs are completed and are approved by NMFS. The work shall be completed as expeditiously as feasible. BPA shall fund the operations and maintenance costs of the reforms and shall reimburse the Federal Treasury for an appropriate share of the capital costs. The Corps shall have begun to implement reforms for the programs affecting the most at-risk species by the 3-year check-in.

Action 173: BPA shall implement the reforms identified in the HGMP planning process for Federal and Federally funded hatcheries, beginning immediately after the relevant HGMPs are completed and approved by NMFS. The work shall be completed as expeditiously as possible. BPA shall have begun to implement reforms for the programs affecting the most at-risk species by the 3-year check-in. BPA is currently responsible for the power-allocated share of O&M and capital costs associated with reforms that will be required under hatchery biological opinions. To the extent that the Action Agencies seek credit for reforms above and beyond this level, appropriate cost-sharing arrangements will have to be worked out between them and other entities involved in funding the particular hatchery program. Funding for necessary reforms at Mitchell Act facilities will be sought through congressional appropriations. To the extent that such additional appropriations are not forthcoming or are insufficient to accomplish all needed reforms as rapidly as possible, offsite mitigation crediting could occur at any artificial production facility if the Action Agencies make funds available for that purpose.

Action 174: Working through regional prioritization processes to the extent feasible and in coordination with NMFS, BPA shall collaborate with the regional, state, Tribal, and Federal fish managers and the Pacific States Marine Fisheries Commission to enable the development and implementation of a comprehensive marking plan. Included in this action are the following four steps:

1. Develop a comprehensive marking strategy for all salmon and steelhead artificial production programs in the Columbia River basin by the end of 2001.
2. Provide funding by March 1, 2001, to begin marking all spring chinook salmon that are currently released unmarked from Federal or Federally funded hatcheries.
3. Provide funding, beginning in FY 2002, to implement the Action Agencies' share of the comprehensive marking plan for production not addressed in (2) above.
4. Obtain funding contributions as appropriate for additional sampling efforts and specific experiments to determine relative distribution and timing of hatchery and natural spawners.

Actions are also required to create artificial propagation safety-net programs for salmon and steelhead populations in the upper Columbia and Snake River basins that are at particularly depressed levels. For many of these populations, safety-net projects designed to intervene with artificial production techniques may be appropriate to prevent extinction. Safety-net projects may be as intensely intrusive as the Stanley Basin sockeye recovery program, with the majority of the population being taken into a captive broodstock program. Others may involve short-term interventions for one or two generations, using more conventional artificial propagation methods such as supplementation using appropriate broodstocks.

Additional work is needed to identify candidates for the safety-net program, but the individual populations identified below are currently thought to warrant intervention. All are located in the Snake River basin, and some intervention may already have begun. Although some of the most at-risk populations are in the upper Columbia River, the immediate safety-net needs in that area are being addressed pursuant to existing and planned processes tied to non-FCRPS mitigation programs, including commitments from the mid-Columbia PUDs. The need for additional safety-net actions in any part of the Columbia and Snake River basins, and the FCRPS' responsibility to support those actions, depend on future assessments of population status.

Action 175: BPA shall, in coordination with NMFS, USFWS, and the relevant state and Tribal co-managers, fund the four-step planning process described above as quickly as possible and, if so determined by that process, implement safety-net projects as quickly as possible at least for the following salmon and steelhead populations: 1) A-run steelhead populations in the Lemhi River, main Salmon River tributaries, East Fork Salmon River, and Lower Salmon River; 2) B-run steelhead populations in the Upper Lochsa River and South Fork Salmon River; and 3) spring/summer chinook populations in the Lemhi, East Fork, and Yankee Fork Salmon rivers, and Valley Creek.

Action 176: BPA shall, in coordination with NMFS, USFWS, and the relevant state and Tribal co-managers, fund the development of HGMPs for the Grande Ronde and Tucannon spring/summer chinook safety-net programs.

Action 177: In 2002, BPA shall begin to implement and sustain [ongoing] NMFS-approved, safety-net projects.

