Artificial Propagation for Pacific Salmon Appendix:

Assessing Benefits and Risks & Recommendations for Operating Hatchery Programs Consistent with Conservation and Sustainable Fisheries Mandates

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NOAA's National Marine Fisheries Service
Hatcheries & Inland Fisheries
Salmon Recovery Division

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Executive Summary

There has been a growing reliance on hatcheries to sustain tribal, public and commercial fishing opportunity, and more recently, to help conserve Pacific salmon as the capacity of natural habitat to produce fish has been eroded. In the course of providing these benefits, there also is the potential for hatchery programs to increase the extinction risk and threaten the long-term viability of natural populations. In this paper we review key factors for assessing the benefits and risks of hatchery programs relative to the conservation of Pacific salmon and to Indian Treaty and sustainable fishery mandates. These key factors include: (1) population viability status and recovery goals, (2) the conservation of genetic resources, (3) hatchery effects on population viability, (4) research monitoring and evaluation, (5) hatchery effects on density-dependent processes, (6) hatchery weirs, and (7) compensation for impacts to Indian treaty, public, commercial and international fisheries. Impacts to habitat and corresponding reductions in production capacity and fish survival can prevent salmon and steelhead from achieving viability and from supporting sustainable fishery mandates. Hatchery programs will have a prominent role to play until degraded and blocked habitats are rehabilitated and restored. We recommend a strategy and supportive hatchery practices to serve harvest goals and a strategy and practices to serve salmon and steelhead conservation objectives. We conclude that hatchery programs can provide benefits for both sustainable fisheries and conservation purposes, with acceptable collateral risks, when the program is designed and operated based on a clear and feasible objective. The National Marine Fisheries Service (NMFS) will use this paper to help guide Endangered Species Act (ESA) and National Environmental Policy Act (NEPA) determinations, ESA recovery planning, and funding allocation decisions as they relate to the artificial propagation of Pacific salmon.

Table of Contents

1. Definitions

Abundance: An indicator or measure of how Pacific salmon are sustaining themselves without human intervention (i.e., separate from and not including any hatchery propagation subsidy). Abundance is natural-origin fish from either naturally spawning natural-origin fish or from naturally spawning hatchery-origin fish included in a salmon Evolutionarily Significant Unit (ESU) or steelhead DPS.

Allee Effects: Is the difficulty finding mates at low population or spawning aggregate abundance.

Captive Broodstock Hatchery Program: A supplementation program that first retains fish for their entire life-cycle before out-planting progeny (juveniles or adults) for reintroduction or supplementation purposes.

Compensation Hatchery Program: Hatchery programs designed to make up for or compensate for reductions in adult returns due to reduced habitat productivity (i.e., for degraded habitats and for habitat taken out of production and no longer accessible to Pacific salmon). They do not operate to conserve or improve Pacific salmon viability with two exceptions. First, Compensation Programs that use fish included in an ESU for broodstock, and that produce fish that mimic life history characteristics of the local natural population, can serve as a gene reserve in the event that fish are needed for conservation purposes. Second, either naturally spawning fish or carcasses from compensation hatchery programs can add important nutrients to streams and, thus, contribute to productivity.

Conservation: The act of preserving, increasing or restoring Pacific salmon viability. Under the Federal Endangered Species Act, "conservation" is defined as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, *propagation*, live trapping, and transplantation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking" (ESA Sec. 3(3)) (emphasis added).

Conservation Hatchery Program: Programs designed to work together with habitat still capable of producing fish or in conjunction with initiatives to restore habitat productivity. Conservation Propagation programs are designed and operated to protect and promote Pacific salmon viability. Conservation programs follow practices that promote population dynamics and that promote survival under local environmental conditions. Conservation programs purposely seed habitats capable of producing fish or attempt to preserve populations until habitat productivity is restored. Conservation programs include reintroduction, supplementation, and captive broodstock programs

Delisting: Removing a species or Distinct Population Segment (DPS) from the list of threatened and endangered species after concluding that the measures provided pursuant to the ESA are no longer necessary and that the species or DPS is not likely to become endangered (the definition of a threatened species) within the foreseeable future throughout all or a significant portion of its range.

Demographic Stochasticity: A natural tendency for salmon and steelhead populations at low abundance to be highly variable and possibly going to zero.

Distinct Population Segment: Under the ESA, the term "species" includes any subspecies of fish or wildlife or plants, and any "distinct population segment" of any species or vertebrate fish or wildlife which interbreeds when mature (ESA Sec. 3(15)). The ESA thus considers a "distinct population segment" of vertebrates to be a "species". It does not however establish how distinctness should be determined. Under NMFS policy (NMFS 1991 II), for Pacific salmon, a population or group of populations will be considered a DPS if it represents an evolutionarily significant unit (ESU) of the biological species.

Educational Propagation Program: Programs designed and operated to inform and educate the public, and to provide opportunities for the public to participate in propagation initiatives.

Evolutionarily Significant Unit (ESU): For Chinook, coho, chum, sockeye, and pink salmon, a population or group of populations that is considered distinct because 1) they are substantially reproductively isolated from other con-specific groups and because 2) they represent an important component in the evolutionary legacy of the biological species. An ESU qualifies as a "species" under the Federal Endangered Species Act.

Experimental population: Any population, including eggs, propagules, or individuals of an endangered species or a threatened species authorized by the Secretaries (of Interior or Commerce depending on the species) for release outside the current range of such species if the Secretary determines that such release will further the conservation of such species (ESA section 10(j)).

Extant population: Existing populations of Pacific salmon.

Genetic Resources: The combination of natural-origin fish (NOF) and hatchery-origin fish (HOF) included in an ESU or steelhead DPS.

Hatchery: A facility that supports one or more hatchery programs.

Hatchery-Origin fish (HOF): Salmon or steelhead from parents (i.e., from either HOF or NOF parents) that were selected for broodstock and spawned artificially.

Hatchery Program: A group of fish that is handled separately and may have different spawning, rearing, marking and release strategies. The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004).

Hatchery Reform: Changes or improvements in practices to accomplish goals for the hatchery program.

Independent Population: Populations that are substantially reproductively isolated from other conspecific fish and that have population dynamics that are substantially independent from other groups. The exact level of reproductive isolation that is required for a population to have substantially independent dynamics is not well understood, but available scientific information indicates that substantial independence will occur when the proportion of a population that consists of migrants or non local fish is less than 10%.

Intrinsic Productivity: Intrinsic productivity is recruit to spawner (R/S) productivity when spawner abundance is low. R/S usually is calculated as an average productivity for all brood cycles during some specified time period. Intrinsic productivity however, considers a subset of those brood cycles with the lowest parental spawner abundance. Intrinsic productivity is an indication of resilience and the potential for a population to bounce-back and recover after periods of low abundance. Intrinsic productivity is expected to be higher than 1.0 because there should be little or no negative effect of density dependence when spawner abundance is low.

Integrated Hatchery Strategy: HOF are intended to be as similar as possible to local NOF. Processes that drive adaptation and fitness in the natural environment must dominate hatchery selection effects. The larger the ratio of NOF in the hatchery broodstock/ HOF spawning naturally + NOF in the hatchery broodstock, the greater the influence of the natural environment relative to the hatchery environment on selection. This ratio must exceed 0.5 in order for the natural environment to dominate or drive selection.

Integrated Fisheries Program: HOF are for harvest and are not intended to spawn naturally. HOF may also serve as a source of genetic resources to initiate a conservation program.

Lambda: Estimates trends in the abundance of natural spawners and counts hatchery-origin fish as both parental stock and recruits. Lambda does not help determine the ability of a population to sustain itself and grow in the absence of hatchery fish that subsidize natural spawning.

Limiting Factor: Any factor (anthropogenic or natural) that, by itself or in combination with other factors, slows or prevents anadromous salmonid population viability from improving.

Isolated Hatchery Strategy: HOF are intended to be dissimilar relative to local NOF and interactions between HOF and NOF are avoided (i.e., HOF are isolated from NOF). NOF are not used for hatchery broodstock and HOF are for harvest and not intended to spawn naturally.

Mitigation: In-kind replacement of what is lost or degraded. Impacts to habitat function (e.g., reduced habitat productivity) are mitigated by replacing or improving habitat function. Hatchery propagation can act as compensation, but it cannot mitigate for lost or degraded habitat.

Natural-Origin Fish (NOF): Fish originating from naturally spawning parents. This includes fish from naturally spawning natural-origin parents and fish from naturally spawning hatchery-origin parents.

Pacific Salmon: Any of the six species of the genus *Oncorhynchus* including *O. gorbuscha* (pink salmon), *O. keta* (chum salmon), *O. kisutch* (coho salmon), *O. nerka* (sockeye salmon), *O. tshawytscha* (Chinook salmon), and the anadromous form of *O. mykiss* (steelhead).

Proportion of Natural Influence (PNI): A measure of geneflow between hatchery-origin and natural origin fish. PNI is calculated as the percent natural-origin fish in the hatchery broodstock divided by the proportion of natural spawners comprised of hatchery-origin fish plus the percent natural-origin fish in the hatchery broodstock. Natural influence decreases and PNI approaches zero as the proportion of natural spawners comprised of hatchery-origin fish increases and as the proportion of hatchery broodstock comprised of natural-origin fish decreases.

Recovery: See the definition for delisting. For these purposes, Recovery occurs when an ESU or Steelhead DPS is determined to have improved such that it is not likely to become an endangered species within the foreseeable future, throughout all or a significant portion of its range, and is no longer in need of protection under the Endangered Species Act.

Returns or Recruits-per-Spawner (R/S): is a measure of whether a salmon or steelhead population is maintaining itself, declining, or growing. If 100 spawners produce 100 progeny that survive to maturity and successfully spawn, the R/S =1.0 and the population is maintaining or replacing itself. When R/S < 1.0, the population is declining.

Research Hatchery Programs: Programs designed to provide scientific information on the operation and performance of artificial propagation.

Returns: Pacific salmon returning to freshwater to reproduce.

Steelhead Distinct Population Segment (DPS): A group that is discrete from other groups and is significant to its taxon (species or subspecies). A group is discrete if it is markedly separated from other groups of the same taxon as a consequence of physical, physiological, ecological, and behavioral factors. Significance is measured with respect to the taxon as opposed to the full species.

Supplementation Hatchery Program: Fish from supplementation programs are intended to spawn naturally. Supplementation programs include captive broodstock, egg-box, and juvenile release programs. Supplementation programs can preserve genetic resources and they can increase the number and distribution of natural spawners. Returns from supplementation programs that are surplus to conservation needs are available for other purposes (e.g., human consumption, stream fertilization, harvest, etc.).

2. Background

The origins and evolution of artificial propagation for Pacific salmon provides important context for analyzing the benefits and risks of hatchery programs. From their origin more than one hundred years ago, hatchery programs have been tasked to compensate for factors that limit anadromous salmonid viability.

