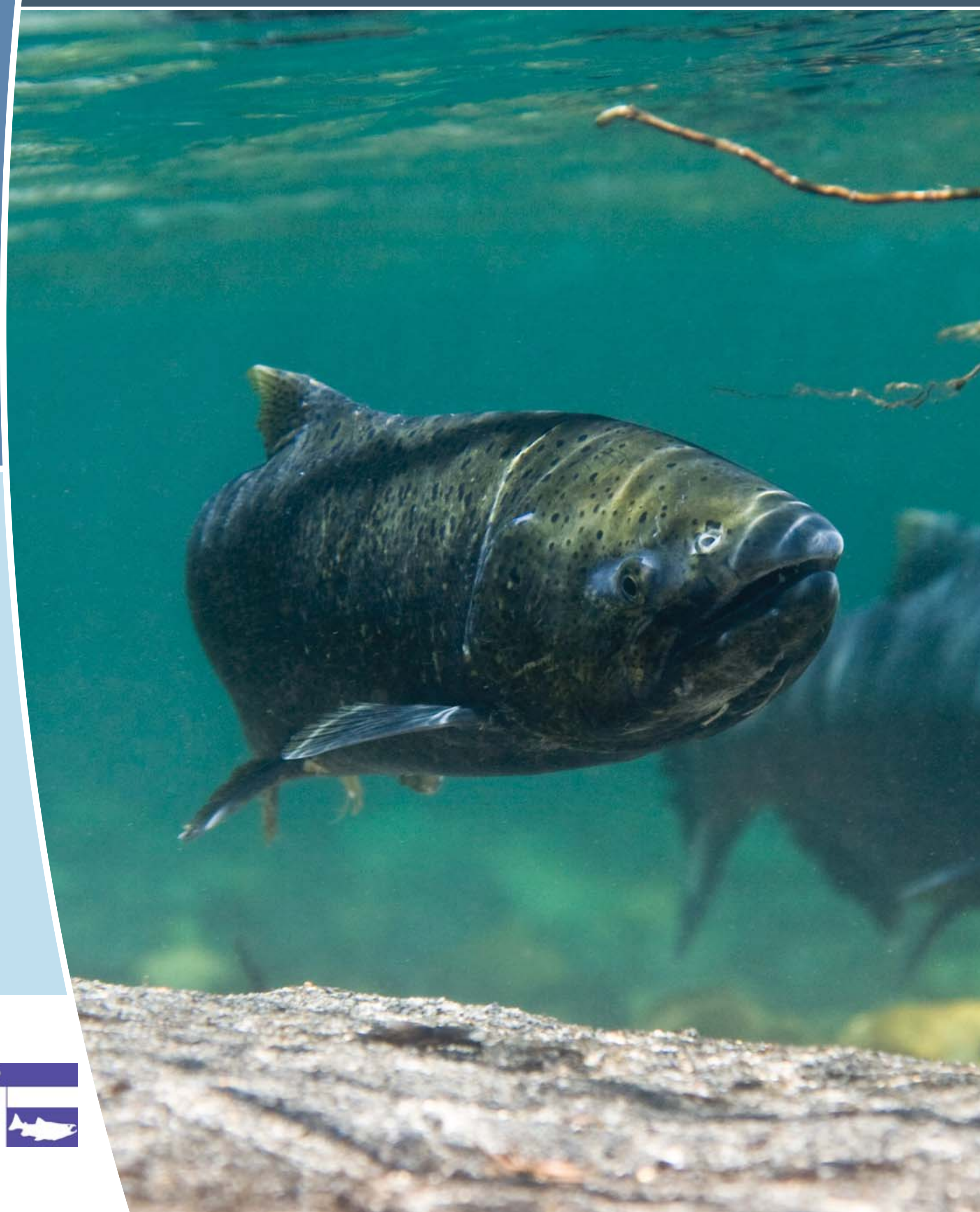
Annual Report to Congress on the Science of Hatcheries, 2015

A report on the application of up-to-date science in the management of salmon and steelhead hatcheries in the Pacific Northwest

July 2015



Hatchery Scientific Review Group
Pacific Salmon Hatchery Reform

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INTRODUCTION

Hatcheries have long played a necessary role in meeting harvest and conservation goals for Pacific Northwest salmon and steelhead. However, a need to reform the hatchery system has been identified by scientists and policymakers based on growing concerns about the potential effects of artificial propagation on the viability of salmon and steelhead in their natural habitats. The US Congress established the Hatchery Reform Project in 2000 as part of a comprehensive effort to conserve indigenous salmonid populations, assist with the recovery of naturally spawning populations, provide sustainable fisheries, and improve the quality and cost-effectiveness of *hatchery programs*. The Hatchery Scientific Review Group (HSRG) was charged with reviewing all state, tribal, and federal hatchery programs in Puget Sound and Coastal Washington. The review used an ecosystem-based approach founded on two central premises: that harvest goals are sustainable only if they are compatible with conservation goals, and that artificially propagated fish affect the *fitness* and *productivity* of natural populations with which they interact. The intent of the project is for science to direct the process of reform. Reforms should ensure that the hatchery system matches current circumstances and management goals.

Since 2000, the HSRG – an independent scientific review panel – has carried out its mission of incorporating the most up-to-date science into hatchery management, with financial support from state and federal sources.

This report to Congress is an update on progress in applying the most recent information and up-to-date science to hatchery management. As new information accumulates and as new technologies, especially in population genetics and information management become available, it is necessary to periodically review and update findings and recommendations. This report confirms the principles and recommendations provided in previous reports. However, as implementation of these recommendations proceeds, the HSRG has concluded that it will be useful to 1) clarify some of the recommendations to help avoid mistakes due to misunderstandings, 2) add more detail and specificity to some of the recommendations as warranted by new information, and 3) make clear that the recommendations are applicable beyond the Columbia River Basin. Note in particular the significant clarifications and expansions to Recommendation 1, Conservation goals, and Recommendation 8, Broodstock management.

Some terms that may have caused confusion have also been clarified in the attached glossary, for example the definition of "pHOS" (hatchery contribution to natural spawning).

Previous reports by the HSRG are available on the HSRG website:

http://www.hatcheryreform.us

HSRG Summary Conclusions, Principles and Recommendations – Updated July 2015

Hundreds of hatchery facilities in the Pacific Northwest are operated by federal, state, tribal, and local governments. Some of these hatcheries have been operating for more than 100 years. Most were built to produce fish for harvest when wild populations declined because of habitat loss, overfishing, and the construction of hydroelectric dams. Hatcheries have generally been successful at producing fish for harvest. However, the traditional mitigation policy of replacing wild populations with hatchery fish is not consistent with today's conservation goals, environmental values, and prevailing science. Hatcheries cannot replace lost habitat and the natural populations that rely on it. It is now clear that the widespread use of traditional hatchery programs has actually contributed to the overall decline of wild populations. The historical use of artificial propagation for harvest mitigation has frustrated the successful integration of management directives and created regional economic inefficiencies.

Today, it is clear that hatchery programs must be seen as just one tool to be used as part of a broader, balanced strategy for meeting watershed or regional resource goals. Such a strategy also incorporates actions affecting habitat, harvest rates, water allocation, and other important components of the human environment.

Pursuant to the Hatchery Reform Project, comprehensive reviews of over 200 propagation programs at more than 100 hatcheries across western Washington were completed in 2004. Based on those reviews, analytical tools were developed in 2005 to support application of the HSRG's principles (HSRG 2009, Paquet et al. 2011). Also in 2005, Congress directed the National Oceanic and Atmospheric Administration—National Marine Fisheries Service to replicate the project in the Lower Columbia River Basin. Ultimately, that scope was expanded to include the entire Columbia River Basin, and the results of this hatchery assessment were reported soon thereafter (HSRG 2009). Three principles emerged early in the HSRG's review and served as guidance for the development of recommendations for hatchery reform. The principles provide a method of incorporating the best available science into policy decisions about the design and operation of hatcheries. The principles and recommendations are presented below with changes from the original 2009 Report to Congress (HSRG 2009). While these recommendations should continue to be reviewed periodically to ensure consistency with new science as it emerges, we note that this is also consistent with the requirement (see Principle 3 below) that all hatchery programs should include flexibility to adapt to new information and a process to ensure that changes warranted by new information are implemented.

1.1 SUMMARY CONCLUSIONS

The HSRG has concluded that hatcheries play an important role in the management of salmon and steelhead populations (HSRG 2004, HSRG 2009, and HSRG 2014). Nevertheless, the traditional practice of replacing natural populations with hatchery fish to mitigate for habitat loss and mortality due to hydroelectric dams is not consistent with today's conservation principles and scientific knowledge. Hatchery fish cannot replace lost habitat or the natural populations that rely on that habitat. Therefore, hatchery programs must be viewed not as surrogates or replacements for lost habitat, but as tools that can be managed as part of a coordinated strategy to meet watershed or regional resource goals, in concert with actions affecting habitat, harvest rates, water allocation and other important components of the human environment.