Action 178: BPA shall commit to a process whereby funds can be made quickly available for funding the planning and implementation of additional safety-net projects for high-risk salmon and steelhead populations NMFS identified during the term of this biological opinion.

Action 182: The Action Agencies and NMFS shall work within regional priorities and congressional appropriations processes to establish and provide the appropriate level of FCRPS funding for studies to determine the reproductive success of hatchery fish relative to wild fish. At a minimum, two to four studies shall be conducted in each ESU. The Action Agencies shall work with the Technical Recovery Teams to identify the most appropriate populations or stocks for these studies no later than 2002. Studies will begin no later than 2003.

Naturally spawning hatchery fish may mask the population trajectory of wild populations. This masking may not only obscures population status, but also may make it difficult to determine population goals and performance standards with certainty. These studies should identify both the genetic contribution of hatchery-origin spawners to subsequent generations and the temporal and spatial distribution of those spawners.

Research is also called for in areas of hatchery research, monitoring, and evaluation.

Action 184: The Action Agencies and NMFS shall work within regional prioritization and congressional appropriation processes to establish and provide the appropriate level of FCRPS funding for a hatchery research, monitoring, and evaluation program consisting of studies to determine whether hatchery reforms reduce the risk of extinction for Columbia River basin salmonids and whether conservation hatcheries contribute to recovery.

This action item is intended to address the overall research, monitoring, and evaluation needs for artificial propagation in the basin. It exceeds research, monitoring, and evaluation needs associated with specific hatchery programs, projects, or facilities that derive from HGMPs. Reform measures and associated actions are described in Section

9.6.4.2. A conceptual framework for conservation hatcheries is also described by Flagg and Nash (1999).

Initially, the objectives for hatchery research, monitoring, and evaluation will include identifying and evaluating current hatchery production goals and level of effort and ensuring that the goals and level of effort are appropriate to the ecological and genetic effects of hatchery production in the local system. This assessment has several components, including the following actions:

- Estimate (if possible) the carrying capacities of rearing habitat and the migration corridor.
- Determine numbers of naturally spawning first-generation hatchery fish (i.e., hatchery escapement).
- Determine the relative reproductive success of naturally spawning hatchery fish compared to those of wild origin.
- Monitor the size, age, health, and smolt quality (growth), as well as release locations, timing, and life stages of hatchery fish.
- Assess (if possible) the frequency and magnitude of ecological interactions between hatchery and wild fish.
- Assess the genetic variability of populations and metapopulations.

Given these elements of the biological context, in which each hatchery program exists, it will be possible to design and/or improve upon hatchery protocols. The goal of hatchery reforms is to reduce or eliminate adverse genetic, ecological, and management effects of hatchery production on natural populations to meet basinwide objectives for conservation and recovery. Thus, the concomitant research, monitoring, and evaluation program would assess the following aspects of natural populations:

- Reduced genetic variation
- Potential transfer of genetic traits from hatchery to wild stock
- Reduced genetic population structure
- Increased ecological interaction with hatchery fish (competition, predation, and disease)
- Masking of natural population status by the presence of naturally spawning hatchery fish

Ultimately, the monitoring and evaluation program must identify hatchery and natural population interactions and isolate their effects on the growth rate of natural populations. To do so, the evaluation program must consider the cumulative effects of hatchery production across the appropriate subbasin, as well as throughout the entire life cycle of the fish. This will require that a relationship be developed between the productivity of the natural populations (as represented, for example, by lambda) and the total production of hatchery fish, which will depend on such factors as survival and productivity during freshwater rearing and seaward migration, ocean residence, and return. Such assessment will provide the statistical power to detect incremental risk of extinction or rates of recovery.