The first hatcheries, beginning in the late 19th century provided additional fish for harvest purposes on top of large relatively healthy salmon and steelhead populations. It wasn't long before the role of hatcheries shifted to replacing losses in fish production attributable to water development and land use practices that blocked access to important production areas or that degraded habitat and reduced salmon and steelhead survival. Hatchery programs were tasked to maintain returns of adult salmon and steelhead, usually for cultural, social or economic purposes, because the capacity of habitat to produce salmon and steelhead was reduced. In the Columbia Basin for example, as development proceeded (e.g., construction of the Federal Columbia River Power System (FCRPS) between 1939 and 1975) and the capacity for the basin to produce fish declined, hatchery production increased. National Fish Hatcheries were constructed in the upper Columbia after federal dams blocked access to approximately 50 percent of the production area for the Upper Columbia spring Chinook salmon Evolutionarily Significant Unit (ESU) and the Upper Columbia steelhead Distinct Population Segment (DPS). In the Snake River, the Columbia's largest tributary, hatchery programs were expected to replace losses of fall Chinook salmon from inundation of their spawning habitat and from reduced survival during their migration to and from the ocean because of the four federal dams on the Lower Snake River. The scope and level of hatchery production increased greatly during this period as impacts from development and the requirement to compensate for those impacts increased.

A new role for hatcheries emerged during the 1980s and 1990s after salmon and steelhead populations declined to unprecedented low levels. Hatchery programs were still expected to compensate for impacts to tribal, public, and commercial fisheries, but they also became a tool to conserve genetic resources, and in some cases, to help improve viability as the factors limiting viability are addressed. Some hatchery programs changed their goals and practices and whole new programs were implemented, including substantial new research to assess the efficacy of artificial propagation as a tool to promote conservation. The role of individual hatchery programs in two areas of the Columbia Basin is illustrated in Figure 1. Today, because nearly 90 percent of the Chinook salmon and steelhead habitat originally available in the Columbia Basin has been lost or degraded (Brannon et al. 2002), fish produced by hatcheries comprise the vast majority of the annual returns to the basin (CBFWA 1990). Annual returns of salmon and steelhead would be reduced by up to ninety percent and there would be little or no tribal, public or commercial fishing opportunity without hatcheries.

Genetic resources that represent the ecological and genetic diversity of a species can reside in fish spawned in a hatchery as well as in fish spawned in the wild (NMFS 1991b; Hard et al. 1992). Natural production has been in decline for over a century and now the vast majority of returning adult salmon and steelhead are hatchery fish. For a list of hatchery fish included in salmon ESUs and steelhead DPSs, see NMFS (2003). Hatchery programs also can be used as a proactive tool to conserve the genetic resources of depressed natural populations and to reduce short-term extinction risk. Hatchery programs can preserve the raw materials (i.e., genetic resources) that ESU and steelhead DPS conservation depends on and buy time until the factors limiting salmon and steelhead viability are addressed. In this role, hatchery programs can reduce the risk of extirpation, and thereby mitigate the immediacy of an ESU's extinction risk. In absence of hatchery programs like this, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. Hatchery programs that only conserve genetic resources however "do not substantially reduce the extinction risk of the ESU in the foreseeable future" or long-term (70 FR 37160; June 28, 2005). Furthermore, hatchery programs that conserve vital genetic resources are not without risk because the manner in which these programs are implemented can have significant impacts on the genetic structure and evolutionary trajectory of the target population by reducing population or ESU/DPS-level variability and patterns of local adaptation (ICTRT 2007). In fact, when hatchery programs are relied upon to conserve genetic resources and reduce short-term extinction risk, there likely is a trade-off between reducing short-term extinction risk and potentially increasing long-term genetic risk.

Population viability and reductions in threats are key measures of salmon and steelhead status relative to recovery. Beside their role in conserving genetic resources, hatchery programs also are a tool that can be used to help improve viability (i.e., hatchery supplementation). In general, these hatchery programs increase the number and spatial distribution of naturally spawning fish (i.e., F1 hatchery-origin fish). They are not however a proven technology for achieving sustained increases in adult production (NRC 1996), and the long-term benefits and risks of hatchery supplementation remain untested (Araki et al. 2007a). In the interim, it is important and necessary to follow a measured and well conceived application of hatchery supplementation as opposed to any widespread moratorium that could do more harm than good for fish. For an overview of the pros and cons/benefits and risks from existing hatchery operations see NMFS 2004a, NMFS 2006b and Hatchery Effects Appendix.

Hatchery actions designed to benefit salmon and steelhead viability sometimes produce only limited positive results. One potential reason for this is that other factors (i.e., limiting factors and threats) can offset or out-weigh the benefits from hatchery actions. For example, in Puget Sound, eight Chinook salmon hatchery programs are specifically implemented to preserve native populations in their natal watersheds "where habitat needed to sustain the populations naturally at viable levels has been lost or degraded" (70 FR 37160; June 28, 2005). These hatchery programs deserve credit for helping "to preserve remaining genetic diversity, and likely have prevented the loss of several populations" (70 FR 37160; June 28, 2005). Until, however, the factors limiting Puget Sound Chinook salmon productivity are addressed, the full benefit (i.e., potential contributions to increased viability) of hatchery actions designed to benefit salmon viability may not be realized. Hatchery programs can serve an important conservation role when habitat conditions in freshwater depress juvenile survival or when access to spawning and rearing habitat is blocked. Under circumstances like these and in the short-term, the demographic risks of extinction likely exceed genetic and ecological risks to natural-origin fish from hatchery supplementation. Benefits like this should be considered *transitory* or short-term and do not contribute to survival rate changes necessary to meet ICTRT abundance and productivity viability criteria. Fixing the factors limiting viability is the key to improving viability. "The fitness of the naturally spawning population, its productivity, and the numbers of adult salmon returning to the watershed, ultimately must depend on the natural habitat, not on the output of the hatchery" (HSRG 2004). Salmon and steelhead populations that rely on hatchery production are not viable (McElhany et al. 2000).

In the course of providing these benefits, there also is the potential for hatchery programs to increase the extinction risk and threaten the long-term viability of natural populations. For almost four hundred hatchery programs up and down the West Coast, NMFS 2004a evaluates benefits and risks at two levels: at the population level and at the ESU or DPS level. For programs in the Interior Columbia (upstream from Bonneville Dam), the Hatchery Effects Appendix in the May 5, 2008 NMFS Biological Opinion for the Federal Columbia River Power System, with input provided by members of the Hatchery and Harvest Workgroup of the FCRPS collaboration; (1) summarized the major factors limiting salmon and steelhead recovery at the population scale, (2) provided an inventory of existing hatchery programs including their funding source(s) and the status of their regulatory compliance under the ESA and under the National Environmental Policy Act , (3) summarized the effects on salmon and steelhead viability from current hatchery operations, and (4) identified new opportunities or changes in hatchery programs likely to benefit population viability. As a follow-up to the Hatchery Effects Report, NMFS developed recommendations for determining hatchery effects, including an overview of hatchery programs in the upper Columbia and Snake River Basin and presented this paper to the Hatchery and Harvest Workgroup and to the Policy Workgroup in August of 2006. NMFS received comments and made edits to this paper to provide updated recommendations for assessing benefits and risks as a result of operating hatchery programs (NMFS 2007a.

Increasing knowledge and experience is another important factor in the application of hatchery supplementation. Hatchery supplementation is an "experimental" technology. It is relatively new and there is little data on long-term benefits and risks – study results for a single generation of Pacific salmon take a minimum of three to five years. The good news is that new information is emerging from ongoing research and important new research will be implemented as a result of NMFSs Biological Opinions. The reproductive fitness of hatchery fish and the effects of hatchery supplementation on population viability will be investigated for steelhead in the Methow River and for fall Chinook salmon in the Snake River. NMFS intends that the information emerging from ongoing and new studies will shape future decisions over hatchery supplementation up and down the west coast.

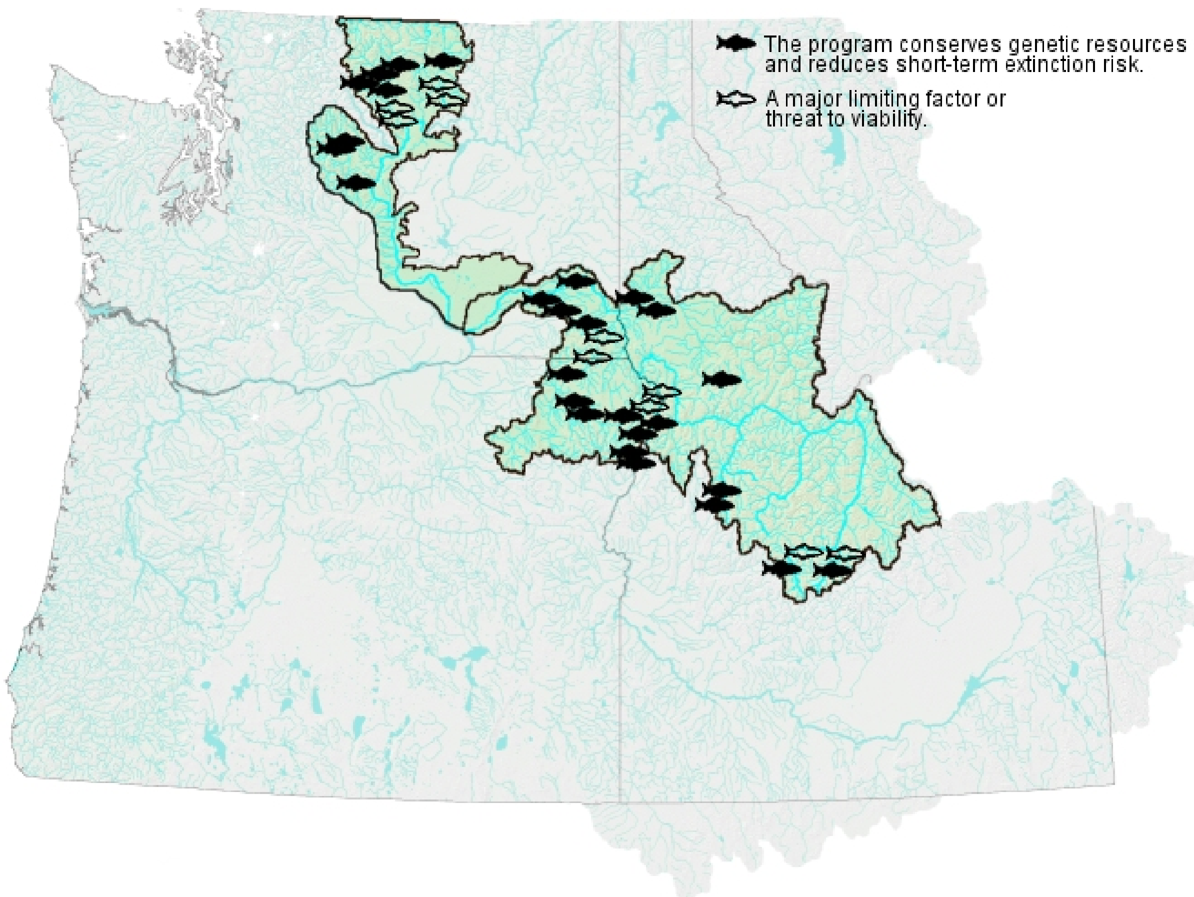


Figure 1. The role of hatchery programs in the upper Columbia and Snake River Basin. For identification and a description of the hatchery programs referenced below, see Table 4.