The HSRG conducted the most comprehensive review of the 178 hatchery programs and 351 salmon and steelhead populations ever undertaken in the Columbia River Basin (HSRG 2009). A similar review was conducted of all tribal, state and federal hatchery programs and affected populations in Puget Sound and Coastal Washington (HSRG 2004). The resulting population-specific recommendations were intended to provide scientific guidance for managing each hatchery program more effectively in the future. Here, these recommendations are updated with the most recent available information provided by hatchery managers and in the scientific literature.

The benefits and risks of a hatchery program depend on the *biological significance* of the affected natural populations and the current and future status of all factors affecting the regional ecosystem within which it operates, including freshwater and marine habitats, hydropower facilities and operations, harvest policies, and other regional hatchery programs. Hatchery programs should be used only to the extent that they provide a better option, from a benefit/risk standpoint, than available alternative methods to meet the same or similar goals.

Hatchery reforms that improve the *fitness* of natural populations (for example, by promoting *local adaptation*) also increase the benefits of current and future habitat improvements. Conversely, when habitat improvements are not made in concert with hatchery and harvest reforms they provide fewer benefits. Improvements in population fitness and productivity from hatchery reform are likely to occur on a shorter time scale than improvements from habitat actions. Given that hatchery reforms enhance habitat potential, there is no reason for these reforms to wait for future habitat improvements or harvest modifications.

Hatchery management must be aligned with harvest management and vice versa. The HSRG has demonstrated that increasing *selective harvest* on hatchery-origin fish can have a conservation benefit (increased *population fitness* and productivity), economic benefit (increased harvest) and increase the value of habitat improvements.

The HSRG has reached several critical, overarching conclusions regarding areas where current hatchery and harvest practices need to be reformed. Managers should:

- Manage hatchery *broodstocks* to achieve proper genetic integration with, or segregation from, natural populations;
- Promote local adaptation of natural and hatchery populations;
- Minimize adverse *ecological interactions* between hatchery- and natural-origin fish;
- Minimize effects of hatchery facilities on the ecosystem in which they operate; and
- Maximize the survival of hatchery fish.

Each of these conclusions (summarized below) must be addressed through policy, management, research, and monitoring.

Manage Hatchery Broodstocks to Achieve Proper Genetic Integration with, or Segregation from, Natural Populations

Hatchery programs should be managed as either genetically integrated with, or segregated from, the natural populations they most directly influence. A fundamental purpose of an *integrated hatchery program* is to increase abundance while minimizing the genetic divergence of hatchery broodstock from the naturally spawning population. An integrated hatchery program is intended to maintain the genetic characteristics of a local, natural population among hatchery-origin fish by minimizing the genetic effects of domestication. This is expected to reduce the genetic risks that hatchery-origin fish may pose to the naturally spawning population.

The intent of a *segregated hatchery program* is to maintain a genetically distinct hatchery population. The only way to reduce risk (genetic and ecological) to natural populations from segregated programs is to minimize the contribution of hatchery fish to natural spawning. The HSRG established standards for hatchery contribution to natural spawning based on the biological significance of the natural populations.

The integrated and segregated strategies both have strengths and weaknesses, so the decision about which strategy to follow must be determined on a case-by-case basis. While the primary purpose of most integrated hatchery programs is to contribute to harvest, they may also contribute to conservation by providing a demographic safety net for the natural population[1].

[1] ***Supplementation*** is a term frequently used when referring to hatchery programs where the intent is for hatchery-origin fish to spawn in the wild and make a contribution to conservation. The HSRG has concluded that this may be possible in some circumstances, but such programs should always be accompanied by comprehensive monitoring and evaluation efforts. In the past, attempts to identify the general conditions under which these net benefits to the population occur have failed (RASP 1992) because generalization is impossible due to the unique environmental conditions in which each population exists. Programs should, therefore, be evaluated on an individual basis where population status and the unique habitat, harvest, hatchery, and hydropower conditions are

However, they can pose a risk to natural populations if the size of the hatchery program is large relative to the size of the associated natural spawning population. On the other hand, segregated hatchery programs can pose significant genetic and ecological risks to natural populations if they reproduce naturally with wild fish. The primary way to reduce these risks from segregated programs is to reduce the number of hatchery fish spawning in the natural environment.

The ideal integrated or segregated hatchery program is nearly impossible to achieve in practice. Because hatchery fish have lower reproductive fitness (even when they come from well-integrated programs), they represent a fitness risk to a natural population (if one is present) when they spawn in the natural environment. Yet, as noted above, hatchery fish on the spawning grounds may confer a net conservation benefit when the demographic extinction risk is high.

In order to address the fitness risks posed by hatchery fish, the HSRG adopted a set of standards for hatchery influence on natural populations. These standards, which vary depending on the *biological significance* and the *recovery phase* of the population, are intended to support recovery of natural populations while retaining overall harvest benefits. They are designed to be simple to implement and monitor. The HSRG has also proposed methods for achieving the standards.

Promote Local Adaptation of Natural and Hatchery Populations

The biological principle behind the broodstock standards for both integrated and segregated populations is promoting *local adaptation*. A major concern with many current hatchery programs is that they have been operated in a manner that disrupts natural selection for population characteristics that are tailored to local environmental conditions. Proper integration or segregation of hatchery programs is the recommended means to minimize the adverse effects of hatcheries on local adaptation of natural populations. Local adaptation of hatchery populations is achieved by using local broodstock (indigenous, in the case of integrated programs; locally returning in the case of segregated programs) and avoiding transfer of hatchery fish among watersheds. It is important to promote local adaptation because it maximizes the viability and productivity of the population and maintains biological diversity within and between populations. Local adaption is also important to enable populations to adjust to changing environmental conditions, for example through climate change.

taken into account. It should be noted, however, that integrated conservation programs are most likely to increase the abundance of natural-origin spawners when natural productivity is relatively low and habitat capacity is high.

Minimize Adverse Ecological Interactions between Hatchery- and Natural-Origin Fish

Another important concern associated with hatchery programs is *ecological interaction* between hatchery and natural fish such as competition for feeding and spawning locations, predation of hatchery fish upon natural-origin fish and the potential transfer of disease from hatchery to natural-origin fish. One way to address these interactions is for hatchery programs to be operated so the released fish are segregated from their natural counterparts in time and space. Alternatively, hatchery fish can be reared and released to be as biologically similar to their natural counterparts as possible, although the latter approach does not always preclude the adverse effects of competition.

For example, competition between hatchery and natural steelhead juveniles is of concern to the HSRG, with adverse effects on the natural population having been documented (e.g., Kostow 2009). The concern is that although hatchery steelhead may compete effectively at the juvenile stage, they appear to have inferior reproductive success. Juvenile hatchery steelhead can also *residualize*, thereby increasing competitive interactions[2]. Size, time, age, location and method of release of hatchery fish affect the severity of this risk. Predation of hatchery fish upon other salmonids is less well understood, but is generally assumed to be less significant than competition.

Hatchery fish can also pose a disease threat to natural-origin fish both before and after their release from the hatchery. To avoid this threat, hatcheries should adopt fish culture practices that minimize or avoid disease risks. Suggested practices include providing suitable water supplies, low rearing densities, appropriate feeds and feeding protocols, careful sanitary procedures, avoiding out-of-basin fish transfers and screening for, then limiting the use of broodstock with high levels of pathogens. Antibiotics should be judiciously used when necessary.

Minimize Effects of Hatchery Facilities on the Ecosystem

Facilities operated in support of hatchery programs (traps, weirs, water intake screens and hatchery effluent discharges) can have adverse effects on salmonid populations and other aquatic species. The HSRG has found that, for the most part, existing laws and regulations related to facilities and operations are adequate to protect the environment. Not all facilities, however, are in compliance with those laws and regulations. It is important that those facilities be identified and brought into compliance. Recognizing that weirs and traps have a legitimate role in controlling hatchery *strays* that could affect naturally spawning populations, the HSRG

[2] The HSRG analysis (HSRG 2009) accounted for competition by life stage for naturally spawning fish through density dependent (Beverton-Holt type) mortality factors from fish spawning in the wild.

encourages the use of low impact weirs (temporary structures with controlled passage and that are appropriately staffed) that have minimal effect on natural populations and their habitats.

Maximize Survival of Hatchery Fish Consistent with Conservation Goals

In order for hatchery programs to effectively contribute to harvest and/or conservation, the reproductive success and survival of hatchery releases must be high relative to those of naturally spawning populations. The primary performance measurement for hatchery programs should be the total number of adults produced (harvest plus *escapement*) per adult spawned at the hatchery. This also allows for the fewest number of hatchery fish to be released to achieve the stated goals of the program, thereby minimizing ecological interactions. All too often in the past, hatcheries have been evaluated based on the number of smolts released.