Therefore, for hatchery operation, performance standards must address genetic integrity, abundance, and productivity (recruits per spawner) of both hatchery and wild fish. The information provided by these metrics defines the standards to minimize genetic and ecological risks to listed fish. Flagg and Nash (1999) identify strategies for minimizing genetic and ecological risks. Many of these postulated reforms will require applied research and field testing. Hatchery monitoring and evaluation objectives will operate primarily on a subbasin or smaller scale. The monitoring and evaluation must be tailored to each species produced and address practices that impact the scale of effects (i.e., release practices, logistics of broodstock recovery, and straying of hatchery fish).

B. Implementation Plan

The Corps, the BOR, and the BPA, collectively known as the Action Agencies, have prepared a 2002-2006 Implementation Plan for the FCRPS to address the challenges of salmon and steelhead recovery in the Columbia Basin (Action Agencies 2001). The Plan responds to the December 2000 FCRPS Biological Opinions issued by the USFWS and the NMFS on the effects to listed species from operations of the hydropower system.

In this document the Action Agencies are proposing Performance Standards for Hatcheries of both a Physical and Biological basis, Hatchery Strategies with Underlying Assumptions, Priorities, Hatchery Actions, and Hatchery Work Plans.

Performance Standards for Hatcheries

<u>Physical</u>

Marking

- Hatchery populations are properly marked so as not to mask the status of the natural-origin populations or the capacity and proper functioning of critical habitat.

Hatchery Planning

- Hatchery goals and objectives, operational protocols, monitoring and evaluation, anticipated effects, and relationship to other critical management and planning processes are fully described in approved HGMPs.

<u>Biological</u>

Broodstock

- Local, within-ESU broodstock is used in propagation programs within critical habitat, unless associated with an isolated program
- Hatchery broodstock used in supplementation programs represent the genetic and life-history characteristics of the natural population(s) they are intended to supplement.
- Non-isolated hatchery programs regularly infuse natural-origin fish into the broodstock as described in an approved HGMP.

Hatchery Fish Straying

- For naturally-spawning populations in critical habitats, non-ESU hatchery-origin fish do not exceed 5 percent; ESU hatchery-origin fish do not exceed 5-30 percent unless specified in an HGMP for a conservation propagation program.

Population Thresholds

- Hatchery operations do not appreciably slow a listed population from attaining its viable population abundance. Hatchery operations do not reduce listed populations that are at, or below, critical population abundance.

Harvest Effects

- Federal hatchery mitigation fish produced for harvest do not cause subsequent over harvest of listed stocks such that their recovery is appreciably slowed. Harvesting reforms are implemented to maintain and enhance harvest mitigation fish in consideration of the constrained productivity of listed stocks caused by the FCRPS and other development.

Quality and Survival

- The quality and survival of hatchery supplementation fish is increasing.

Hatchery Strategies

- Implement hatchery reforms to reduce or eliminate potentially harmful effects of artificial production on ESA-listed populations;
- Use a safety net program on an interim basis to avoid extinction while other recovery actions take place; and
- Use hatcheries in a variety of ways and places to conserve listed populations, to aid recovery of listed populations, and to address mitigation mandates, especially tribal fishing needs.

The overall goal of hatchery reforms is to reduce or eliminate adverse genetic, ecological, and management effects of artificial production on natural populations while retaining and enhancing the potential of hatcheries to contribute to basinwide objectives in conservation and recovery. The goal includes providing fishery benefits to achieve mitigation mandates and meet obligations to tribes, but now must also include an increased emphasis on conservation and recovery a mission for which many older hatchery programs were not designed.

The document guiding reform of each facility is a HGMP. At the regional level, the NMFS and USFWS FCRPS Biological Opinions and the Northwest Power Planning Council's APR all require or recommend HGMPs to address hatchery reform and supplementation issues. Other reports also recognize the need for hatchery reform and the need for new conservation hatcheries to aid in salmon recovery.

Underlying Hatchery Assumptions

A significant amount of uncertainty surrounds the issue of artificial production, including the extent and nature of its risks and its potential benefits as a conservation and recovery tool. Accordingly, the Action Agencies will apply an adaptive management approach designed to reduce these uncertainties, with particular emphasis on the use of HGMPs and learning more about the effects of hatchery production. A comprehensive Research Monitoring and Evaluation (RM&E) program will address the effects of hatcheries on natural production and the relative effectiveness of hatchery production spawners.