Hatchery programs are mitigation for factors limiting salmon and steelhead survival. The nearly two hundred programs that operate in the Columbia Basin are mitigation for Federal and public and private utility projects and the funding level and funding source for these programs is provided in Table 1.

Table 1. Estimated FY 2006 hatchery operation and maintenance funding for nearly 200 salmon and steelhead hatchery programs in the Columbia River Basin.

Funding Source	Annual Funding Level in millions of dollars
Bonneville Power Administration	$50.1
Utilities	$14.0
National Marine Fisheries Service, Federal Mitchell Act	$11.4
Corps of Engineers	$5.1
Bureau of Reclamation	$4.6
Oregon	$1.3
Federal Pacific Coast Salmon Restoration Fund	$1.0
Total	$87.5

3. Assessing the Benefits and Risks of Salmon and Steelhead Hatchery Programs

It is important and necessary to better understand the effects of hatchery programs. This paper offers a framework for determining the benefits and risks of existing hatchery programs and of alternative or proposed new hatchery actions. Seven factors are described here for assessing the benefits and risks of hatchery programs. These factors include: (1) population viability status and recovery goals, (2) the conservation of genetic resources, (3) effects, positive and negative, on population viability, (4) research monitoring and evaluation, (5) hatchery effects on density-dependent processes, (6) effects of hatchery weirs, and (7) compensation for impacts to Indian treaty, public, commercial and international fisheries.

3.1 Status and Viability Goals

3.1.1 *Status of the Fish*

Status of the fish at the population, major population group, and ESU or steelhead DPS scales is an important factor or consideration in assessing the benefits and risks of hatchery programs.

Status of the fish is determined by their level of viability and by threats to their survival. "Management actions ultimately need to be related to population and ESU viability" (McElhany et al. 2000). In general, the greater the viability of a fish population and the greater the protection from threats, the lesser the need and potential benefit of hatchery supplementation and the greater the risk tolerance of the fish to negative hatchery effects. For example, a viable population is at less risk from hatchery fish straying than a population at low viability with respect to protecting productivity and diversity. Conversely, direct hatchery supplementation confers fewer potential benefits to a population at high viability than to one at low viability.

Increasing viability must also be accompanied by a decreasing level of threat for population status to improve. This means that even as the viability of a population improves, continued hatchery supplementation may be important and beneficial until identified threats to a population's continued existence are addressed. For example, hatchery supplementation may be followed by only temporary increases in the abundance and spatial distribution of natural spawners and in the abundance of natural-origin fish unless known threats to the fish are alleviated. Changing environmental conditions (e.g., cycles in ocean productivity) also may lead to temporary increases in viability.

Hence, the level of viability and the level of threats are key components for assessing benefits and risks from existing and proposed new hatchery programs. One potentially useful guideline might be that hatchery effects pose the greatest benefits and risks when natural populations are below their critical threshold for viability and self-sustainability compared to natural populations that exceed those critical thresholds.

3.1.1 *Viability Goals*

Another important factor in assessing the benefits and risks of hatchery programs is the viability goal for salmon and steelhead populations. Recovery Plans are one place to find viability goals and these goals are determined in cooperation with Technical Recovery Teams (TRT). Viability goals are based on the importance of a population to ESU or steelhead DPS recovery and the viability goal for a population can range widely, from highly viable to maintaining minimum viability. The importance of a population and its corresponding viability goal depends on several factors including the potential size and any unique characteristics of the population. For example, larger populations in general stand a better chance of surviving or persisting during downturns in environmental conditions and unique life-history characteristics (e.g., populations including a summer-returning fish among populations where the spring-run characteristic dominates) decreases extinction risk by benefiting spatial distribution and diversity and acts to buffer a population against environmental variability. Populations like these likely must achieve a higher level of viability for an ESU or DPS to achieve recovery. Viability goal is a factor in a population's tolerance for negative effects. In general, the higher the viability goal, the lower tolerance to negative effects, including any risks posed by hatchery programs. For example, there should be a lower tolerance for stray hatchery-origin fish spawning together with a population that has a high viability goal. A higher level of hatchery strays could be acceptable for populations with a lower viability goal. The viability goal is thus a critical consideration in assessing the level of benefits and the potential risks from one or more hatchery programs. More than half of the 52 ESUs and steelhead DPSs up and down the West Coast are protected under the ESA and viability goals can be found in completed Recovery Plans.

3.2 Conservation of Genetic Resources

Natural production has been in decline for over a century and now the vast majority of returning adult salmon and steelhead are hatchery fish. Genetic resources that represent the ecological and genetic diversity of a species can reside in fish spawned in a hatchery as well as in fish spawned in the wild (NMFS 1991b; Hard et al. 1992). For a list of hatchery fish included in salmon ESUs and steelhead DPSs, see NMFS 2004b. Hatchery programs also can be used as a proactive tool to conserve the genetic resources of depressed natural populations and reduce ESU and steelhead DPS extinction risk. For example, in determining whether Lower Columbia River (LCR) coho salmon warranted listing under the ESA, NMFS concluded that "hatchery programs collectively mitigate the immediacy of extinction risk for the LCR coho ESU in-total in the short term", and this is an important benefit that hatchery programs can provide. However, hatchery programs that only conserve genetic resources "do not substantially reduce the extinction risk of the ESU in the foreseeable future" or for the long-term (70 FR 37160; June 28, 2005). "Hatcheries are not a proven technology for achieving sustained increases in adult production" (NRC 1996), and the long-term effects of hatchery supplementation remain untested (Araki et al 2007a).

Hatchery programs preserve the raw materials (i.e., genetic resources) that ESU and steelhead DPS conservation depends on. In the absence of hatchery programs like these, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. This beneficial effect, however, should be considered transitory because increasing dependence on hatchery intervention results in decreasing benefits and increasing risk. In fact, when hatchery programs are relied upon to conserve genetic resources and reduce short-term extinction risk, there likely is a trade-off between reducing short-term extinction risk and potentially increasing long-term genetic risk (ICTRT 2008). Hatchery supplementation programs, including captive-broodstock or safety-net programs, or hatchery programs that also function as gene reserves, fit into this category. In general, these hatchery programs can increase the number and spatial distribution of naturally spawning fish (i.e., F1 hatchery-origin fish), but, because they do not address the factors limiting viability (e.g., mainstem survival, habitat conditions, ocean productivity), increased population viability cannot be attributed to the program. For example, hatchery programs can serve an important conservation role when habitat conditions in freshwater depress juvenile survival, or when access to spawning and rearing habitat is blocked.

Hatchery actions designed to benefit salmon and steelhead viability sometimes produce only limited positive results. One potential reason for this is that other factors (i.e., limiting factors and threats) can offset or out-weigh the benefits from hatchery actions. For example, in Puget Sound, eight Chinook salmon hatchery programs are specifically implemented to preserve natural populations in their natal watersheds "where habitat needed to sustain the populations naturally has been lost or degraded" (70 FR 37160; June 28, 2005). These hatchery programs benefit conservation of an ESU or steelhead DPS and have helped "to preserve remaining genetic diversity, and likely have prevented the loss of several populations" (NMFS 2005 III). Until however the factors limiting salmon and steelhead productivity are addressed, the full benefit (i.e., potential contributions to increased viability) of hatchery actions designed to benefit salmon and steelhead viability may not be realized.

Hatchery programs can buy time until the factors limiting salmon and steelhead viability are addressed. "The fitness of the naturally spawning population, its productivity, and the numbers of adult salmon returning to the watershed, ultimately must depend on the natural habitat, not on the output of the hatchery" (HSRG 2004). Without a hatchery program like this, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. Under circumstances like these and in the short-term, the demographic risks of extinction exceed genetic and ecological risks from hatchery supplementation. Benefits from this category of effects should be considered *transitory* or short-term and do not contribute to survival rate changes necessary to meet ICTRT abundance and productivity viability criteria.

3.3 Effects on Population Viability

"The presence of well distributed self-sustaining natural populations that are ecologically and genetically diverse provides the most certain basis to determine that an ESU or steelhead DPS is not likely to become endangered in the Foreseeable future (i.e., whether a species is threatened or listing is not warranted)" (70 FR 37160; June 28, 2005). NMFS includes hatchery fish in assessing an ESU's status in the context of their contributions to conserving natural-self-sustaining populations.

The primary criteria for determining the viability of salmon and steelhead populations are described by McElhany et al. (2000). These criteria are the abundance, productivity, spatial distribution and diversity of natural-origin fish (NOF). Hatchery origin fish (HOF) can benefit or harm salmon and steelhead viability. In determining the effects (positive or negative) of hatchery programs on salmon and steelhead viability, it is necessary then to determine their influence on these criteria. It is also is important to recognize that a single hatchery effect can and often does influence multiple viability criteria. For example, increases in NOF attributable to a hatchery program can benefit both abundance and spatial distribution while on the other hand, the removal of NOF for hatchery broodstock reduces abundance and can reduce productivity and spatial structure also. Ultimately, the number, nature and scale of hatchery programs must be consistent with the maintenance of naturally self-sustaining ESUs or steelhead DPSs. "A population that depends upon naturally spawning HOF for its survival is not viable" (McElhany et al. 2000).

The following guidance describes what to look for when assessing hatchery programs for their effects (i.e., benefits and risks) on parameters that determine salmon and steelhead population viability.

Abundance

Abundance is the number of fish produced by natural processes that have spent their entire life cycle in nature (i.e., natural-origin fish). This is often referred to as gravel-to-gravel survival or fish originating from naturally spawning parents that hatch from the gravel and that survive to spawn naturally themselves years later. The effect of a hatchery program on salmon and steelhead abundance should be determined by:

a. The proportion and number of natural-origin fish (NOF) removed from any population or spawning aggregate to provide hatchery broodstock (i.e., NOF that are taken into a hatchery instead of left to spawn naturally).

b. The proportion and number of NOF killed or injured by hatchery facilities (e.g., hatchery water intakes) and handling effects.

c. The reduction and loss of natural production caused by hatchery facilities that block, delay, or impede adult fish from returning to spawning areas (e.g., weirs, ladders or traps).

d. Sustained increases in NOF (compared to a condition absent or previous to hatchery intervention) attributable to successful reproduction of hatchery-origin fish intended to spawn naturally (i.e., hatchery supplementation). Eggs and juveniles released into streams and adult returns from these releases, serve to seed freshwater spawning and rearing areas. These naturally spawning hatchery-origin fish may reproduce successfully under natural conditions to increase the abundance of natural-origin juveniles and returning adults. Ultimately, the survival and natural reproductive success of natural-origin progeny (i.e., the progeny of naturally spawning parents, whether of natural-origin or hatchery-origin) determine the overall viability of any supplemented population.

e. The injury or mortality (i.e., from catch and release or from retention) of NOF or HOF intended to spawn naturally from fisheries targeting surplus HOF.