1.2 PRINCIPLES AND SYSTEM-WIDE RECOMMENDATIONS

The principles and system-wide recommendations that follow represent the key findings of the HSRG. The more closely hatchery programs adhere to these principles and recommendations, the greater the likelihood of their contribution to the managers' harvest and conservation goals. The HSRG's three principles for hatchery management are presented below, with each of 17 system-wide recommendations listed under the principle from which it is derived.

Principle 1: Develop Clear, Specific, Quantifiable Harvest and Conservation Goals for Natural and Hatchery Populations within an "All H" Context

During its reviews, the HSRG observed that goals for fish populations were not always explicitly communicated and/or fully understood by the managers and operators of hatchery programs. These goals should be quantified, where possible, and expressed in terms of values to the community (harvest, conservation, education, research, etc.). At times, goals have been expressed in terms of the numbers of smolts to be released without specifying whether or how this hatchery production contributes to harvest and/or conservation. Hatchery production numbers may be the means of contributing to harvest and/or conservation values, but they are not endpoints. When *population goals* are clearly defined in terms of conservation and harvest, hatcheries can be managed as tools to help meet those goals.

To be successful, hatcheries should be used as part of a comprehensive *"All-H" strategy* where habitat, hatchery, hydropower, and harvest management are coordinated to best meet resource management goals that are defined for each population in the watershed. Hatcheries are by their very nature a compromise—a balancing of benefits and risks to the target population, other populations, and the natural and human environment affected by the hatchery program. Use of a hatchery program is appropriate when benefits significantly outweigh the risks and when the benefit/risk mix from the program is more favorable than the benefits and risks associated with non-hatchery strategies for meeting the same goals.

The HSRG offers the following three system-wide recommendations for defining goals for natural and hatchery populations.

Recommendation 1: Express conservation goals in terms of a population's biological significance (Primary, Contributing, Stabilizing) and viability (natural-origin spawning abundance and productivity), and identify the current recovery phase of the population and the associated triggers for phase shifts.

The *biological significance* of a stock is a function of the origin of the stock and its inherent genetic diversity, its biological attributes, uniqueness, local adaptation, and the genetic structure of the population relative to other conspecific populations. A population can be considered highly significant if it exhibits unique genetic and biological attributes that are not shared with other adjacent stocks. These attributes may include unique life history, physiological, morphological, behavioral, and disease resistance characteristics with a genetic basis.

In an effort to achieve a simple and consistent regional approach, the HSRG suggests that managers adopt the *population designations* defined by the Lower Columbia Fish Recovery Board to describe salmon and steelhead populations (LCFRB 2004).

- *Primary*: populations must achieve at least high viability
- *Contributing*: populations must achieve at least medium viability
- *Stabilizing*: populations must maintain at least current viability

The designation of a population as Primary, Contributing or Stabilizing is a science informed policy decision. *Population viability* is defined in terms of *abundance*, *productivity*, *population structure* and *diversity* (McElhany et al. 2000).

- Viability goals should be expressed in terms of population productivity and abundance
- Viability goals should also take into account spatial structure and diversity

Four *phases of recovery* have been defined by the HSRG (2014): Preservation, Re-colonization, Local Adaptation, and Full Restoration.

Priorities during the *Preservation phase* are to:

- Prevent extinction.
- Retain genetic diversity and identity of the existing population.
- Increase abundance.
- Restore habitat.

Priorities during the *Re-colonization phase* are to:

- Re-populate restored and/or depleted habitat.
- Increase abundance and temporal and spatial diversity (spawning and rearing) of the population.
- Retain genetic diversity and identity of the existing population.

Priorities during the *Local Adaptation phase* are to:

- Meet and exceed minimum viable spawner abundance for natural-origin spawners.
- Increase fitness, reproductive success and life history diversity through local adaptation (e.g., by reducing hatchery influence by maximizing *PNI*).

Priorities during the *Full Restoration phase* are to:

- Maintain a viable population, based on all *viable salmonid population (VSP)* attributes using long-term *adaptive management*.

Triggers for moving between Phases:

- Triggers should be biologically based (observed population abundance, productivity and diversity), rather than timelines.
- Triggers should allow movement both up and down the Phases.
- The larger the trigger threshold, the longer local adaptation benefits (e.g., increased productivity) are deferred.

Recommendation 2: Express harvest goals in terms of a population's contribution to specific fisheries

Harvest goals should be expressed quantitatively where possible, either in terms of catch (number of *HORs* and *NORs* in specific fisheries, e.g., tributary sport or other *terminal fisheries*), or as mixed-stock, pre-terminal, sustainable harvest rates.

Recommendation 3: Ensure conservation and harvest goals for individual populations are coordinated and compatible with those for other populations that might be affected.

Many important populations of salmon and steelhead do not meet the conservation and harvest expectations identified by managers. Achieving these expectations requires that population goals be developed that consider other populations. Efforts to harvest abundant hatchery fish from one population can impact natural fish in another population; hatchery strays can and do interact with natural populations from different locations within a region. The contribution of each hatchery program to the cumulative impact of all hatchery programs also needs to be considered. In coordinating population goals, identify watersheds where hatchery programs can be located to provide harvest opportunities compatible with conservation.

Principle 2: Design and Operate Hatchery Programs in a Scientifically Defensible Manner

Once a set of well-defined population goals has been identified, the scientific rationale for a hatchery program in terms of benefits and risks must be formulated, explaining how the program expects to achieve its goals. The purpose, operation, and management of each hatchery program must be scientifically defensible:

- Programs should be based on an explicit *working hypothesis* that describes assumptions about the population (smolt to adult survival rates, fish passage survival, harvest rates, natural productivity, impacts of hatchery fish on natural populations, etc.).
- The working hypothesis must be consistent with current scientific literature and available data and information.
- Biological principles used to manage natural populations should be applied equally in management of hatchery populations.

In general, *scientific defensibility* will occur at three stages:

1. During the deliberation stage, to determine whether a hatchery should be built and/or a specific hatchery program initiated;
2. During the planning and design stage for a hatchery or hatchery program; and
3. During the operations stage.

This approach ensures a scientific foundation for hatchery programs, a means for addressing uncertainty, and a method for demonstrating accountability. Documentation for each program should include a description of analytical methods and should be accompanied with citations from the scientific literature. The analytical approach used by the HSRG in its review is described in Appendix C of the 2009 HSRG Report to Congress. This approach is intended to serve as an example and a starting point in an evolving process. Standard reports that document the rationale for hatchery programs should be developed. HSRG recommendations 4 through 13 are aimed at ensuring scientifically defensible hatchery programs.

Recommendation 4: Identify the purpose of the hatchery program (i.e., conservation, harvest or both)

Once the population goals, including the designation and recovery phase, have been established, it is necessary to identify the *purpose of hatchery programs* affecting that population.

A *conservation program* is one that is compatible with the goals for biological significance (Primary, Contributing or Stabilizing), viability (productivity, abundance, diversity and spatial structure), and the recovery phase of the population.

For example, during the preservation phase, the purpose a hatchery program can serve is to contribute to the priority objectives (see above) for the population by increasing abundance to prevent extinction while habitat is restored. During re-colonization, a hatchery may help speed colonization by out-planting adults and/or juveniles in the freshwater habitat and testing the sustainability of natural production.

During the local adaptation and full recovery phases, where fitness of the naturally spawning fish is a priority, the hatchery may serve as a demographic safety net for the population, but direct hatchery influence on natural spawning must be managed to encourage local adaptation to the natural environment.

A *harvest program* is one that contributes to specific fisheries at specified rates or harvest numbers, and is compatible with identified conservation objectives for all populations. Hatchery programs may be used to augment harvest in any of the four recovery phases, so long as they are operated consistently with the conservation goals and priorities for each phase.

In the past, the stated purpose of many hatchery programs was described as the release of specified numbers of juveniles, without identifying whether those releases were intended to achieve conservation goals, harvest goals, or both. Unless the purpose of a hatchery program is clearly articulated, it is not possible to effectively design, operate or evaluate the program.

Recommendation 5: Explicitly state the scientific assumptions under which a program contributes to meeting the stated population goals and hatchery purpose

Once population goals have been defined and the purpose(s) of a hatchery program (harvest, conservation, or both) have been established, the scientifically defensible justification for the program must be documented (numbers of juveniles to release, release location, type of fish, etc.). The scientific justification explains, in terms of benefits and risks, how the hatchery program is expected to achieve its purpose. The purpose, operation and management of the program must be scientifically defensible and the chosen strategy must be consistent with current scientific knowledge. Where there is uncertainty, hypotheses and assumptions should be documented, so those assumptions can be evaluated and modified as new information becomes available. Documentation should include citations from the scientific literature and analytical tools that take into account the various factors that will affect the success of the program (predation assumptions, cumulative effects, etc.)[3]. This approach ensures a scientific foundation for hatchery programs, a means to address uncertainty, and a method to demonstrate accountability.