The Hatchery Strategy was developed based on the following assumptions:

- Artificial production may pose significant ecological and genetic risks to naturally produced salmonid populations.
- Using proper management techniques and operational protocols as defined by approved HGMPs to control deleterious effects, artificial production, due to its survival advantages, can provide a net benefit to depressed stocks.
- Artificial production can be used to seed barren habitat and/or help speed rebuilding of seriously depressed populations to carrying capacity.

Priorities

Initially, Priorities for hatchery actions will largely reflect the logical and necessary sequence of actions that must occur in the hatchery arena, such as the development of HGMPs, the planning and risk assessment of candidate populations for the safety net populations, and the development of the comprehensive marking strategy. Within these categories of activities, implementation priorities will take into account, among other things, extinction risk, survival improvements necessary to achieve conservation and recovery, and practical and fiscal feasibility issues.

Prioritization Criteria:

- Rescue an ESU from extinction;
- Rescue a population within an ESU from extirpation;
- Result in reforming hatchery practices that reduce deleterious effect and/or better align mitigation mandates with conservation and recovery missions, with an emphasis on those species that are most at risk;
- Facilitate distinguishing between hatchery and naturally produced fish

Hatchery Actions

The Hatchery Actions include two broad categories of actions: offsite mitigation actions called for under the NMFS FCRPS Biological Opinion and ongoing BPA-funded Council Fish and Wildlife Program artificial production actions. All actions may be grouped into subcategories of marking, hatchery reform, safety-net artificial propagation, or RM&E.

Hatchery Work Plans

The Hatchery Work Plan provides a general overview of the sequence the Action Agencies will take to implement hatchery actions. The NMFS FCRPS Biological

Opinion calls for three hatchery programs – Hatchery reform, safety net, and marking of fish. The Action Agencies propose a step down program structure to be followed across the programs to manage the implementation plan. For each program a team of Action Agency representatives will be formed to develop a detailed implementation plan to include scheduling, project coordinators, and cost. These core groups will oversee the implementation of the agency specific actions. The core group will also coordinate with oversight groups comprised of NMFS, FWS, Council, Tribes, and additional stakeholder groups as needed. The Action Agency core group representatives will work to ensure completion of agency specific responsibilities under the FCRPS Biological Opinions.

IV. FUTURE NEEDS

Ongoing, presently authorized projects under the Mainstem and Systemwide Province should provide a foundation of information on uses and effects of artificial propagation. However, it is critically important to also begin to develop an understanding of the magnitude of differences in a number of important genetic, behavioral, ecological, nutritional, health, life history variation, and age of maturation parameters. Studies need to be conducted to measure the relative fitness of hatchery fish spawning in the wild. Likewise, experiments need to be conducted to estimate the rate of domestication in a hatchery setting, the rate of readaptation to a natural setting, and to provide information into what traits are under selection in different environments.

Quantification of the annual population growth rate (lamda) is needed for wild stocks in subbasins with little or no hatchery influence, for fish in basins with traditional augmentation hatcheries, and for stocks in basins with conservation hatcheries. The additional variable of implementing hatchery reform in clusters of hatcheries will strengthen research. Specific information needs to be developed on the biology, physiology, ecology, behavior, health and life history variation of wild stocks to provide a template for recovery actions.