Productivity

Productivity, as a measure of salmon and steelhead viability for ESA purposes, is the adult-replacement rate of natural-origin fish spawning naturally. It is usually quantified or described by the ratio (R/S) or the number of adult-offspring recruits (R) per adult-parent spawners (S) of the previous generation. It is a measure that directly relates to the potential ability for a population or spawning aggregate to be self-sustaining. For example, the productivity measure used by the Interior Columbia Technical Recovery Team (ICTRT) is expressed in terms of recruits per spawner or the rate at which natural spawning adults in one generation are replaced by natural-origin natural spawning adults in the next generation. This measure of life-cycle productivity is affected by mortality and survival at all life stages combined. Consequently, there are only five situations where hatchery-origin fish spawning naturally can increase productivity: (1) if productivity is limited by the number of natural spawners (e.g., fish have difficulty finding mates or experience “Allee effects”), (2) the natural population has undergone inbreeding depression due to multiple generations of very low abundances (e.g., less than 20 spawning pairs per year for more than two generations) and the hatchery-origin fish are not of that same inbred stock, (3) habitat is being re-colonized via reintroductions using hatchery-origin fish, (4) HOF carcasses increase nutrients in spawning and rearing areas, and (5) naturally spawning HOF “clean” (i.e., reduction in fine sediments) spawning gravels. The effect of a hatchery program on salmon and steelhead productivity should be determined by:

a. The natural reproductive success of HOF spawning naturally relative to NOF spawning naturally.
b. The productivity of natural-origin progeny, otherwise referred to as fitness, derived from naturally spawning HOF (i.e., the life-cycle survival or replacement rate of progeny of naturally spawning HOF) relative to naturally spawning NOF.
c. The life history characteristics of naturally spawning HOF compared to naturally spawned NOF (e.g., age-of-return, size-at-return, spawn timing, fecundity, etc.).
d. In addition to a-c, the Proportion of Natural Influence (PNI) for hatchery programs that supplement natural spawning aggregates or populations of salmon and steelhead.
e. Competition for food or habitat between NOF and released HOF (i.e., density-dependent mechanisms).
f. Maintenance of within-population substructure (e.g., multiple spawning aggregates).
g. Whether hatchery facilities (e.g., weirs, ladders, diversions) affect escapement back to the area of origin, rates of natural straying, or dispersal of fish (adults and juveniles) into under-used habitats, especially when adult returns are large.
h. Competition for prime spawning areas and redd superimposition (another density-dependent mechanism, e.g., if large numbers of hatchery-origin adults with lower reproductive success displace natural-origin spawners).
i. Predation on juvenile NOF by released HOF.
j. Interbreeding between HOF and NOF that reduces reproductive genetic fitness of natural-origin adult recruits relative to the progeny of NOF only.
k. HOF nutrient contribution to freshwater rearing areas.
l. Changes in intrinsic productivity.

Spatial structure

Spatial structure is the range or distribution of NOF. Any viability evaluation must consider spatial structure within a population (or group of populations) because spatial structure affects extinction risk (McElhany et al. 2000). In general, HOF can increase spatial structure only when NOF (i.e., the progeny of naturally spawning hatchery-origin fish) expand their distribution and recolonize former range. The effect of hatchery programs on salmon and steelhead spatial structure should be determined by:

a. Whether reintroductions using HOF assist in reestablishing viable salmon and steelhead populations within their former range.
b. Whether hatchery supplementation slows any reduction in spatial structure.
c. Whether hatchery facilities (i.e., weirs, ladders, diversions, etc.) affect escapement back to the area of origin, rates of natural straying, or dispersal of fish (adults and juveniles) into under-used habitats, especially when adult returns are large.

d. Competition for prime spawning areas and redd superimposition.
e. Competition between HOF and NOF juveniles for rearing areas.
f. Predation on juvenile NOF by HOF.
g. Spawning between HOF and NOF that reduces reproductive genetic fitness and thereby reduces spatial structure via reduced abundance of natural-origin recruits in subsequent generations. (e.g., outbreeding depression).
h. HOF nutrient contribution to freshwater rearing areas.

Diversity

Diversity refers to the distribution of traits within and among populations of salmon and steelhead. These traits include anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, physiology and molecular genetic characteristics. Combinations of genetic and environmental factors largely cause phenotypic diversity. Variation or diversity in these and other traits is important to viability because 1. it allows fish to take advantage of a wider array of environments, 2. it spreads the risk (e.g., different ocean distribution patterns mean not all fish are at risk from local or regional varying ocean conditions) and 3. genetic diversity allows fish to adapt to changing environmental conditions. Hydropower, habitat, harvest, and hatchery factors can all affect diversity. In the case of hatchery programs, gene flow and local adaptation strongly influence patterns of diversity within and among salmon and steelhead populations. The effect of hatchery programs on salmon and steelhead diversity should be determined by:

a. The origin of hatchery broodstock (i.e., the source relative to the affected natural population), the number of generations in captivity, and evidence of domestication selection.
b. The similarity of HOF traits relative to NOF traits, relative survivals, and how the hatchery program affects effective population size.
c. Gene flow of HOF into a natural population or spawning aggregate. Natural rates of gene flow have helped salmon and steelhead to persist and adapt to local conditions. For groups of salmon and steelhead determined important to recovery (i.e., for groups that must maintain at least viable status), the natural or background level of gene flow (including duration) between spawning aggregates, between populations, between Distinct Population Segments and between Evolutionarily Significant Units should be maintained.
d. The extent to which a hatchery program preserves or builds salmon or steelhead genetic resources, including potential increases in life history diversity and the establishment of new, locally-adapted populations via habitat expansions and reintroductions.

3.4 Research, Monitoring and Evaluation

The Hatchery Fish Fraction of Natural Spawners

Valid estimates of the proportion of natural spawners comprised of HOF (i.e., the hatchery fish fraction of natural spawners) should be provided for individual spawning aggregates and populations. ESA authorization to operate a hatchery program and funding agreements should include a condition that valid hatchery fraction estimates must be calculated on an annual basis.

"Valid estimates of natural productivity are impossible to obtain for supplemented populations in which the abundance of naturally-produced and hatchery produced fish on the spawning grounds are not estimated separately" (McElhany et al. 2000). Average R/S provides the most realistic assessment of the likelihood that a population will trend toward recovery in the absence of continued hatchery programs (i.e., natural productivity). This is because the metric considers only the survival of NOF. This metric also requires the most data for each population, since brood-year specific estimates of hatchery fraction and age structure are necessary. For a number of populations, this requires assumptions and extrapolations from other populations or time periods.

The Spatial and Temporal Distribution of Hatchery Spawners

T*he spatial and temporal distribution of naturally spawning HOF must be monitored.* Understanding to what extent HOF spawn at the optimal time and in preferred habitats and to what extent HOF interbreed with NOF is crucial to assessing the benefits and risks of hatchery programs.

Hatchery Fish Fitness in Nature

Valid estimates of HOF fitness in nature are needed to assess the benefits and risks of hatchery programs that produce fish that spawn with NOF.
When HOF spawn naturally, "It is necessary to know or estimate the relative fitness of HOF compared to NOF in order to estimate natural productivity of the population" (Berejikian and Ford 2004). In the 2000 Federal Columbia River Power System Biological Opinion, NMFS estimated productivity (lambda) twice for 152 salmon and steelhead populations assuming that HOF in general were either 20% or 80% as fit as NOF. New information has become available since 2000, and it is now possible to assign HOF to fitness categories based on a common set of factors that studies show influence HOF fitness in the natural environment. This allows better estimates of lambda for natural populations where hatchery and natural fish co-occur in spawning areas. This is a new area of research and further studies are needed to improve the accuracy of hatchery fitness predictions including, replicate studies on other species subject to different hatchery practices and particularly on species with abbreviated freshwater life histories (e.g., ocean-type Chinook salmon).

Hatchery Affects on Density-Dependent Processes

Evaluating the factors that influence or drive density dependent effects under different freshwater conditions (e.g., hydrosystem) and ocean conditions is an important area of future research. Information gaps need to be filled to help managers make cost-effective decisions that serve both conservation and sustainable fisheries mandates. The significance of hatchery effects on density-dependent mechanisms and natural populations is largely unknown and this hampers the ability to assess the return from prospective investments in hatchery reform or the effects of additional hatchery production. In this section, we summarize how to provide additional insights into the effects of HOF on Pacific salmon viability and identify future research needs that would help inform management decisions.

Additional analyses incorporating more recent and broader ranging data from the Columbia River Basin may provide an example of how large-scale hatchery releases can affect natural populations through density-dependent mechanisms (Berejikian et al. 2007). The numbers of HOF released in the Columbia River Basin has steadily declined from the peak year of 1982, so adding years in which fewer HOF were released will improve the ability to quantify hatchery effects.

Tools that can be used to better understand potential effects on NOF growth and survival at each life stage and location in the life cycle are needed to help inform hatchery policy and management decisions and for recovery planning purposes in general. A model that explores direct competition for food and habitat and indirect mechanisms such as changes in the foraging activity of predators could provide important guidance. The first step would be to model salmon size and growth rates as functions of the physical (e.g., temperature, light, flow/currents) and biological (i.e. biomass and community composition of the prey base) environments. It would then be possible to estimate food demands to support natural fish relative to the supply. Next, data on the size and composition of the predator community (fish, birds, marine mammals) would be used to model predation risk for salmon and steelhead as a function of their species and size. Through “scenarios” that reflect various endpoints for hatchery release schedules, number of releases, and sizes of fish at the time of release, it would be possible to evaluate the (1) competitive effects of HOF with NOF for food, (2) effects of increased total prey biomass on predator foraging (including the possibility of predator “swamping”), and (3) the indirect effects of increased predator biomass on NOF due to increases in overall prey abundance (i.e. millions of hatchery smolts).

At the local level, additional data is needed to determine which ESUs, steelhead DPSs and Major Population Groups are affected by hatchery releases, is the growth and survival of NOF affected by just local hatcheries, or by the summed magnitude of hatchery releases across a larger landscape, and is NOF survival affected by hatchery releases of conspecifics only, or also by releases of heterospecifics? Studies that address these questions should incorporate important measures of ocean productivity (e.g., PDO, ENSO, spring transition date).

3.5 Hatchery Effects on Density-Dependent Processes

Evidence of HOF effects on density-dependent processes in freshwater and marine environments is presently insufficient to guide policy on the appropriate scale of hatchery releases (Berejikian et al. 2007). There is however, considerable interest and speculation over the issue of density-dependent effects on natural populations. For example, because of concerns for three salmon ESUs and one steelhead DPS, the Draft Snake River Salmon ESA Recovery Plan went so far as to propose a "limit on annual releases of anadromous fishes from Columbia Basin Hatcheries". This proposal however was tempered by the acknowledgement that there is little definitive information available to directly address the effects of ecological factors on the survival and growth of fish from natural populations of Pacific salmon (NMFS 1995c).

Pacific salmon at all abundance levels and at all life stages are subject to density-dependent processes. Many factors influence these processes including, changes in habitat quality and quantity, prey base, the abundance and distribution of predators, natural fluctuations in environmental conditions (e.g., summer stream flows and ocean productivity), and interactions among species and between natural and hatchery fish that depend on the same natural environments. The question is, how and to what extent do HOF, in combination with these and other factors, affect density-dependent processes and the growth and survival of NOF.