Recommendation 6: Select an integrated or segregated broodstock management strategy based on population goals and hatchery program purpose

One of the most critical needs in hatchery reform is to improve hatchery *broodstock management.* Hatchery programs should be managed as either genetically integrated with, or

[3] For example, the HSRG (2009) used the Beverton-Holt production function to capture effects of habitat, harvest, and hatchery factors on survival by life stage. The effect of hatchery-origin spawners on productivity of the naturally spawning population was based on the Ford fitness model as adapted by Campton and Busack.

segregated from, the natural populations they most directly influence. A fundamental purpose of most integrated hatchery programs is to increase abundance for harvest, while minimizing the genetic divergence and reproductive fitness differences between the hatchery broodstock and the naturally spawning population. In some cases, integrated programs also serve as a demographic safety net for vulnerable natural populations. An integrated program is intended to maintain the genetic characteristics of a locally adapted natural population and minimize the potential genetic effects of domestication.

For segregated hatchery programs, the intent is to maintain a genetically distinct hatchery population that is isolated reproductively from natural populations. Ideally, fish from this type of hatchery program would be propagated solely from hatchery returns and not allowed to spawn with the natural population. The primary intent of a segregated program is to create a hatchery-adapted population to meet goals for harvest.

The biological principle behind the broodstock standards for both integrated and segregated populations is local adaptation, i.e., allowing a population to adapt to the environment it inhabits. Disruption of local adaptation continues to be a major concern with many current hatchery programs because programs have often been operated in a manner that disrupts natural selection for population characteristics that are tailored to the local environmental conditions. Proper integration and segregation of hatchery programs is the HSRG's recommended means for minimizing adverse effects of hatcheries on local adaptation.

The typical benefit of reforming broodstock management is that abundance goals for conservation and harvest can be met while at the same time improving the productivity of natural populations. Many current hatchery programs have been responsible for loss of fitness and genetic diversity through the influence of maladapted hatchery-origin fish on the spawning grounds. Hatchery fish on the spawning grounds always represent a compromise between the demographic benefits and the genetic risk, even when they come from a well-integrated program. The HSRG concluded that when its broodstock management standards for an integrated or segregated program are met and managers' abundance goals are achieved, the benefits of the hatchery program outweigh the risks.

The HSRG also recommends establishing hatchery-free populations as a means of reducing the genetic and ecological risks to an *MPG* or *ESU*. These hatchery-free populations provide both a hedge against unknown or poorly understood hatchery influences and a reference for future changes in abundance and productivity of all populations.

Recommendation 7: Size hatchery programs based on population goals and as part of an "All H" strategy

A hatchery program should be sized to achieve abundance goals for harvest and conservation, while reducing the effects on natural populations from straying, ecological interactions and from collecting more natural broodstock than the population can support. The appropriate size of an integrated or segregated program is directly related to the productivity and abundance of the natural population, taking into account the effects of harvest, hydropower operations and habitat conditions. The abundance and productivity of the natural population, as well as the ability to fully harvest hatchery-origin fish, determine the effect of hatchery straying on the natural population. These factors, in turn, determine the proper size of a hatchery program.

Concerns about ecological interactions can be addressed in part by making the hatchery program as small as possible, while ensuring that benefits from the program still outweigh the risks. Time, size, age and location of released hatchery fish also affect straying, survival and ecological interactions. When a hatchery program is sized appropriately, the demographic benefits to harvest and/or conservation outweigh the genetic and ecological risks.

It is not uncommon for excessive adults (above broodstock needs) to return to a hatchery. These surpluses— the consequence of incorrectly sized programs and/or under-harvesting of hatchery fish—lead to lost economic benefits, unneeded expenditure for production, and increased conservation concerns. The HSRG recommends that managers alter their hatchery and harvest programs to reduce these surpluses while using some of the surplus fish to provide ecological benefits through nutrient enhancement of streams and rivers where disease risks are not a cause for concern.

Recommendation 8: Manage harvest, hatchery broodstock, and natural spawning escapement to meet HSRG standards appropriate to the affected natural population's designation of biological significance and recovery phase

Effectively managing harvest, hatchery broodstock and natural spawning escapement is essential to controlling genetic risks due to straying of hatchery adults. Straying can result in fitness loss in natural populations. To limit these risks and meet conservation goals, the HSRG developed quantitative standards for the effective proportion of natural-origin spawners made up of hatchery-origin fish (*$pHOS_{eff}$*), the proportion of hatchery broodstock derived from natural-origin fish (*pNOB*), and the *proportionate natural influence (PNI)* on an integrated population that results from the combination of $pHOS_{eff}$ and pNOB.

Effective pHOS ($pHOS_{eff}$) is defined as the genetic contribution of hatchery-origin adults to the natural population in the next generation as measured at the adult stage. This is first generation gene flow.

$pHOS_{eff}$ can be estimated directly from genetic analysis of the naturally spawning population. It can also be approximated from more traditional census data. For example, $pHOS_{eff}$ can be estimated from the observed abundance of hatchery-origin and natural-origin spawners (*HOS* and *NOS*) and a *correction factor* (cf) as $pHOS_{eff}$ = (HOS x cf)/[(HOS x cf) + (NOS)].

If the correction factor (cf) is set to 1, $pHOS_{eff}$ =HOS/(HOS+NOS), which is referred to as *census pHOS*.

The correction factor reflects the reduced reproductive success of first generation hatchery-origin fish due to behavioral differences between natural- and hatchery-origin fish in terms of spawn timing and/or location. The correction factor is likely to vary from case to case, and further empirical studies should be encouraged to refine correction factor estimates. An example of correction factors developed for steelhead is provided in Table 1.

Table 1 Correction factors for steelhead used by the HSRG.

	Affected Natural Populations		
Hatchery population	**Late Winter Steelhead**	**Summer Steelhead**	**Summer A-run and B-run**
Early Winter Steelhead (Chambers)	0.11	0.11	-
Summer Steelhead (Skamania)	0.17	0.18	-
Late Winter Steelhead (Native)	0.8	0.8	-
Summer Steelhead (Native)	0.8	0.8	-
Summer A and B-Run (Segregated hatchery)	-	-	0.25
Summer A and B-Run (Native)	-	-	0.8

The designation of a population as Primary, Contributing or Stabilizing is a science-informed policy decision. Standards recommended by the HSRG for broodstock management are generally described as follows:

- HSRG criteria for hatchery influence on Primary populations
    - The proportion of effective hatchery-origin spawners ($pHOS_{eff}$) should be less than 5% of the naturally spawning population, unless the hatchery population is integrated with the natural population.
    - For integrated populations, the proportion of natural-origin adults in the broodstock should exceed $pHOS_{eff}$ by at least a factor of two, corresponding to a PNI value of 0.67 or greater. To reduce ecological risks, the HSRG recommends that census pHOS, as

defined above, be less than 0.30. This is an interim standard that should be reviewed and updated as better information becomes available.

- HSRG criteria for hatchery influence on Contributing populations
    - The proportion of effective hatchery-origin spawners ($pHOS_{eff}$) should be less than 10% of the naturally spawning population, unless the hatchery population is integrated with the natural population.
    - For integrated populations, the proportion of natural-origin adults in the broodstock should exceed pHOSeff, corresponding to a PNI value of 0.50 or greater. To reduce ecological risks, the HSRG recommends that census pHOS, as defined above, be less than 0.30. This is an interim standard that should be reviewed and updated as better information becomes available.
- HSRG criteria for hatchery influence on Stabilizing populations
    - The current operating conditions were considered adequate to meet conservation goals. No criteria were developed for proportion of effective hatchery-origin spawners ($pHOS_{eff}$) or PNI.

In order to meet these standards, the number of hatchery fish on the spawning grounds must be monitored and controlled. It is possible to accomplish this by reducing or totally eliminating hatchery fish. These options, however, would severely reduce most fisheries and the associated economic and cultural benefits, as well as reduce the demographic benefits provided by hatchery programs. Eliminating hatchery programs would not allow many populations to meet conservation goals for abundance.

The HSRG's reviews (HSRG 2004, HSRG 2009) showed that both conservation goals and harvest goals can be met with an appropriate combination of reduced hatchery production, selective harvest of hatchery fish, and/or selective removal of hatchery adults with tributary traps or weirs. Marking or tagging all hatchery fish so that they are easily distinguished (in real time) from natural-origin fish is a basic requirement for selective harvest, as well as for monitoring and achieving desired levels of $pHOS_{eff}$, pNOB and PNI.[4]

[4] The HSRG's review of the Lower Columbia River Chinook ESU (HSRG 2009) provides an example of harvest and broodstock management changes that would result in appropriate pHOS and PNI standards consistent with conservation goals, while simultaneously increasing harvest over current levels. The HSRG's proposal would (1) reduce hatchery production by three percent and move it to terminal release areas where selective fisheries could occur; (2) increase selective harvest in the ocean, mainstem and terminal areas; and (3) add two weirs. These solutions project an increase in overall harvest while contributing to conservation objectives by increasing natural productivity by 75% and natural-origin spawner abundance by 25% for Primary populations.