In addition to large-scale studies of subbasins, studies of interactions on target and non-target species need to be conducted in tributary, migration corridor, estuary and nearshore ocean habitats, although these become increasingly complex and logistically challenging. Factors that need to be assessed in studies of ecological interactions of hatchery and wild stocks include competitive and non-competitive interactions, direct interactions including displacement, agonistic interactions, competition for food and space, relative growth rates of hatchery and wild fish, relative physiological responses of hatchery and wild fish to environmental cues, disease transmission, migratory interactions (pied piper effects), predation, and attraction and saturation of predators. Competition and predation are particularly important interactions that may pose ecological risks to wild salmonid populations. Although there is evidence that released hatchery fish can disrupt natural social patterns in streams and may affect the abundance, growth, and survival of wild salmonids, there have been no replicated field or laboratory experiments that have attempted to determine the nature and extent of the ecological risks to wild salmonid populations that are associated with the release of hatchery fish. Replicated field and laboratory experiments designed to test the effects of interactions from hatchery-released fish on the behavior, growth and survival of wild salmonids should be undertaken. Quantitative estimates of the effects of competition and predation from released hatchery fish on the growth and survival of wild salmonids are required for the development of models to estimate hatchery-related ecological risks to wild salmonid populations.

Hatchery reform measures such as NATURES have become crucial tools for redevelopment of hatchery strategies in the Columbia River Basin. However, many critical questions remain to be answered for NATURES research, including: Does enriched habitat rearing increase survival to adult?, Do NATURES benefits apply at hatchery scale and across all hatchery types (e.g., mitigation, enhancement, and conservation) and geographic ranges?, Can NATURES reduce domestication? Questions of operational efficiencies of NATURES variables are paramount as regional studies using offshoots of NATURES concepts are proceeding without basic scientific foundations. For instance, there is an urgent need to determine the effectiveness of different types of substrates (loose gravel, gravel pavers, and painted bottoms) in increasing postrelease survival as some regional studies that differ primarily in substrate type are yielding quite different results. Research must also be conducted to determine the behavioral and ecological interactions of NATURES and wild fish. Production-scale evaluations of NATURES variables, their interactions, and their effects on salmon behavior and ecological interactions are necessary to fully refine and validate concepts.

Reforms in captive broodstock technology will have to encompass problems encountered in all life history stages of salmon, and reform of current practices should be approached by applying several scientific disciplines including: genetics, physiology, behavior, nutrition, and fish health. One of the major aims of the captive broodstock program is to optimize reproductive performance of captive broodstock, which are either introduced to the wild or spawned artificially in captivity. Salmon reared to the adult stage in captivity exhibit poor reproductive performance when released to spawn naturally. Poor fin quality and swimming performance, incomplete development of secondary sex characteristics, changes in maturation timing, and other factors may contribute to reduce reproductive success. Improving natural reproductive performance is critical for the success of captive broodstock programs in which adult-release is a significant reintroduction strategy for maintaining ESA-listed populations. Research is needed on the effects of rearing environment and endocrine processes on reproductive success and factors that affect it. Evaluations should be carried out under experimental conditions with replication and rigorous application of treatments and under natural conditions.

In addition to reproductive deficiencies during natural spawning, captive broodstocks display a variety of reproductive dysfunctions including: asynchronous maturation of males and females within a season; atretic eggs; variable egg quality; reduced egg size and egg number; delayed timing of ovulation and spermiation compared with wild counterparts; and higher rates of early male maturation than wild populations. Such problems result in a significant reduction in offspring production severely reducing the effectiveness of these recovery programs. Research should focus on developing rearing regimes that produce natural age and size at maturation and life history transitions such as smolting and maturation. In addition the effects of timing of freshwater transfer and rearing temperature on seasonal timing of spawning in spring chinook salmon would aid in understanding impacts of temperature on reproductive performance of either captively-reared fish or migrating adults.

There is a need to carefully study the empirical patterns of "mate choice" in hatcheries as practiced operationally, to model the patterns of evolution by drift and selection that may occur in the hatchery, and to compare these patterns to those observed by behavioral and genetic means in natural populations. Currently not enough is known to set spawning guidelines or protocols that are sufficiently grounded in theoretical conservation genetics or fundamental salmonid biology.

Inbreeding depression remains the most important genetic concern of captive breeding programs involving threatened or endangered species. However, the consequences of inbreeding in Pacific salmon, and whether these vary between different production environments, are not known. Research should address these consequences with an aim to evaluating the extent to which inbreeding has led to and continues to impede viability in salmon populations. That is, does inbreeding limit the effectiveness of recovery efforts involving captive broodstocks?