There is increasing evidence of density-dependent effects on salmon and steelhead growth and survival but the underlying factor or factors (e.g., HOF) remain poorly understood. For example, reduced growth and survival rates have been linked to high salmon abundance in the open ocean (e.g., Peterman 1984), but the role of HOF in reduced growth and survival rates remains unknown. Ruggerone et al. (2003) concluded that growth and survival of Bristol Bay sockeye salmon was inversely related to Asian pink salmon abundance but the contribution of hatchery reared Asian pink salmon to reduced growth and survival of sockeye salmon is unknown. Evidence of competition was apparent over the 45-year period of study, but the effect was most pronounced when survival rates and abundance levels were high for both species. Levin et al. (2001) tested the hypothesis that the sum of Chinook releases from Columbia Basin hatchery programs reduced the survival of natural-origin Chinook salmon from the Snake River Basin. The study concluded that releases of hatchery spring/summer Chinook salmon were not associated with natural-origin Chinook salmon survival, unless the data were divided post-hoc into years when the oyster condition index (a measure of near-shore ocean productivity; OCI) was low. There was a significant negative correlation between numbers of hatchery spring/summer Chinook released and natural-origin Snake River Chinook survival during low OCI. In contrast, Levin and Williams (2002) found no significant associations between the number of steelhead released from Snake River Basin hatchery programs and natural-origin Snake River steelhead regardless of ocean conditions (based on the El Niño-Southern Oscillation; ENSO). Survival of steelhead and Chinook salmon were not correlated with ENSO. However, there was a negative association between the number of hatchery steelhead released and natural-origin Chinook salmon survival. One likely explanation for the effect on Chinook occurs via predation from Caspian Terns that are attracted to the Columbia River estuary and feed on large aggregations of hatchery steelhead. For Oregon coastal coho salmon, Nickelson (2003) found a negative relationship between the average number of hatchery releases and population productivity (as estimated by the Ricker "a" parameter). The study did not determine how HOF reduced coho productivity but the author suggested that the likely effect occurs via predation, such that predators are attracted to large aggregations of hatchery coho and that NOF are thus more susceptible to piscivorous fish, birds, and mammals.

Another consideration is that ocean conditions, including spatial and temporal variations in ocean productivity, affect interactions among species and between hatchery and natural-origin salmon and steelhead. *Ruggerone and Goetz (2004)* suggested that abundant pink salmon protected hatchery Chinook salmon from predation during high ocean productivity but lead to competition-based mortality and reduced survival during poor ocean years. Evaluating the factors that influence or drive density dependent effects under different freshwater (e.g., hydrosystem) conditions and ocean conditions is an important area of future research because it will help managers make cost-effective decisions that serve conservation and sustainable fisheries mandates. In section 3.4, we summarize how to provide additional insights into the effects of HOF on natural salmon growth and survival.

Emerging data and analysis from ongoing studies is not going to be enough to guide decision-making processes that have important social, legal and economic implications. That's because the significance of hatchery effects on density-dependent mechanisms and natural populations is still largely unknown. This unknown hampers the ability to assess the return from potential investments in hatchery reform or the effects of additional hatchery production. There are practices that hatcheries can and should implement in the mean time to reduce potential affects on density-dependent mechanisms and corresponding threats to salmon and steelhead growth and survival. Hatchery programs that intend to supplement natural populations should:

1. monitor the accessibility, distribution, carrying capacity, and natural seeding level of spawning and rearing habitats in the area,
2. control the quantity of egg box and pre-smolt juvenile releases so that natural and hatchery fish combined do not exceed rearing habitat carrying capacity,
3. juvenile releases should mimic the size and condition of natural fish to avoid competitive advantages relative to natural fish,
4. juvenile releases should mimic the size and condition of natural fish to reduce hatchery fish residualism,
5. juvenile releases should mimic the size and condition of natural fish to reduce predation on natural or other hatchery fish,
6. acclimate hatchery smolts to improve the homing fidelity of adult returns and limit straying,
7. control HOF natural spawning to avoid superimposition of NOF spawning redds and to limit competitive interactions between the progeny of naturally spawning HOF and naturally spawning NOF,

8. control hatchery fish natural spawning so that rearing habitat carrying capacity is not exceeded, and
9. ensure that hatchery operations and structures allow unobstructed passage and distribution of juvenile and adult salmon and steelhead and that properly functioning habitat conditions are not degraded.

Practices that isolate or avoid interactions between HOF and NOF should be implemented for programs that produce fish exclusively for harvest purposes. Such practices include:

1. release fish at a size and condition factor that reduces residualism,
2. releasing fish away from populations that are important to salmon and steelhead recovery,
3. acclimate hatchery smolts to improve homing fidelity so that adult returns can be harvested and collected at hatchery facilities and so hatchery fish do not spawn naturally and produce offspring that compete with natural salmon and steelhead,
4. release fish at a size and condition factor that leads to their prompt emigration to the ocean, and
5. mark fish externally so they can be distinguished for harvest purposes and collected for hatchery broodstock.

3.6 Hatchery Weirs

The proper design and operation of hatchery weirs, including the monitoring of potential risk factors, can appreciably reduce the risks they pose to Pacific Salmon (Hevlin and Rainey 1993; NMFS 2008). Weirs are a tool for broodstock collection and for removing adult hatchery fish or for maintaining the appropriate level of hatchery fish that spawn naturally (i.e., supplementation hatchery programs). They can also assist in determining and tracking the status of Pacific salmon populations or spawning aggregates and in research projects, including hatchery effectiveness studies. These functions may be crucial to the operation of existing or prospective hatchery programs but weirs also pose risks that must be factored into design and implementation decisions.

Risk factors from the physical presence of a weir or trap include:

- Delaying upstream adult migration,
- Causing the fish to reject the weir or fishway structure, thus inducing spawning downstream of the trap (displaced spawning),
- Contributing to fallback of fish that have passed above the weir,
- Injuring or killing fish when they attempt to jump the barrier (Hevlin and Rainey 1993, Spence et al 1996), and
- Reducing the spatial distribution of juvenile salmon and steelhead seeking preferred habitats.

Potential risks from operating a weir or trap include:

- Physically harming the fish during their capture and retention whether in the fish holding area within a weir or trap, or by the snagging, netting or seining methods used for certain programs;
- Harming fish by holding them for long durations;
- Physically harming fish during handling; and
- Increasing their susceptibility to displacement downstream and predation, during the recovery period.

Other Considerations include:

- Aesthetic or visual effects,
- Changes to stream hydrology in the vicinity,
- Impacts to properly functioning habitat conditions, and
- Costs to construct, maintain, and operate the weir.

The installation and operation of weirs and traps are very dependent on water conditions at the trap site. High flows can delay the installation of a weir or make a trap inoperable. A weir or trap is usually operated in one of two modes. Continuously – where up to 100 percent of the run is collected and those fish not needed for broodstock are released upstream to spawn naturally, or periodically – where the weir is operated for a number of days each week to collect broodstock and otherwise left opened to provide fish unimpeded passage for the rest of the week. The mode of operation is established during the development of site-based broodstock collection protocols and can be adjusted based on in-season escapement estimates and environmental factors.

The potential impacts of weir rejection, fallback and injury from the operation of a weir or trap can be minimized by allowing unimpeded passage for a period each week. Trained hatchery personnel can reduce the impacts of weir or trap operation, by removing debris, preventing poaching and ensuring safe and proper facility operation. Delay and handling stress may also be reduced by holding fish for the shortest time possible, less than 24 hours, and any fish not needed for broodstock should be allowed to recover quickly from handling and be immediately released upstream to spawn naturally. However, it may be necessary to hold fish longer at the beginning and the end of the trapping season when the adult numbers are low.

There are alternatives to using weirs and a preferred option should be selected based on site-specific considerations. Beach seines, hook and line, gillnets and snorkeling are potential options for collecting hatchery broodstock and managing the escapement and natural spawning of HOF. All of these methods pose risks to NOF through injury, delaying their migration, changing their holding and spawning behavior, and increasing their susceptibility to predation and poaching. Some artificial production programs collect juveniles for their source of broodstock. Programs can collect developing eggs or fry by hydraulically sampling redds or collected emerging juvenile fish by capping redds (Shaklee et al. 1995; WDFW et al. 1995; Northwest Indian Fisheries Commission and WDFW 1998). Seines, screw traps and hand nets can also be used to collect juveniles. Each of these methods can adversely affect natural fish through handling or harming the juvenile fish that remain.

3.7 Hatchery Compensation for Impacts on Indian Treaty, Public, and Commercial Fisheries

Since time immemorial, the religion, economy and culture of Native Americans has depended on salmon and steelhead resources. These fisheries were so important that the United States signed treaties with many of the sovereign tribes that explicitly preserved Indian fishing rights. NMFS is committed to conserving salmon and steelhead in a manner that is fully consistent with the Government's treaty obligations and Indian trust responsibilities.

NOAA Fisheries' mission statement includes a strategic objective to "manage and rebuild fisheries to population levels that will support economically viable and sustainable harvests". The Policy for Conserving Species Listed or Proposed for Listing Under the ESA While Providing and Enhancing Recreational Fisheries Opportunities (NMFS and USFWS 1996), was jointly published by NMFS and the U.S. Fish and Wildlife Service on June 3, 1996. This policy was issued pursuant to Presidential Executive Order 12962, issued on June 7, 1995. That order requires Federal agencies, to the extent permitted by law, and where practicable and in cooperation with States and Tribes, to improve the quality, function, sustainable productivity, and distribution of aquatic resources for increased fishing opportunity. Among other actions, the order requires all Federal agencies to aggressively work to promote compatibility and reduce conflict between administration of the ESA and the management of fisheries.

Hatchery programs cannot restore habitat productivity but they are expected to compensate for impacts on cultural and economic values. From California to Canada, the vast majority of fisheries, including tribal treaty fishing, now depend on hatchery fish. In many places, hatchery fish are the only salmon or steelhead left to fish for and there would be little or no tribal or public fishing for salmon and steelhead without them. This function that hatchery programs serve constitutes a high positive value and benefit.