Table 2 summarizes the broodstock management standards recommended by the HSRG by population designation and recovery phase of the natural population.

Table 2 Broodstock management standards for conservation and harvest programs.

Natural Population		Hatchery Broodstock Management	
Designation	**Status**	**Segregated**	**Integrated**
Primary	Fully Restored	**pHOS<5%**	**PNI>0.67**
	Local Adaptation	**pHOS<5%**	**PNI>0.67**
	Re-colonization	**pHOS<5%**	Not Specified
	Preservation	**pHOS<5%**	Not Specified
Contributing	Fully Restored	**pHOS<10%**	**PNI>0.50**
	Local Adaptation	**pHOS<10%**	**PNI>0.50**
	Re-colonization	**pHOS<10%**	Not Specified
	Preservation	**pHOS<10%**	Not Specified
Stabilizing	Fully Restored	Current Condition	Current Condition
	Local Adaptation	Current Condition	Current Condition
	Re-colonization	Current Condition	Current Condition
	Preservation	Current Condition	Current Condition

Both segregated and integrated strategies can have a role in hatchery broodstock management; however, recent studies and further analyses based on the Ford (2002) fitness model suggest that segregated hatchery programs should be used with greater caution.

Table 3 compares the relative fitness effects of pHOS and PNI standards on naturally spawning populations as predicted by the Ford model. In the example shown in Table 3, note that the standard for a segregated population (pHOS < 5%) results in a significantly lower relative fitness (0.62) than the corresponding fitness value (0.83) for an integrated population with a PNI > 0.67. This suggests that the HSRG standard for segregated populations may be insufficient to safeguard the long-term viability of the affected naturally spawning Primary and Contributing populations.

Table 3 Predicted long-term effects on fitness as a function of PHOS and PNI for segregated and integrated hatchery programs. Shading indicates HSRG standards for Primary (green) and Contributing (blue) populations.

Segregated		Integrated	
			Fitness Factor
$pHOS_{eff}$	Fitness Factor	PNI	$pHOS_{eff}$ =30%
2%	0.85	0.77	0.91
3%	0.76	0.75	0.9
4%	0.68	0.71	0.87
5%	0.62	0.67	0.83
6%	0.57	0.60	0.77
10%	0.20	0.50	0.67

Recommendation 9: Manage the harvest to achieve full use of hatchery-origin fish

Many salmon fisheries can be restructured to increase the beneficial harvest of hatchery salmon, while reducing the adverse biological effects of excessive numbers of hatchery fish spawning in the wild. Hatchery fish from harvest programs need an external mark (adipose fin-clip) so they can be distinguished from natural-origin fish and selectively harvested in various fisheries.

Many current fisheries are incapable of harvesting available adult hatchery salmon without over-harvesting natural populations. Harvest of hatchery salmon predominantly occurs in mixed stock fisheries, where harvest rates are restricted to protect weaker natural populations. Consequently, significant economic benefits are unrealized, hatcheries often get large surpluses of returning salmon that are of little benefit to the public, and many natural spawning salmon populations are swamped with excessive escapement of hatchery fish, depressing the natural populations' viability.

Because salmon survival in any given year can vary by an order of magnitude, fisheries must be flexible enough to harvest highly variable numbers of hatchery salmon. In many cases, if fisheries are not managed to remove more hatchery salmon, hatchery programs need to be reduced or terminated to avoid adverse effects on natural populations.

To both increase salmonid harvests and minimize adverse biological effects on natural populations, the HSRG recommends that most fisheries be managed as selective fisheries, where marked hatchery fish are retained and unmarked fish are released with minimal mortality. Selective commercial fishing gear needs to be developed and evaluated. Additionally, the HSRG recommends that more hatchery fish be transferred to and acclimated in terminal fishing locales, distant from Primary and Contributing populations, where they can be harvested in known stock fisheries with little mortality to other populations.[5]

Recommendation 10: Ensure all hatchery programs have self-sustaining broodstocks

Many current hatchery programs import juveniles from out-of-subbasin sources. This practice inhibits local adaptation, which is important to long-term productivity and sustainable harvest of both natural and hatchery populations. The practice of importing broodstock and juveniles to a number of out-planting locations also contributes to the loss of genetic diversity within and among populations. Use of local broodstock and in-basin rearing (even in segregated programs) promotes selection for traits favorable to survival in the local environment and improves homing fidelity, thereby reducing straying risks to other populations.[6] In this context, the same biological principles used to manage wild populations should be used to manage hatchery populations. Exceptions to this are the designated terminal area fisheries, where the intent is to harvest all returning adults (e.g., Youngs Bay).

For integrated programs, managers are encouraged to monitor the status of the source of natural-origin populations to ensure that broodstock collection can be accommodated within abundance objectives for that population. Similarly, removal of natural-origin fish for integrated hatchery programs can be expected to increase pHOS, so managers should consider pHOS effects relative to HSRG standards. The HSRG suggests that managers increase the escapement goals for natural-origin fish to accommodate the needs of hatchery broodstock for integrated programs.

Recommendation 11: Coordinate hatchery programs to account for the effects of all hatchery programs on each natural population and each hatchery program on all natural populations

Hatchery fish production needs to be regionally coordinated if regional conservation and harvest goals are to be met. Regional coordination would allow oversight of the effects of all hatchery programs on each natural population and the effects of each hatchery program on all natural populations. The focus should be on limiting negative ecological and genetic impacts of harvest

[5] One example of the HSRG's suggested solution is for Youngs Bay coho (HSRG 2009). The HSRG projected that annual harvests at the Youngs Bay terminal fishery site could increase by 12,000 coho and hatchery surpluses could be decreased by a similar amount if an additional 1 million hatchery fish were transferred to the site. The HSRG also recommends that the Washington coastal and lower Columbia River sport and commercial Chinook fisheries be managed selectively. By doing so, harvest of threatened wild Lower Columbia River Chinook would be reduced by about 36% under HSRG projections. Similarly, hatchery fish harvest would increase by about 13% and wild summer Chinook harvest would decline by about 7% if the Columbia River sport and terminal summer Chinook fisheries were managed as selective.

[6] An example is the Wenatchee coho reintroduction program. Lower Columbia broodstock was replaced with in-basin adults in an effort to select for population traits that could withstand the rigors of migration over seven additional mainstem dams into the upper Wenatchee watershed.

production on naturally rearing populations, and ensuring that system-wide hatchery propagation does not overwhelm individual, biologically significant, natural populations.

The anadromous fish released in each subbasin will interact with wild and hatchery fish from other subbasins as they migrate through the downstream corridor, estuary and ocean. In some cases, these interactions may be positive (i.e., hatchery fish may provide food for natural populations or for predators that would normally prey on natural populations). In other cases, effects could be negative. Hatchery fish may compete for food and space, attract predators, or prey on natural and hatchery fish from other subbasins. Negative interactions can also be genetic. Hatchery fish from one subbasin may stray and spawn with fish in other subbasins, reducing the natural population's fitness.

The effects of these ecological interactions are heightened as the cumulative number of hatchery fish released for harvest increases. Therefore, in order to minimize the negative ecological impacts on stocks of special concern, overall anadromous fish production should be limited to the minimum number needed to meet system-wide harvest and conservation goals of the various managers. In addition, the combined natural and hatchery production should take into account the carrying capacity of the migratory corridor, estuary and ocean. Meeting these system-wide limitations on production requires coordination of the number of anadromous fish released by all hatchery operators. The result of this type of coordination could be invaluable in achieving conservation, while maintaining or increasing harvest.

Regional coordination would require that decision-makers have convenient access to reports showing population goals, current status of populations and fisheries, and expected and realized contributions from hatchery programs. This information should be up to date and easily accessible via the Internet. It should be possible to view the information at several levels, e.g., by population, ESU and species.

Recommendation 12: Ensure that facilities are constructed and operated in compliance with environmental laws and regulations

Hatchery facilities include adult collection, spawning, incubation and rearing and release facilities as well as structures to remove and discharge water. These structures are usually located in riparian areas or within streams and can affect habitat quality and quantity, as well as the use of habitat by juvenile and adult fish. Hatchery structures can create obstacles to migration for juvenile and adult fish, change instream flow, alter riparian habitat and diminish water quality through hatchery discharges.

Water for hatchery use is often drawn from an adjacent stream via pumps or gravity. Improperly designed and maintained water intakes can impinge migrant or resident juveniles on hatchery screens or cause fish to be trapped in hatchery facilities. Structures such as adult weirs and water intake dams can also block natural passage of salmonids to spawning or rearing areas. Water diverted from adjacent streams for fish culture purposes is often returned downstream and can reduce the amount of water for juvenile rearing and upstream adult migration between the area of intake and discharge. Hatchery discharge can also diminish water quality below the point of discharge through changes in temperature, settleable and suspended solids, chemical composition, and presence of therapeutic drugs.