Infectious diseases continue to impact the success of salmon captive broodstock projects and artificial productions operations. Of the many possible protozoan, bacterial, and viral diseases that afflict salmonids, epizootics caused by the bacterium *Renibacterium salmoninarum,* the causal agent of bacterial kidney disease (BKD), continue to negatively impact captive rearing programs of both sockeye and chinook salmon. Various vaccine formulations need to be assessed for their ability to protect captive salmon populations from BKD. These include formalin-fixed attenuated *R. salmoninarum* and Renogen, as well as DNA-based vaccines that have been shown to stimulate protective cell-mediated immunity against intracellular bacterial pathogens such as *R. salmoninarum*. Even if an effective vaccine for *R. salmoninarum* is identified, the need for antibiotic therapy under certain circumstances will continue, as there are circumstances that vaccine protocols are not successful. The region must continue to support the infrastructure and identify additional studies necessary to complete the approval process for this drug. Some conservation hatcheries in the region will need to participate in monitoring and evaluation to adequately detail for FDA and others an understanding of the risks of developing resistant microorganisms as a result of antibiotic therapy.

Removing salmon from their natural environment may impair physiological and behavioral development, reducing subsequent homing ability of released fish. Increased straying by hatchery-reared fish may jeopardize efforts to restore endangered populations in two ways: 1) stray hatchery fish may interbreed or compete directly with endangered wild populations, and 2) captively-reared, endangered fish released as adults to spawn naturally, could stray and be lost from the gene pool. Studies of hatchery effects on straying (homing and imprinting) are needed to manage straying rates of hatchery adults and assess the effects of straying on wild populations and stream productivity. However, if captivity-reared adults are of suitable genetic quality, and if they stray to nearby streams within the geographic boundary of the ESU, they may actually help colonized vacant habitat, or boost production in that stream. Straying may not always detrimental it may have some positive affects.

Hatchery reform measures are currently being implemented in many fisheries augmentation, mitigation, supplementation and conservation hatcheries. Research programs are needed to identify measures and assure there are sufficient monitoring and evaluation activities to determine their impacts on wild salmon populations. Data needs to be collected and evaluated on survival and fishery contribution of hatchery reared fish from augmentation and supplementation hatcheries and from captive broodstock programs. Uniform collection of data variables in a spatial and temporal scale appropriate to the salmonid life history will allow evaluation, comparison, and coordination of activities related to hatchery and wild stock management in a data rich environment. Life cycle based monitoring and statistically sound evaluation of life history data will further help to implement adaptive management of Columbia River Basin salmonids on an ecosystem level. Data needs to be analyzed to determine which, if any, reform protocols improve survival of both hatchery and wild populations. Hatchery reform measures showing promise to minimize impacts to wild fish and aid in recovery of listed populations will need to be further evaluated and refined on laboratory and test fishery scales and tested at production scale to ensure adequacy for application.

Although a key measure is adult return and performance of hatchery fish, whether in fisheries, in the hatchery, or in the natural environment, it may be important to partition survival particularly to assess if certain survival parameters are specific to hatchery fish. In order to determine the fate of hatchery released juveniles it is critically important to use techniques like PIT tags which allow for partitioning survival from release in the tributaries, to mainstem reaches, estuary and ocean habitats. Evaluating performance of anadromous hatchery stocks in terms of adult return is extremely complex and will require extensive tagging studies to discriminate survival bottlenecks.

Additional studies should be conducted to test whether domestication selection occurs in hatchery programs and reduces the fitness for natural spawning and rearing. One or more additional studies should be done with spring chinook salmon to indicate the generality of the results for that species, and several similar studies should be done with fall chinook salmon and coho salmon to determine how well generalizations from steelhead and spring chinook salmon apply to other species. Some of this work may be possible only in basins outside the Columbia River.

Studies should be initiated to determine the rate of naturalization – i.e., the rate at which fitness increases when a domesticated population spawns and rears naturally. The "balance" between rates of domestication and naturalization will determine the short- and long-term effects of supplementation on fitness.