4. Operating Hatchery Programs Consistent with Conservation & Sustainable Fisheries Mandates

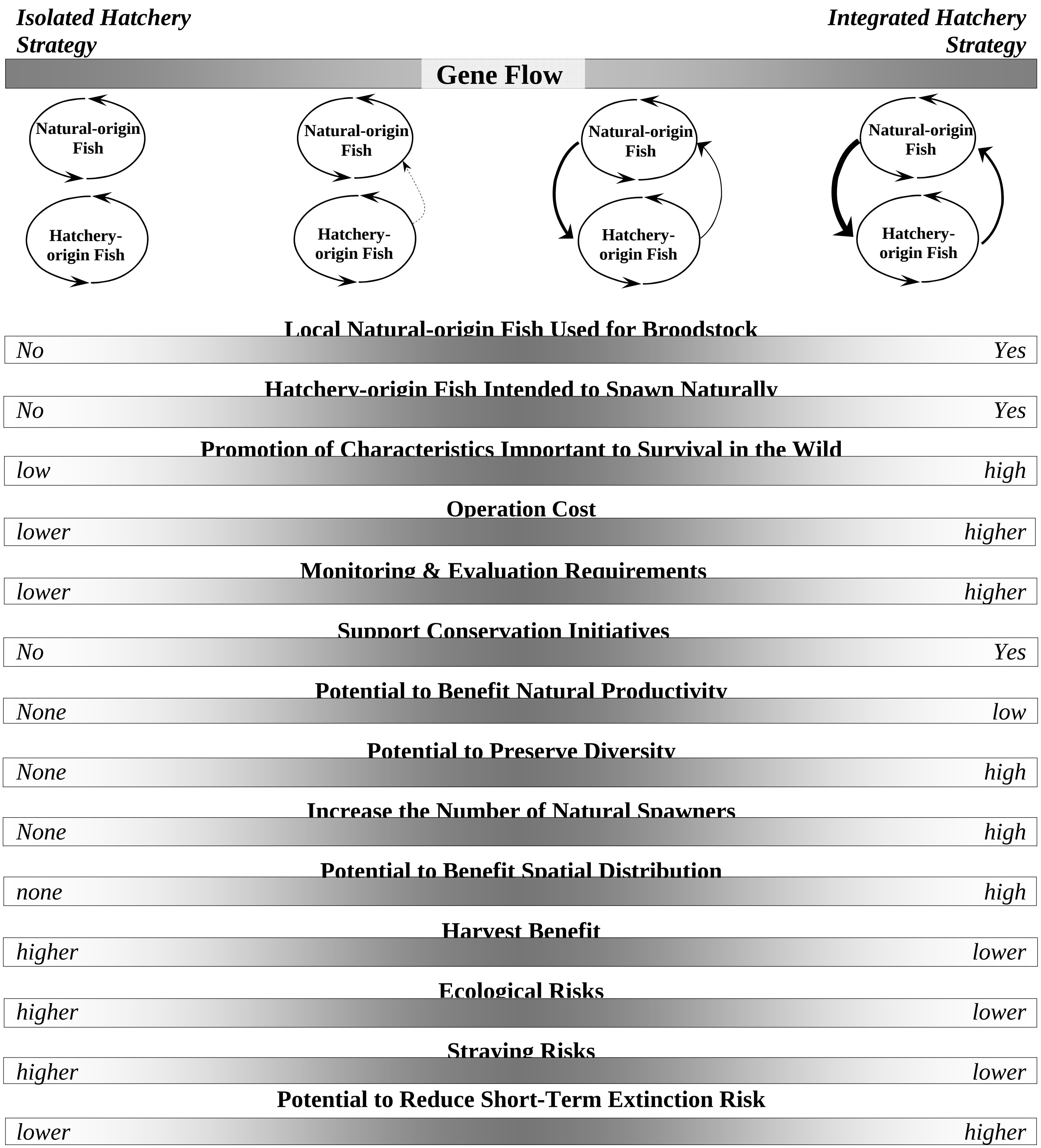
Implementation of the appropriate hatchery strategy, supportive hatchery practices, and accompanying monitoring, evaluation and reform, can benefit conservation and fishing opportunities with limited risks to salmon and steelhead viability.

There is no universal strategy or one-size-fits-all set of *prescriptive* "best management practices" that work well or can apply to all hatchery programs. Hatchery programs operate under a wide range of biological and environmental conditions and they are funded to serve different mandates (e.g.., International and Native American treaty obligations), public laws (e.g., the Water Resources Development Act of 1986 that authorizes the Lower Snake River Compensation Plan), and legal requirements (e.g., Federal Energy Regulatory Commission license agreements). The operation and management of every hatchery program is therefore unique in time, and specific to an identifiable stock and its native habitat (Flagg et al. 2004).

An alternative to assessing hatchery performance against a universal set of criteria (e.g., a specific Proportion Natural Influence: (PNI) threshold) is acknowledging a range of possible practices and corresponding effects, and assessing a particular program against this scale (Figure 2). The "Integrated Strategy" is recommended when HOF are intended to spawn naturally and the better integrated (i.e., moving to the right in Figure 2.) the greater the potential benefit. The "Isolated Strategy" is recommended when HOF are intended to be harvested and not intended to spawn naturally, and the better isolated (i.e., moving to the left in Figure 2) the greater the potential benefits (and lesser risks). For example, the better integrated it is (i.e., moving from left to right in Figure 2) the greater potential for a hatchery program to reduce short-term extinction risk for a target population. Conversely, the better a hatchery program isolates itself or limits interactions between HOF and NOF (e.g., limiting straying and competition between NOF and HOF), the lower are the risks or threats to salmon and steelhead viability.

Under the “isolated” strategy, hatchery fish represent an independent population that is genetically-distinct and potentially domesticated. The exact extent and duration of reproductive isolation that is required for a population to have substantially independent population dynamics is not certain, however, available information indicates that substantial independence will occur when the proportion of a population that consists of migrants is less than 10% (Hastings 1993; McElhany et al. 2000; Mobrand et al. 2005). A hatchery program, for example, would be expected to diverge and become independent from a local natural population when the hatchery broodstock is comprised of less than 10% NOF from the local population.

Figure 2. A comparison of benefits and risks between the Isolated Hatchery Strategy and the Integrated Hatchery Strategy. The level of isolation and the potential to benefit fisheries increases from right to left and the level of integration and the potential to benefit salmon and steelhead conservation increases from left to right.



"Isolated" hatchery programs provide fish for harvest purposes. In general, they are not a tool to promote conservation and can pose significant genetic risks to natural populations. The Hatchery Scientific Review Group (HSRG) has recommended for example that "hatchery-origin spawners from genetically segregated programs represent <5% of the natural spawners as an upper-limit guideline" (Mobrand et al. 2005). Fish from isolated hatchery programs are not the best source for starting a supplementation program. When NOF and fish from an integrated hatchery program do not exist, however, fish from isolated hatchery programs may be used to start an integrated supplementation program. Isolated programs should not be used to supplement natural populations, and natural spawning between fish from isolated hatchery programs and fish from populations important to salmon and steelhead recovery should be strictly limited.

Conversely, under the "integrated" strategy, the natural-to-hatchery gene flow rate must exceed the reverse (hatchery-to-natural) gene flow rate, both for hatchery and natural-origin fish, in order for natural selection effects of the natural environment to exceed hatchery domestication effects (Ford 2002). When a population targeted for supplementation is at very low abundance, it may be impossible, at least immediately, to achieve the desired level of integration. As population abundance increases (abundance is defined here as NOF), it is paramount that the natural-to-hatchery gene flow rate increase because the lesser a hatchery program is integrated with a population targeted for supplementation, the lesser the potential benefit of the program to support recovery. For populations important to ESU or steelhead DPS recovery, the natural population should become capable of sustaining itself without hatchery supplementation, and eventually, the influence of hatchery-origin fish should be strictly limited. "The risks associated with continuing artificial propagation for conservation, harvest supplementation, or both can be reduced, but not entirely eliminated by improving culture practices" (ICTRT 2007). Risks from continued hatchery supplementation should be weighed against the risk of extinction in the absence of hatchery supplementation. Table 2 illustrates hatchery practices under the "Integrated" strategy that will be implemented in the Imnaha River of Northeast Oregon to support the recovery of spring/summer Chinook salmon. The HSRG recommends that for spawning aggregates and populations that are of "moderate or high biological significance or if the goal is to maintain or improve the natural groups viability", the Proportion of Natural Influence (PNI) should meet or exceed 0.7.

Table 2. One example of an adult management sliding scale using the current production program (360,000 smolts and 242 adults for broodstock) for the Imnaha River in Northeast Oregon above the hatchery weir.

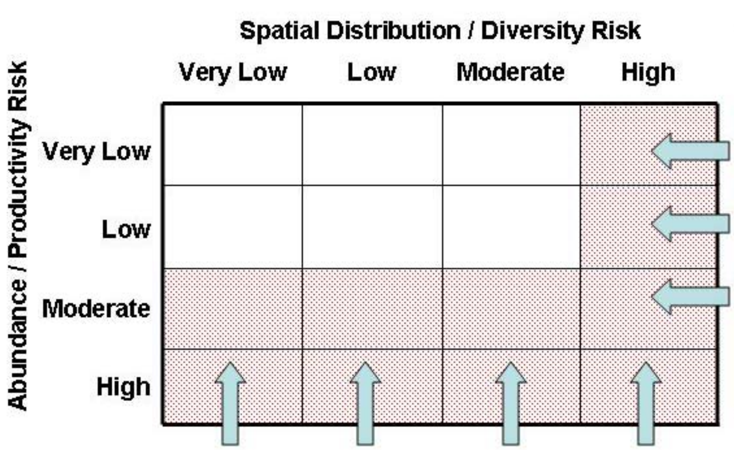
Estimated NOF (ADULTS) to the mouth of the Imnaha River as a Proportion of the Minimum Abundance Threshold (MAT) recommended by the Interior Columbia Technical Recovery Team	Number of ADULT NOF to River Mouth	Expected Handle Rate at Weir of ADULT NOF (50%)	Max % NOF for Broodstock	Number of ADULT NOF Retained for Broodstock (Proportion of Natural Brood)	Proportion of Natural Influence (PNI) Based on Number of NOF Retained for Broodstock	Hatchery Fraction of Natural Spawners
<.05 of Critical	> 15	> 8	0	0		NA
.05 - .5 of Critical	15 - 149	8 - 74	50%	04 - 37 (0.2 - 0.15)		NA
.5 Critical - Critical	150 -299	75 -149	40%	30 - 60 (0.12 - 0.15)	0.15 - 0.26	70%
Critical - .5 of MAT	300 - 499	150 -249	40%	60 - 100 (0.25 - 0.41)	0.29 - 0.41	60%
.5 MAT - MAT	500 - 999	250 - 499	30% **35%**	75 - 150 (0.31 - 0.62) **87 - 175** **(0.36 - 0.72)**	0.38 - 0.55 **0.42 - 0.59**	50%
MAT - 1.5 MAT	1000 - 1499	500 - 749	30% **35%**	150 - 225 (0.62 - 0.93) **175 - 242** **(0.72 - 1.0)**	0.61 - 0.7 **0.67 - 0.73**	40% **35%**
1.5 - 2 MAT	1500 - 1999	750 - 999	25%	188 - 250	0.76 - 0.8	25%
> 2 Times MAT	> 2000	> 1000	25%	> 250	>0.91	<10%

BOLD values would be used after 3 consecutive years greater than minimum abundance threshold (MAT) is achieved.
MAT = Minimum Abundance Threshold

The more closely a hatchery supplementation program meets or exceeds these guidelines for the integrated strategy, the greater the potential benefit of the program from a conservation perspective. In general, and particularly in the case of spawning aggregates or populations that are important for recovery, supplementation hatchery programs are justified only when the demographic risks to a natural population or spawning aggregate exceed the genetic risk from supplementation itself. An analysis of benefits and risks should be a prerequisite to the continued operation of existing hatchery programs and to the implementation of new programs directed at any population determined to be important to the conservation of an ESU or steelhead DPS. Three cases for considering hatchery supplementation include: (1) A natural population is at very low levels of abundance relative to historical levels but the factors limiting viability have been rectified, thus providing the potential or capability of self-sustainability in nature; (2) the natural population is on an extinction trajectory and hatchery intervention is necessary to conserve genetic resources, slow that trajectory and preserve the population until the factors limiting viability are rectified, and (3) reestablishing natural populations throughout all or some portion of their natural or former range.