The HSRG has noted that, for the most part, existing laws and regulations related to facilities and operations are adequate to protect the environment; however, not all facilities are in compliance with those laws and regulations. It is important that those facilities come into compliance. If hatchery facilities and operations are not in compliance with environmental laws and regulations, the consequence could be loss of natural production. In addition, failure to comply with these requirements could lead to closure of facilities and the loss of any harvest or conservation benefit derived from the programs.

Recommendation 13: Maximize survival of hatchery fish consistent with conservation goals

Maximizing the survival of hatchery fish enables conservation programs to accelerate their rebuilding efforts. It allows production hatcheries to reduce their ecological impacts on natural populations. Conservation hatcheries producing juveniles with high survival generate more spawners on the spawning grounds. This, in turn, accelerates the rate at which recovery programs move toward meeting their goals. Production programs may have to reduce release numbers to decrease negative ecological impacts on natural populations. Increasing post-release survival can offset this reduction and enable managers to meet their harvest goals.

There are many approaches to increasing fish survival. Releasing fish at the appropriate time, size, age and location can significantly increase their recruitment to fisheries and natural escapement. Releasing rapidly migrating smolts rather than fry increases survival and reduces negative ecological interactions in the freshwater environment. Similarly, releasing healthy fish produces more fish for harvest and less opportunity to spread disease to natural populations. Improving water quality and reducing loading and density during rearing are also proven tools used by fish culturists to enhance fish survival. Adoption of volitional release (allowing smolts to outmigrate when they are ready, rather than “forcing” them out at a preset date) with removal of residuals (fish that do not outmigrate) may increase the long-term survival of released fish, while decreasing negative ecological interactions with natural populations. Proper acclimation and imprinting of hatchery juveniles can reduce straying and enhance survival to the desired location for their harvest or artificial spawning.

Developing and adopting these and other culture and release practices that maximize fish survival and minimize negative ecological interactions by reducing production release numbers, can aid conservation programs in rebuilding runs and reducing the conflict between harvest programs and conservation goals for natural populations.

Principle 3: Monitor, Evaluate and Adaptively Manage Hatchery Programs

In addition to establishing resource goals (the first principle) and a defensible scientific rationale for a hatchery program (the second principle), the HSRG recommends that managers' decisions be informed and modified by continuous evaluation of existing programs, changing circumstances and new scientific information. Systems affected by hatchery programs are dynamic and complex; therefore, uncertainty is unavoidable. The only thing certain is that the unexpected will occur. Managing hatchery programs is an ongoing and dynamic process.

Hatchery managers' decision-making processes must include provisions to monitor the results of their programs and identify when environmental conditions or scientific knowledge has changed. Climate change and human population growth are examples of the factors that must be taken into consideration in the future. New data will change our understanding of the ecological and genetic impacts of hatchery programs. Recognizing these changes should lead directly to changes in hatchery operations.

This approach will require a substantial increase in scientific oversight of hatchery operations, particularly in the areas of genetic and ecological monitoring. The process should be structured to allow directed research, innovation and experimentation, so that hatchery programs may be effectively modified to better contribute to new goals and incorporate new concepts in fish culture practice.

Recommendation 14: Regularly review goals and performance of hatchery programs in a transparent, regional, "all-H" context

The HSRG recommends that management decisions be informed and modified by periodic evaluations of existing programs in light of new scientific information. This evaluation process should be on-going to allow incorporation of new knowledge as soon as possible. Comprehensive reviews of hatchery programs should be conducted at regularly scheduled intervals.

The 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008) requires periodic reviews at five and ten year intervals to monitor progress toward implementing actions and assess progress toward achieving expected benefits. These types of periodic reviews assess the region's implementation progress and allow consideration of new information and adjustment of plans to achieve managers' objectives. Hatcheries should also be subject to comprehensive review every five years. This review should include hatchery operation and performance, as well as hatchery program performance standards, to ensure continued consistency with overall population goals.

For many programs, this approach will require a substantial increase in scientific oversight of hatchery operations, particularly in the areas of genetic and ecological monitoring. Well-defined, responsive decision-making processes will need to be in place to accommodate new information and recommendations resulting from these hatchery reviews. These periodic reviews will help keep the region focused on hatchery reform implementation and will help monitor benefits and risks over time.

The HSRG believes that hatcheries can be managed in a more flexible and dynamic manner in response to changing environmental conditions, new scientific information, and the changing economic value of the resource. Decisions about hatcheries must also be made in a broader, integrated context, and hatchery solutions must meet the test of being better, in a benefit-risk sense, than alternative means to meet similar goals. Results of monitoring and evaluation must be brought into the decision-making process in a clear and concise way so that needed changes can be implemented. This responsive process should be structured to allow for innovation and experimentation, so that hatchery programs may incorporate new goals and concepts in fish culture practice.

The HSRG has concluded that certain information is critical to operating hatchery programs in a responsible manner. Hatchery fish should not be released unless the contribution of those fish to natural spawning escapement can and will be estimated with reasonable accuracy on an annual basis. Contribution from each hatchery program to fisheries should also be monitored annually. Increased tagging rates and improved sampling of fisheries and spawning escapement will be needed to ensure sufficient accuracy in estimating contributions of specific hatchery programs to harvest and natural spawning. Natural spawner abundance of populations affected by hatchery fish should be estimated each year, with the highest priority placed on Primary populations.

Recommendation 15: Place a priority on research that develops solutions to potential problems and quantifies factors affecting relative reproductive success and long-term fitness of populations influenced by hatcheries

Hatcheries have demonstrated that they can successfully provide fish for harvest. Scientific uncertainty remains about the reproductive success of hatchery-origin fish in the wild. A growing body of research has shown that traditional hatchery practices produce adults that may exhibit lower reproductive success in nature than locally adapted natural-origin fish. In addition, it appears that a number of natural populations continue to have low productivity and are at risk of going extinct.

Hatcheries have played a role in preserving some at-risk populations in the short term, but the longer-term effects are unknown. Hatcheries will continue to be used to preserve natural populations in the foreseeable future. Current research is focused on quantifying the *relative reproductive success* of hatchery- and natural-origin fish using traditional practices, but has not attempted to identify factors or test solutions to improve upon this performance.

The environmental phenotypic component (i.e., the reproductive success of first generation hatchery-origin fish) needs further investigation for different species and culture conditions. Also, long-term fitness loss as a function of the proportion of hatchery fish in natural spawning populations and the proportion of natural fish in the hatchery broodstock must be addressed, among other factors. Future research should be prioritized to identify factors causing reduced fitness and reproductive success of hatchery fish and investigate whether changes to fish culture practices can overcome these problems.

Recommendation 16: Design and operate hatcheries and hatchery programs with the flexibility to respond to changing conditions

The concept of adaptive management is well established. Adaptive management is a structured, iterative process of optimal decision-making in the face of uncertainty, aimed at reducing uncertainty over time through system monitoring and evaluation. The HSRG developed its recommendations using analyses based on best available scientific knowledge, reasonable assumptions where information was lacking, and management goals (as understood by the group). The HSRG's recommendations are based on the interactions among and between hydropower and hatchery operations, as well as harvest and habitat variables. The analytical methods used to develop those recommendations will need to be updated, and management decisions adapted accordingly as new knowledge is gained through the implementation, monitoring and evaluation of hatchery reform. It will be important for hatchery managers to design and operate hatchery programs with the flexibility to respond to both new knowledge and changing conditions. This is likely to be increasingly important in light of changing climate conditions.

Recommendation 17: Discontinue or modify programs if risks outweigh the benefits

Many hatchery programs were initiated in the 1950s and 1960s and were designed to support high levels of harvest. The importance of maintaining viable natural populations was not well understood and was not a priority during the development of hatchery infrastructure. Scientific information since then has shown that hatchery fish can pose significant risks to natural populations if managed improperly. In addition, recent Endangered Species Act (ESA) listings of salmon and steelhead have elevated conservation of viable natural populations to a management priority. Many of the hatchery programs designed to support a single harvest objective must be modified to also achieve conservation goals for natural populations. Both conservation and harvest goals can be achieved if resources are provided to modify these hatchery programs. Without these investments, programs will have to be reduced or discontinued, in order to achieve the conservation goals. This will result in loss of harvest benefits.

1.3 NEXT STEPS IN HATCHERY REFORM

Hatchery design, programming and reform often occur simultaneously due to the myriad funding, regulatory and management entities and forums. These activities are complicated by the large number of hatchery programs and salmon and steelhead populations across multiple political jurisdictions. If hatchery benefits and risks are to be scientifically assessed, a common language and framework is needed within the Pacific Northwest to ensure such critical work is efficiently and effectively completed. To that end, the HSRG recommends application of its implementation framework.

The framework consists of the scientific principles, assessment tools and the 17 system-wide recommendations. These will be available and maintained on a public web site to ensure a consistent and transparent assessment for management and reform of hatchery programs. The HSRG recommends that the fishery managers use the HSRG's program-specific population reports, data sets and analytical tools as a starting point for future hatchery assessments.