Studies should be initiated to determine whether hatchery environments or practices could be modified to substantially reduce domestication. For example, does the NATURES approach substantially reduce domestication?

The opportunities for learning from current and planned artificial production programs in the Columbia River basin should be rigorously evaluated, and realistic strategies should be identified and proposed for maximizing the knowledge gained from existing and planned programs. Managers and stakeholders need to know how the productivity and resilience of naturally spawning populations are affected by continued supplementation. Integrating artificial and natural production involves many facets beyond domestication (e.g., indirect genetic effects, competition, predation, disease, increased nutrients and stream fertility, increased population size). These facets vary from place to place, and can only be evaluated collectively in production-scale supplementation programs. Specific questions to be addressed include:

- What and where are adequate control or reference populations (accounting for possible habitat changes for either supplemented or reference populations)?
- What attributes should be monitored in supplemented and reference populations?
- What are alternative “meta-designs” (alternative treatments and treatment/reference combinations) and how would yield of information vary among these designs?
- What is the expected time frame for a supplementation program to approach a steady state?
- What is the minimum period for monitoring, and what are acceptable monitoring schedules?

Preliminary modeling suggests that deleterious genetic consequences of supplementation would not be fully manifest for at least seven generations [approximately 28 years] even with no environmental variation), so rigorous *long-term* comparisons between supplemented and comparable unsupplemented (“reference”) populations will be necessary. This work requires rigorous experimental design and uncertainty analysis to provide the best possible studies (or experimental management) and realistic expectations for the products of these studies.

Research, monitoring and evaluation are needed in supplementation hatcheries to determine the extent of variation in life history traits in age of smolting and maturation between the hatchery and natural rearing target populations. Of particular concern is the earlier age of male maturation that may occur in hatchery chinook salmon and steelhead reared on high rations of high energy diets. High rates of precocial male maturation may reduce effectiveness of supplementation programs and results in negative ecological impacts and a high degree of straying.

Supplementation and conservation projects typically release juveniles from acclimation sites to enhance homing to target areas and to reseed vacant habitat. The efficacy of such sites for improving homing and the genetic, ecological and behavioral interactions between these hatchery fish and wild spawners has not been investigated. Studies to test the efficacies of acclimation sites for imprinting and homing to target areas and the interactions and ecological overlap of these fish with wild populations should be initiated.

The two major goals of genetic monitoring continue to be critical elements in future research: 1) to evaluate the nature and extent of genetic changes in hatchery stocks to be used for outplanting, and 2) to quantify the genetic impact of outplanting on targeted natural stocks and non-targeted wild stocks. Almost nothing is known about the environmental and management correlates of successful supplementation of natural populations. It is important to continue genetic monitoring of hatchery supplementation on two fronts. First, there is a need for continued evaluation of changes in gene frequency through time. However, we believe that at this point those efforts can be successful with an abbreviated sampling regime relative to the nearly annual sampling employed thus far. As monitoring studies shift from allozymes to DNA markers, historical scale samples can be used to evaluate genetic changes over longer periods of time. Second, reproductive success studies exploiting DNA pedigree information have proven extremely powerful for real-time evaluation of natural spawning by hatchery fish. The ability to evaluate reproductive success on an individual and a family basis also allows study of other factors that contribute to differential success. Finally, the more intensive (but geographically and temporally limited) studies of reproductive success through parentage analysis provide insight into fine-scale population structure within river systems, as well as, direct estimates of genetic effective population size. Although monitoring of gene frequencies through time and parentage analysis share the goal of understanding the genetic effects of artificial propagation, they each provide unique perspectives and both need to be part of future genetic monitoring studies.

Because many populations are in decline and may be approaching extinction, there is a clear sense of urgency in making progress on these questions regarding the appropriate utilization of artificial propagation technology. Likewise, the need for sustainable fisheries augmentation from hatcheries to support commercial, recreational, and tribal mandates obligates full development of the technology.

V. REFERENCES

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