Under Case 1, supplementation would be used to quickly increase the number of natural spawners and ultimately, the number of natural-origin recruits (the so-called jump-start approach, see Figure 3). The goal for the hatchery program (i.e., the number of years or fish generations in operation and or some minimum threshold of natural-origin recruits) should be predetermined to establish when supplementation has served its purpose and should be terminated. In this case, artificial propagation and supplementation can improve population viability and biological status and benefit salmon and steelhead recovery. A hatchery program under this scenario may be redirected to serve strictly harvest, research or educational purposes, but only if it did not appreciably reduced progress towards ESU or steelhead DPS recovery.

Figure 3. Hatchery actions that can reduce risk and benefit population abundance and productivity (the vertical axis) and risk to spatial distribution and genetic diversity (the horizontal axis). (HOF is hatchery origin fish and NOF is natural-origin fish.)



1. When hatchery programs conserve genetic resources and reduce short-term extinction risk until the factors limiting recovery are addressed.
2. Jump-start self-sustaining populations after the factors limiting population productivity are addressed.
3. Reduce the dependence on hatchery supplementation and the hatchery fraction of natural spawners as NOF abundance and productivity increases.
4. Limit HOF from spawning naturally when they are derived from a non-local population or spawning aggregate or when they are from an Isolated Hatchery Program.
5. Improve juvenile and adult fish passage at hatchery facilities.

1. Improve natural population growth rate when the populations small size is, in itself, a predominant factor limiting population growth.
2. When offspring from naturally spawning HOF jump-start self-sustaining populations after the factors limiting population productivity are addressed.
3. Reduce the influence of any HOF that potentially depress NOF productivity (i.e., HOF that do not share the same population dynamics and fitness as NOF).
4. Reduce the number of NOF killed or injured by hatchery water diversions.
5. Freshwater nutrient levels increase due to HOF carcasses.
6. Reduce HOF predation on NOF through HOF size, release timing, and release location measures.
7. Reduce competition with NOF for food and space through HOF size, release timing, and release location measures.

Under Case 2, the natural population is not-viable under current conditions and hatchery intervention is necessary to prevent extinction. In this case, artificial propagation conserves genetic resources, serves as a "life-support" system, and supplementation is the primary mechanism for preserving at least naturally-spawning fish and natural-origin recruits for a hatchery-maintained population. Supplementation provides a mechanism to produce natural-origin recruits for inclusion into the hatchery broodstock each year, but the natural population is not able to sustain itself and depends on artificial propagation. In this case, artificial propagation and supplementation *cannot* increase viability to meet criteria for ESA recovery until the factors limiting natural population viability are rectified. Artificial propagation in this case can "buy time" until those factors are addressed. Because in this case artificial propagation conserves genetic resources, it can also help to speed recovery as the factors and threats limiting viability are addressed.

The removal of adults from a naturally-spawning population has the potential to reduce the size of the natural population (sometimes called "mining"), cause selection effects, and remove nutrients from upstream reaches (Spence et al. 1996; NRC 1996; Kapuscinski 1997). In cases where a natural population is below its critical threshold for abundance and not replacing itself, a hatchery supplementation program can slow trends toward extinction and buy time until the factors limiting population viability are corrected. Risks to the natural population, including numerical reduction and selection effects, are in some cases subordinate to the need to expeditiously implement the hatchery program and reduce the likelihood of extinction in the short term (e.g., Redfish Lake sockeye).

Under Case 3, hatchery supplementation can improve population viability and biological status and benefit recovery by increasing abundance, spatial structure and, inevitably, diversity following establishment of a self-sustaining natural population (or spawning aggregation).

5. Progress in Hatchery Reform

The process of learning and adjusting and improving hatchery practices has been underway from the fish hatchery programs. Advances in nutrition, disease treatment and prevention, genetics and marking technologies for example, have been profound and have been implemented at hatchery programs to great affect. Examples in hatchery reform are summarized in Table 3**.**

Table 3. A summary of progress in hatchery reform effecting seven distinct groups of Interior Columbia Basin salmon and steelhead.

Evolutionarily Significant Unit or Steelhead Distinct Population Segment	Progress in Hatchery Reform
Snake River fall Chinook	The Snake River fall Chinook programs have increased ESU genetic resources and spatial structure. Hatchery programs have helped jumpstart the ESU, and natural-origin fall Chinook returns have increased from <100 in 1990 to between 2,000 and 5,000 from 2001 through 2004. Spatial distribution has expanded into the Clearwater and lower Grande Ronde River sub-basins. Changes at the Umatilla program have reduced straying into the Snake River and reduced threats to genetic diversity. Monitoring of hatchery supplementation effectiveness and effects on productivity is scheduled to begin in 2008.
Snake River spring/summer Chinook	Grande Ronde Basin hatchery programs are using local fish for broodstock after terminating the use of Rapid River Chinook in the mid-1990s. Locally derived broodstock is being used in the Tucannon, Imnaha, S. Fork Salmon, Pahsimeroi, and upper Salmon Rivers. Rescue/safety net hatchery programs are conserving genetic resources and reducing short-term extinction risk for populations in Catherine Creek, the upper Grande Ronde, the Tucannon, and the Lostine. A new program, starting in 2001 is reintroducing Chinook into Lookingglass Creek. A new sliding-scale for collecting hatchery broodstock and for controlling the proportion of natural spawners comprised of hatchery-origin fish will help put populations in the Imnaha and Grande Ronde on a trend towards recovery.
Upper Columbia spring Chinook	A rescue program is reducing short-term risk of extinction for White River Chinook. Termination of the Entiat program in 2007 will eliminate a key factor limiting spring Chinook viability. The Winthrop National Fish Hatchery continues a transition (which began in 2001) to a locally derived broodstock and has phased-out the use of Carson lineage stock.
Upper Columbia Steelhead	The use of broodstock derived from lower Columbia Skamania stock steelhead was terminated in the mid 1990s. A local broodstock was developed to replace Wells stock in the Wenatchee. The use of early spawned hatchery fish has been minimized, to promote more natural spawn timing of hatchery fish. Steelhead releases were terminated in the Entiat beginning in 1997. Wells Hatchery has increased the proportion of natural-origin steelhead in the annual broodstock, and has taken steps to synchronize the maturation of hatchery-origin steelhead with natural-origin steelhead in order to increase the reproductive success of hatchery fish spawning in the wild. Monitoring of hatchery supplementation effectiveness and effects on productivity is scheduled to begin in 2008.

Evolutionarily Significant Unit or Steelhead Distinct Population Segment	Progress in Hatchery Reform
Middle Columbia Steelhead	The Umatilla program terminated the use of broodstock derived from lower Columbia Skamania stock steelhead beginning in 1981. The Walla Walla and Touchet programs have reduced the size of their juvenile releases by more than 25% to reduce straying. A local broodstock is being tested to replace Lyons Ferry stock in the Touchet River.
Snake River Steelhead	Hatchery releases in the lower Salmon River basin have been restricted to the Little Salmon River. Locally derived broodstock is being developed and tested for use in the Tucannon River and in the East Fork Salmon River. Use of hatchery-origin steelhead in tributary habitat has been reduced.

6. Technical Recovery Team Criteria

The ICTRT has included HOF considerations in their work and it is important to understand the relevance of ICTRT developments to hatchery effects assessments which are the subject of this report.

There are multiple considerations in assessing hatchery effects on population risk. The ICRTRT flow-chart approach or graphical representation of risk criteria associated with natural spawner composition (ICTRT 2007), is only one consideration in assessing hatchery effects and genetic risks to population structure and the ICTRT itself makes the point that "we do encourage case-by-case treatment of conditions that may affect the risk experienced by the population" (ICTRT 2005). Flagg et al. 2004 also advises against any single approach to assessing hatchery effects and states that "Genetic risks from any particular strategy must be estimated on a case-by-case basis."

Case-by-case analysis or treatment of hatchery effects is particularly important when a hatchery program is part of a recovery action. ICTRT criteria provide a sound general approach for "assigning risk" based on the source, level, and duration of exogenous fish spawning naturally. Exogenous fish are defined as all fish of hatchery-origin AND all natural-origin fish that are present due to unnatural, anthropogenically-induced conditions, and case-by-case considerations are particularly important when "exogenous" fish are from hatchery programs implemented to promote or aid in recovery.

Hatchery programs can be called upon and used as a tool to aid or promote recovery and reduce population risk (Hard et al. 1992, Flagg et al. 2004). For example, forgoing the possibility of rebuilding a population in the shortest time using artificial propagation potentially increases population risk. Under conditions when the size of a population is very low, then regardless of the amount of genetic variability present, the population may become extinct for demographic reasons (Leigh 1981, Goodman 1987, Lande 1988) and in this case, the risks posed by artificial propagation may be outweighed by its potential to rapidly increase the number of natural spawners and avoid extinction (Hard et al. 1992). Under conditions like these, violating spawner composition criteria (e.g., the percentage of exogenous HOF spawning naturally) may be necessary, and even considered a credit to a hatchery program if NOF adult returns fall to critically low levels and/or the natural population is on an extinction trajectory under current conditions. Clearly then, assessments of hatchery effects and population risk should depend on case-by-case conditions in combination with spawner composition risk criteria developed by the ICTRT.

ICTRT criteria alone do not constitute “best management practices” for operating hatchery programs and for determining hatchery effects. There is no “one-size-fits-all” set of prescriptive “best management practices (see section 4.3.3, Hatchery Practices) and the ICTRT states that “we do not specify specific management practices” but “rather we suggest that hatchery programs that conform to the principles described in recent publications (Flagg et al. 2004, Olson et al. 2004, Mobrand et al. 2005) could be considered to have “best management practices” (ICTRT 2007).

7. Hatchery Overviews

An overview of 45 hatchery programs in the upper Columbia River and Snake River Basin found that 23 programs conserved salmon and steelhead genetic resources and reduced short-term extinction risk while nine programs were determined to be a limiting factor or a threat to viability. To a certain extent, then, the reasons the latter programs represent threats largely indicate the course for correction. Our assessment also concluded that a large number of improvements and new programs have been implemented in recent years and that it is too early to assess their effects.

NMFS (2004a) provides an overview at two levels: at the population level and at the ESU or DPS level. For programs in the Interior Columbia (upstream from Bonneville Dam), Hatchery Effects Appendix (NMFS 2006a) developed with input provided by members of the Hatchery and Harvest Workgroup of the FCRPS collaboration, (1) summarized the major factors limiting salmon and steelhead recovery at the population scale, (2) provided an inventory of existing hatchery programs including their funding source(s) and the status of their regulatory compliance under the ESA and under the National Environmental Policy Act (NEPA), (3) summarized the effects on salmon and steelhead viability from current hatchery operations, and (4) identified new opportunities or changes in hatchery programs likely to benefit population viability. As a follow-up to the Hatchery Effects Report, NMFS developed recommendations for assessing hatchery effects, including an overview of Interior Columbia Basin hatchery program effects, and presented this paper and results to the Hatchery and Harvest Workgroup and to the Policy Workgroup in August of 2006 (NMFS 2006b). NMFS received comments and made edits to this paper (NMFS 2007).

An overview of effects for selected hatchery programs is provided in Table 4. The four categories of effects are; (1) A key factor limiting viability, (2) genetic resources are conserved, (3) viability improves, and (4) provides fishery mitigation. Effects assessments for the category "A key factor limiting viability" are based on available limiting factors and threats analysis (see footnote 1).