Institutionalizing an implementation framework is critical to achieving meaningful and sustained reform and to optimizing long-term management. In addition to its scientific underpinnings, this framework is also beneficial because it allows managers and their constituents to consider future hatchery reforms and affected fisheries in a quantitative manner. It allows sound scientific principles and standards to be applied using sets of comprehensive parameter values and stated assumptions for individual populations and the ecosystem as a whole. Being able to assess future management scenarios will allow managers and constituents to more easily visualize future options and adapt current management to achieve greater biological and social benefits while reducing biological and social risks.

Implementation Recommendations

Hatchery management and the reforms recommended by the HSRG could affect many entities. Fishery managers, funding authorities such as utilities, the Bonneville Power Administration and Congress, and regulators such as NOAA Fisheries will all have important roles in implementation of hatchery reform. Hatchery reform is also important to the Northwest Power and Conservation Council (NPCC) which is mandated to develop a comprehensive fish and wildlife program. Additionally, proper hatchery management affects the full range of land and water use and users, since hatchery practices greatly influence the success of, and investment in, habitat protection and restoration for steelhead and salmon conservation. The entire region, therefore, has a stake in hatchery reform and the HSRG's recommendations.

The work of the HSRG will add significant value to fisheries management only if the principles and system-wide recommendations are fully integrated into everyday hatchery and harvest planning and operations. To this end, the HSRG provides the following recommendations for implementation:

- The region's hatchery managers should incorporate the HSRG implementation framework into their ongoing hatchery program planning and reviews. This framework is, at this time, the most comprehensive method available to programmatically review hatchery programs and apply the best available scientific information in a methodical and consistent manner. In its current ESA consultations on each hatchery program, NOAA Fisheries should include assessments of hatchery programs by applying the HSRG standards, tools and data in development of Hatchery and Genetic Management Plans (HGMPs). HGMPs should also address how each hatchery program incorporates the HSRG's system-wide recommendations. The HSRG tools will allow consultations on hatchery management to be quantitatively integrated into an All-H or ecosystem management context along with population effects from hydropower, harvest and habitat. NOAA should also fully consider the HSRG solutions presented in HSRG reports (2004, 2009) in its reviews of each hatchery operation.
- The HSRG encourages the regional hatchery funding entities (utilities, BPA, Army Corps of Engineers, Bureau of Reclamation, and USFWS) to adopt the HSRG framework and system-wide recommendations as a basis for future funding and accountability of their respective hatchery mitigation or enhancement programs. Similarly, the NPCC is encouraged to integrate the HSRG framework and the 17 system-wide recommendations into its three-step hatchery planning process, along with previous independent scientific guidance on hatchery programs from the Independent Science Advisory Board and Independent Scientific Review Panel.
- An implementation plan, as well as maintaining and updating the current data sets and population reports, is needed to fully realize the substantial benefits of adopting the HSRG framework. The HSRG recommends that hatchery operators make a commitment to maintain and update data sets and analytical tools, and that the hatchery funding entities and NPCC include annual information updates as a requirement for, and a component of, hatchery program funding.
- The publicly-accessible website housing the HSRG framework, data sets and analytical tools will require a permanent home and long-term funding, which has yet to be secured. This is critical to ensuring that the data sets are up to date. The website must include the HSRG tools and data sets so that hatchery managers can access them, create and update population reports, and make the reports available to the funding entities, NOAA, the NPCC and the public. The data sets will also need to be accessible to watershed and mainstem passage planning groups to update critical habitat and passage survival information. The HSRG had to apply many assumptions in its assessment of hatchery

programs. As scientific knowledge evolves from ongoing research, these assumptions will need to be documented and changed. The HSRG tools readily allow for such revisions.

Finally, implementation of the HSRG recommendations involves regular programmatic performance reviews of hatchery programs. While hatchery operators should review programs annually, the HSRG recommends a regional performance review of hatchery programs that assesses program performance against the managers' goals, the HSRG standards and system-wide recommendations. These reviews could be undertaken at the regional level and scheduled so that hatchery programs in each region are publicly reviewed every five years. The reviews could accomplish necessary oversight for a number of processes, including funding, ESA regulation, consistency with NPCC's program, consistency with the US v. Oregon management plan, independent scientific oversight, and for public accountability. As part of the scientific oversight, each hatchery program should be rated on its conservation and harvest performance objectives and its adherence to the HSRG system-wide recommendations.

GLOSSARY

Adaptive Management

Adaptive management is a structured, iterative process of optimal decision-making in the face of uncertain outcomes, with the goal of reducing uncertainty over time. Key elements of adaptive management include an explicit process for testing assumptions (e.g., through a well-designed monitoring and evaluation program) and a systematic feedback process through which new data and information are used to periodically re-evaluate and modify management strategies.

All H Analyzer (AHA)

The *All H Analyzer (AHA)* tool was developed by the HSRG in 2005 as part of the Columbia River Basin Hatchery Review (HSRG 2009). The tool allows managers to compare alternative management strategies for salmon and steelhead populations. AHA predicts population outcomes in terms of natural production and harvest for management policies implemented over a long period of time (HSRG 2014).

All H Strategy

An *All H Strategy* jointly addresses habitat, hatchery, harvest, and hydropower impacts as part of an integrated management strategy for salmon and steelhead populations (HSRG 2014).

Biological Significance

The biological significance of a stock is a function of the origin of the stock and its inherent genetic diversity, biological attributes, uniqueness, and local adaptation, and the genetic structure of the population relative to other conspecific populations. A population can be considered highly significant if it exhibits unique genetic and biological attributes that are not shared with other adjacent stocks. These attributes may include unique life history, physiological, morphological, behavioral, and disease resistance characteristics with a genetic basis (HSRG 2004). Levels of **biological significance** are expressed as **population designations**.

Broodstock

Adult fish used by hatcheries to propagate the next generation.

Broodstock Management:

Integrated Program

In an *integrated program*, hatchery and natural populations are two components of a single population. The intent of an integrated program is for the natural environment to drive the adaptation of the combined hatchery-natural population. This is accomplished by using natural-origin fish for a portion of the broodstock and by limiting the proportion of hatchery fish spawning in the wild. The intent is to minimize genetic divergence between the hatchery and natural populations. The purpose of an integrated program may be to contribute to conservation and/or harvest goals. A hatchery program is integrated with one specific natural population. It is segregated relative to all others (HSRG 2014).

Segregated Program

A *segregated program* establishes a new, hatchery-adapted population that is genetically distinct from all natural populations with which it might interact. Only hatchery-origin fish are used in the broodstock. The intent is to maintain a gene pool that is separated from all natural populations. Genetic and ecological risks to the natural population are minimized by limiting pHOS and strays. The purpose of a segregated program is typically to contribute to harvest goals (HSRG 2014).

Stepping Stone Program

A *stepping stone program* is a two-stage program that may be established when natural production is too low to support an integrated program (or tolerate a segregated one) of sufficient size to meet harvest objectives. Initially, a small integrated program produces broodstock for a larger segregated program, and the segregated program produces fish for harvest. Program fish are differentially marked. Eventually, when sufficient natural-origin broodstock are available, the program may transition into a fully integrated program (HSRG 2014).

Distinct Population Segment

A *distinct population segment* (DPS) is a listable entity under the Endangered Species Act (ESA). The ESA provides for listing species, subspecies, or distinct population segments. A population is considered distinct under the ESA if it is discrete from other populations of its species in terms of physical, behavioral, or genetic characteristics, occupies a unique ecological setting, or its loss would represent a significant gap in the species' range (NMFS 2015).

Ecological Interactions

Ecological interactions between hatchery and natural fish include competition for feeding and spawning locations, predation of hatchery fish upon natural-origin fish and the potential transfer of disease from hatchery to natural-origin fish (HSRG 2014).

Escapement
The portion of a run that is not harvested or used for hatchery broodstock and returns alive to the spawning grounds. Escapement includes those fish that die on the spawning grounds prior to spawning.

Evolutionarily Significant Unit
An *evolutionarily significant unit* (ESU) is a Pacific salmon population or group of populations that is 1) substantially reproductively isolated from other conspecific populations and 2) represents an important component of the evolutionary legacy of the species (NMFS 2015).

Fitness
Individual fitness is the mean number of adult offspring produced by an organism. *Population fitness* is the mean fitness of all individuals within a population.

Hatchery-origin Broodstock
Hatchery-origin broodstock (HOB) is the number of hatchery-origin fish used as hatchery broodstock.

Hatchery-origin Recruit
Hatchery-origin recruits (HORs) are the sum of hatchery-origin spawners, hatchery-origin broodstock, and hatchery-origin fish intercepted in fisheries.

Hatchery-origin Spawners
Hatchery-origin spawners (HOS) are hatchery-origin fish that spawn in the wild.

Hatchery Program
A *hatchery program* is defined by the hatchery purpose (harvest and/or conservation), type of program (integrated, segregated, or stepping stone), the natural population with which it is associated (integrated programs), number of fish released, and type and size of releases (HSRG 2014).