For the category "genetic resources are conserved", gamete preservation, juvenile and adult hatchery production, and naturally spawning hatchery fish (i.e., only hatchery fish included in an ESU or steelhead DPS) can; (1) reduce the immediate risk of extinction when NOF abundance is low and declining, or (2) potentially help to accelerate the rate of recovery as limiting factors and threats are addressed. A key feature of the ESU concept is the recognition of genetic resources that represent the ecological and genetic diversity of the species. These genetic resources can reside in a fish spawned in a hatchery as well as in a fish spawned in the wild. Genetic resources are defined as all fish included in an ESU or steelhead DPS. NMFS listing determinations describe which NOF and HOF are included in each ESU or steelhead DPS (70 FR 37160; June 28, 2005).

NOF effects qualify under the category "viability improves". The previous category "genetic resources are conserved", represented the effect of conserving all the resources included in an ESU or steelhead DPS (i.e., NOF and HOF combined) in the absence of any associated improvement in NOF abundance, productivity, diversity, and spatial distribution. Under this category, improvements in NOF viability must be measurable or determined reasonably certain to occur as a result of hatchery actions. Reductions in limiting factors or threats (e.g., reduced HOF naturally spawning that potentially depresses NOF productivity), improved environmental conditions including improved stream flows, spawning gravel composition and nutrient levels, and increases in NOF abundance, productivity, diversity or spatial distribution are considered beneficial or creditable because they reduce the extinction risk of an ESU or steelhead DPS in the foreseeable future (i.e., long-term extinction risk is reduced). The status or viability of an ESU generally depends on four key attributes: abundance; productivity; genetic diversity; and spatial distribution. "The effects of HOF on the status of an ESU will depend on how the HOF within the ESU affect each of the attributes" (70 FR 37160; June 28, 2005). Only HOF included in an ESU or steelhead DPS will be included in assessing an ESU or DPS's status in the context of their contributions to conserving natural self-sustaining populations. "A population that depends upon naturally spawning HOF for its survival is not viable" (McElhany et al 2000).

Another important question is the level or extent of effect (positive or negative) resulting from hatchery actions in each of these categories. For example, a "yes" under the category 'genetic resources are conserved", would constitute a high positive value and benefit if the population affected was determined to be important to recovery and at high risk.

The category "provides fishery mitigation" summarizes which fisheries are served by individual hatchery programs. For example, Columbia River Indian Treaty, recreational, and commercial fisheries under US v. Oregon jurisdiction are supported by production from the Leavenworth hatchery program. Snake River fall Chinook hatchery programs help support ocean fisheries from California to Alaska, and tribal, commercial and public fishing in the Columbia River.

Table 4. An overview of selected hatchery programs.

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Leavenworth NFH	Federal mitigation for Grande Coulee Dam	Wenatchee R. spring Chinook	No	No	No	No	USvOR
Entiat fishery mitigation		Entiat R. spring Chinook	No	Yes Program terminated in 2007 last returns in 2010	No	No	USvOR
Winthrop supplementation & fishery mitigation		Methow R. spring Chinook	Yes	No	Yes	No	USvOR
Winthrop fishery mitigation		Okanogan R. spring Chinook	No	No	No	No	USvOR and Colville fisheries
Chiwawa supplementation & fishery mitigation	PUD mitigation for Rock Is. Dam	Wenatchee R. spring Chinook	Yes	No	Yes	No	USvOR
White River supplementation		Wenatchee R. spring Chinook	Yes	No	Yes	New program	None

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Methow supplementation & fishery mitigation	PUD mitigation for Wells Dam	Methow R. spring Chinook	Yes	No	Yes	No	USvOR
Twisp supplementation & fishery mitigation		Methow R. spring Chinook	Yes	No	Yes	Unknown	USvOR
Wenatchee supplementation	PUD mitigation for Rock Is. Dam	Wenatchee R. steelhead	Yes	No	Yes	Unknown	USvOR
Wells Dam supplementation & fishery mitigation	PUD mitigation for Wells Dam	Methow R. steelhead	Yes	Yes	Yes	No	USvOR
		Okanogan R. steelhead	Yes	Yes	No	New program	USvOR and Colville Tribal

Hatchery Program	**Authority for the Hatchery Program**	**Affected Fish**	**Hatchery fish are included in an ESU or steelhead DPS[1]**	**Hatchery Program Overviews[5]**			
				A major factor limiting viability[2]	**Genetic resources are conserved[3]**	**Viability improves[4]**	**Provides fishery mitigation**
Winthrop NFH supplementation & fishery mitigation	Federal mitigation for Grand Coulee Dam	Methow R. steelhead	Yes	Yes	No	No	USvOR
Winthrop NFH supplementation & fishery mitigation		Okanogan R. steelhead	Yes	Yes	Yes	No	USvOR and Colville Tribe
Tucannon supplementation & fishery mitigation	Federal mitigation for Lower Snake Dams	Tucannon R. spr/sum Chinook	Yes	No	Yes	New program unknown	USvOR
Lostine supplementation mitigation (captive brood phase)		Lostine R. spr/sum Chinook	Yes	No	Yes	New program unknown	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Catherine Crk supplementation mitigation (captive brood phase)	Federal mitigation for Lower Snake Dams (cont.)	Catherine Crk spr/sum Chinook	Yes	No	Yes	New program unknown	USvOR
Upper Grande Ronde supplementation mitigation (captive brood phase)		Upper Grande Ronde spr/sum Chinook	Yes	No	Yes	New program unknown	USvOR
Imnaha supplementation & fishery mitigation		Imnaha R. spr/sum Chinook	Yes	No	Yes	No	USvOR
Imnaha supplementation & fishery mitigation		Big Sheep & Lick Crks. spr/sum Chinook	Yes	No	Yes	Unknown	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Lookingglass supplementation & fishery mitigation	Federal mitigation for Lower Snake Dams	Lookingglass Crk. spr/sum Chinook	Yes	No	Yes	Unknown	USvOR
McCall fishery mitigation	Federal mitigation for Lwr Snake Dams (cont.)	SF Salmon spr/sum Chinook	Yes	No	Yes	No	USvOR
Sawtooth fishery mitigation		Upper Salmon spr/sum Chinook	Yes	No	No	No	USvOR
Tucannon supplementation mitigation (captive brood phase)	Northwest Power Act	Tucannon R. spr/sum Chinook	Yes	No	Yes	Unknown	USvOR
Johnson Cr supplementation mitigation		SF Salmon spr/sum Chinook	Yes	No	Yes	Unknown	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Rapid River fishery mitigation	Idaho Power Company mitigation for Snake R Dams	Little Salmon spr/sum Chinook	No	No	For spring Chinook originating above Hells Canyon	No	USvOR
Pahsimeroi, fishery mitigation		Pahsimeroi R. spr/sum Chinook	Yes	No	No	No	USvOR
Tucannon, fishery mitigation	Federal mitigation for Lower Snake River Dams	Tucannon R. steelhead	No	No	No	No	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Tucannon, supplementation & fishery mitigation	Federal mitigation for Lower Snake River Dams (cont.)	Tucannon R. steelhead	Yes	No	Yes	Unknown	USvOR
Clearwater supplementation & fishery mitigation		SF Clearwater B-steelhead	Yes	No	Unknown	Unknown	USvOR
Dworshak Lolo Crk supplementation & fishery mitigation		Lolo Crk B-steelhead	Yes	No	Unknown	Unknown	USvOR
Little Salmon fishery mitigation		Little Salmon & Rapid R steelhead	No	No	No	No	USvOR
East Fork Salmon supplementation mitigation		East Fork Salmon R B-steelhead	Yes	No	Yes	Pending	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
East Fork Salmon fishery mitigation	Federal mitigation for Lower Snake River Dams (cont.)	East Fork Salmon R B-steelhead	No	No	No	No	USvOR
Sawtooth fishery mitigation		Upper Salmon R Steelhead	No	Threat	No	No	USvOR
Wallowa fishery mitigation		Wallowa, Minam, Lostine, Deschutes & John Day Steelhead	No	Threat	No	No	USvOR
Cottonwood Pond fishery mitigation		Lwr Grande Ronde steelhead	No	Threat	No	No	USvOR
Little Sheep supplementation & fishery mitigation		Imnaha steelhead	Yes	Threat	Yes	No	USvOR

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Dworshak supplementation & fishery mitigation	Federal mitigation for Dworshak Dam	SF Clearwater B-steelhead	Yes	Unknown	Yes	No	USvOR
Dworshak fishery mitigation		NF Clearwater B-steelhead	Yes	No	Yes	Unknown	USvOr
Pahsimeroi fishery mitigation	Idaho Pwr Company mitigation for Snake R Dams	Pahsimeroi R steelhead	No	No	No	No	USvOR
Oxbow fishery mitigation		Hells Canyon tributaries steelhead	No	Threat	No	No	USvOR
Lyons Ferry supplementation & fishery mitigation (includes Pittsburg Landing, Cpt John Rapids and Big Canyon acclimation sites)	Federal mitigation for Lower Snake R. Dams	Lwr Mainstem Snake fall Chinook	Yes	No	Yes	Yes	USvOR , PFMC, US/Canada

Hatchery Program	Authority for the Hatchery Program	Affected Fish	Hatchery fish are included in an ESU or steelhead DPS[1]	Hatchery Program Overviews[5]			
				A major factor limiting viability[2]	Genetic resources are conserved[3]	Viability improves[4]	Provides fishery mitigation
Nez Perce Tribal supplementation & fishery mitigation	Northwest Power Act	Clearwater fall Chinook	Yes	No	Yes	New program	USvOR, PFMC, US/Canada
Oxbow fishery mitigation	Idaho Pwr Company mitigation for Snake R Dams	Mainstem Snake fall Chinook	Yes	No	Yes	Unknown	USvOR, PFMC, US/Canada
Stanley Basin supplementation mitigation	Northwest Power Act	Redfish, Alturas & Petit Lakes Sockeye	Yes	No	Yes	No	No

[1] Hatchery fish included in an ESU or steelhead DPS are identified in NMFS 2003 and in 2004a. Hatchery fish not included in an ESU or steelhead DPS cannot conserve ESU or DPS genetic resources or improve their viability.
[2] Limiting factors are identified on a population scale by final and draft ESA Recovery Plans, recovery planning expert panels, NMFS 2004b and PCSRF 2005, 2006, and 2007.
[3] When abundance is low and declining, hatchery programs, following best management practices, can buy time and reduce short-term extinction risk by preserving genetic resources. Hatchery fish and recruits from naturally spawning hatchery fish increase ESU or DPS resources and reduce short-term extinction risk.
[4] Increases in NOF viability (i.e., effects across the four viability parameters is a net positive) can be attributed to a hatchery program. Can reduce long-term risk of extinction and counts toward achieving criteria for ESA recovery and reducing survival gaps.
[5] See Salmonid Hatchery Inventory and Effects Evaluation Report: An evaluation of the effects of artificial propagation on the status and likelihood of extinction of West Coast salmon and steelhead under the Federal Endangered Species Act (NMFS 2004a).

8. References

For a complete list of literature cited, see Supplementary Comprehensive Analysis, Chapter 12