Hatchery Purpose
Hatchery programs are tools for meeting resource goals. Thus, hatchery programs have a purpose not a goal, just like a hammer has a purpose and not a goal.

Conservation Program
A conservation program may be designed to prevent extinction, preserve the population's genetic diversity, and/or provide a demographic safety net. Conservation programs have four phases (see Phases of Recovery below).

Harvest Program
A harvest program is designed primarily to provide recreational, tribal, and/or commercial harvest opportunities. Harvest programs should be designed to meet well-defined goals (e.g., specific harvest levels) without causing adverse impacts to naturally spawning populations.

Local Adaptation — *Local adaptation* is the evolutionary product of natural selection in a population that inhabits and reproduces within a specific environment for many generations until the optimum phenotype that confers maximum fitness is reached.

Major Population Group — A major population group (MPG) is comprised of salmon populations that are geographically and genetically cohesive. The MPG is a level of organization between demographically independent populations and the ESU or DPS (NMFS 2015).

Natural-origin Broodstock — *Natural-origin broodstock* (NOB) is the number of natural-origin fish used as hatchery broodstock.

Natural-origin Recruit — *Natural-origin recruits* (NORs) include the sum of natural-origin spawners, natural-origin broodstock, and natural-origin fish intercepted in fisheries.

Natural-origin Spawners — *Natural-origin spawners* (NOS) are natural-origin fish that spawn in the wild.

pHOS:

Effective pHOS ($pHOS_{eff}$) — *Effective pHOS* is defined as the mean proportion of natural spawners in a watershed or stream composed of hatchery-origin spawners (HOS), where HOS is discounted by a correction factor (see below). It may also be thought of as the genetic contribution of hatchery-origin adults to the natural population in the next generation as measured at the adult stage. This is first generation gene flow. $pHOS_{eff}$ = (HOS x cf)/[(HOS x cf) + (NOS)]

Census pHOS ($pHOS_{cen}$) — *Census pHOS* is defined as the mean proportion of natural spawners in a watershed or stream composed of hatchery-origin adults. $pHOS_{cen}$ = (HOS)/(HOS + NOS)

Correction Factor (cf) — The *correction factor* discounts the genetic contribution of hatchery-origin adults to the natural population by a factor that accounts for the assumed lower reproductive success of HORs. Value ranging from 0 to 1.0. If the correction factor is 1.0, $pHOS_{eff} = pHOS_{cen}$. See calculations below.

PNI — *Proportionate Natural Influence* (PNI) for a composite hatchery- and natural-origin population is calculated as pNOB/(pNOB + pHOS). It can also be thought of as the percentage of time the genes of a composite population spend in the natural environment.

pNOB

Mean proportion of a hatchery broodstock composed of natural-origin adults. Calculated as NOB/(HOB + NOB).

Population Designation

Three population designations were defined by the Lower Columbia Fish Recovery Board (LCFRB 2004) and reflect the **biological significance** and the expected level of contribution of the population to recovery of the **Evolutionarily Significant Unit (ESU)** or **Distinct Population Segment (DPS)**. The HSRG encourages co-managers to assign a population designation to each natural population associated with a hatchery program. The designation is a science-informed policy decision. The HSRG has recommended standards for hatchery influence (i.e., pHOS and PNI) for each designation.

Primary A population of high biological significance. Primary populations are critical to recovery of the ESU or DPS. They should meet the highest standards of viability.

Contributing A population of medium biological significance. Contributing populations are important to the diversity of the ESU or DPS. They should meet high standards of viability.

Stabilizing A population of lower biological significance than primary or contributing ones. Stabilizing populations should maintain current levels of viability.

Population Goal

The *population goals* for a program should be quantified, where possible, and expressed in terms of values to the community (harvest, conservation, education, research, etc.).

Population Viability

Population viability is defined in terms of four parameters: abundance, productivity, population spatial structure, and diversity (McElhany et al. 2000).

Abundance Size of the population, typically measured in terms of the number of spawning adults.

Productivity The average number of surviving offspring per parent. Productivity is used as an indicator of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner. If productivity is less than one, the population is failing to replace itself. If this occurs consistently, the population may be at risk of extinction.

Population Structure

The spatial structure of a population refers to the degree to which subpopulations occupy habitat patches connected by low to moderate stray rates (also referred to as “metapopulations”). Population spatial structure depends on habitat quality, spatial configuration of the habitat, and dispersal of individuals.

Diversity

Population diversity includes both genetic and phenotypic (life history, behavioral, and morphological) variation, and contributes to population resilience and the ability to adapt to short-term and long-term changes in the environment. In salmonids, variation is expressed in terms of fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, male and female spawning behavior, etc.

Phases of Recovery

The HSRG defined 4 *phases of recovery* for conservation programs. The phase depends on the 1) program objectives for the population, and 2) ecosystem conditions (HSRG 2014). Moving from one phase to the next occurs when **triggers for phase shifts** are achieved (see below).

Preservation

The primary objective in the *preservation phase* is to prevent extinction and preserve the genetic diversity of the population. Suitable for populations with low abundance where the habitat is unable to support a self-sustaining population.

Re-colonization

The objective in the *re-colonization phase* is to re-populate suitable habitat. Suitable once the population is no longer at risk of extinction and when underutilized habitat is available to re-colonize.

Local Adaptation

In the *local adaptation phase*, the objectives are to meet and exceed the minimum viable spawner abundance for natural-origin spawners, and increase population fitness, reproductive success, and life history diversity through local adaptation (e.g., achieved by reducing hatchery influence by maximizing PNI). This phase is reached when specific population triggers are met and the habitat is capable of supporting abundances that meet these population objectives.

Full Restoration In the *full restoration phase*, the goal is to maintain a viable population as defined by the viable salmonid population (**VSP**, see below) attributes. This phase is reached when specific population triggers are met and the habitat is fully restored and protected.

Triggers for Phase Shifts Moving from one phase to the next occurs when specific *triggers for phase shifts* are met. These are biologically based, quantitative goals (e.g., number of NOS) and are typically based on a 5-year average so that phase shifts are based on long-term population trends. Phase shifts can be either up or down depending on the population trend.

Relative Reproductive Success The *relative reproductive success* (RRS) of hatchery-origin adults as compared to natural-origin adults generally refers to the difference in the number of progeny produced or genetic contribution to the next generation by hatchery- versus natural-origin spawners. Factors that may influence RRS include domestication selection, choice of hatchery broodstock, and the size, age, and location of hatchery releases (HSRG 2014).

Residualization Hatchery fish that remain in freshwater for extended periods. Residualized juveniles may compete with or predate upon natural-origin juveniles.

Scientifically Defensible A *scientifically defensible* program is one that explains, in terms of benefits and risks, how the hatchery program expects to achieve its purpose. The benefits of the program must outweigh the risks, and the chosen strategy must be consistent with current scientific knowledge. Where there is uncertainty, hypotheses and assumptions should be documented so that those assumptions can be evaluated and modified as new information becomes available (HSRG 2014).

Selective Harvest *Selective harvest* programs are designed to target hatchery-origin adults. The purpose of such programs is to reduce the number of hatchery-origin fish on the spawning grounds. Hatchery-origin fish must be differentially marked. Specific gear types are being developed and tested (e.g., tangle nets) for large-scale selective harvest programs on mainstem fisheries such as the lower Columbia River (HSRG 2014).

Stray Rate

The *stray rate* is the proportion of adult spawners that do not return to their natal stream, but enter and spawn in another stream. This includes hatchery-origin recruits (HORs) that do not return to the stream of origin or release. The HSRG recommends taking measures to limit the straying of HORs.

Supplementation

Supplementation is a term frequently used when referring to hatchery programs where the intent is for hatchery-origin fish to spawn in the wild and make a contribution to conservation. The HSRG concluded that this may be possible in some circumstances, but such programs should always be accompanied by comprehensive monitoring and evaluation efforts. In the past, attempts to identify the general conditions under which these net benefits to the population occur have failed (RASP 1992) because generalization is impossible due to the unique environmental conditions in which each population exists. Programs should, therefore, be evaluated on an individual basis where population status and the unique habitat, harvest, hatchery, and hydropower conditions are taken into account. It should be noted, however, that integrated conservation programs are most likely to increase the abundance of natural-origin spawners when natural productivity is relatively low and habitat capacity is high.

Terminal Fishery

The *terminal fishery* takes place in the final portion of the migration route of fish returning to freshwater to spawn.

Viable Salmonid Population

A *viable salmonid population* (VSP) is defined as an independent salmonid population that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and changes in genetic diversity over a 100-year time frame (McElhany et al. 2000). A VSP is defined in terms of four population attributes (abundance, productivity, population structure, and diversity; see **Population viability** above).

Working Hypothesis

Hatchery programs should be based on a *working hypothesis* that takes into account the best available scientific information about the population (smolt-to-adult survival rates, fish passage survival, harvest rates, natural productivity, impacts of hatchery fish on natural populations, etc.).

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