Part 2 – Summary Conclusions, Principles and System-Wide Recommendations

2.1 Summary Conclusions

The HSRG concluded that hatcheries play an important role in the management of salmon and steelhead populations in the Columbia River Basin. 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. The resulting population-specific recommendations are intended to provide scientific guidance for managing each hatchery more effectively in the future.

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

Hatchery reforms that improve fitness of the natural populations from the current condition (for example, by promoting local adaptation) also increase the benefit of current and future habitat improvements. Conversely, when habitat improvements are made without hatchery and harvest reforms, the resulting benefits will be less than with hatchery reform. 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 (population fitness and productivity), economic benefit (increased harvest) and increase the value of current habitat and 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 a hatchery broodstock from a naturally spawning population. An integrated 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]. But they can pose a risk to natural populations if the size of the hatchery program exceeds 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.

[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, e.g., RASP 1991. 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 1991) 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.

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 of the population, are intended to support recovery of natural populations while retaining overall harvest benefits. They are also designed to be simple to implement and monitor. The HSRG also proposes methods for achieving those 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 the 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.

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 in the Columbia River Basin is of concern to the HSRG, with adverse effects on the natural population having been documented (e.g., Kostow 2008). 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[2],

[2] Hatchery steelhead juveniles sometimes fail to migrate to the ocean after release; instead they remain in the freshwater (residualize).

increasing competitive interactions[3]. 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 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 (Appendix A, Antibiotics in Salmonid Aquaculture).

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 noted 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 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

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 adults produced (harvest plus escapement) per adult spawned at the hatchery. All too often in the past, hatcheries have been evaluated based on the number of smolts released.

2.2 Principles and System-Wide Recommendations

The principles and system-wide recommendations that follow represent the key findings of the HSRG in its review of Columbia River Basin hatcheries. 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 (applicable to programs across the Columbia River Basin hatchery system) listed under the principle from which it is derived. These principles and system-wide recommendations are the basis for the HSRG solutions presented in Part 3 - ESU/MPG Roll-Up Reports section of this report. The ESU reports are not presented as

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

the only possible solution for those populations, but rather as a clear demonstration that current hatchery programs can be redirected to better meet both conservation and harvest goals.

Principle: 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 strategy where habitat, hatchery management and harvest 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. It should be noted that the HSRG review and population-specific recommendations found in Appendix E of this report are based on the HSRG's interpretation of goal statements provided by the managers or found in their planning documents.

Recommendation 1: Express conservation goals in terms of a population's biological significance (Primary, Contributing, Stabilizing) and viability (natural-origin spawning abundance and productivity)

Different definitions of biological significance are used by the managers throughout the Columbia River Basin. In an effort to provide a consistent analysis, the HSRG applied the designations for biological significance and population viability used by the Lower Columbia River 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
- Viability goals should be expressed in terms of population productivity and abundance
- Viability goals should also take into account spatial structure and diversity

The designation of a population as Primary, Contributing or Stabilizing is a policy decision; however, for its analysis, the HSRG made assumptions based on the status of each population and goal statements provided by the managers or found in planning documents.

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 fish) in specific fisheries (e.g., tributary sport or other terminal fisheries), or as mixed-stock, pre-terminal, sustainable harvest rates.

Recommendation 3: Ensure goals for individual populations are coordinated and compatible with those for other populations in the Columbia River Basin

Many important populations of salmon and steelhead do not meet the conservation expectations identified by managers. Achieving these expectations requires that population goals be developed that consider other populations in the Columbia River Basin, watershed or ESU. 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 in the Basin also needs to be considered.

Principle: 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. The strategy chosen must be consistent with current scientific knowledge. Where there is uncertainty, hypotheses and assumptions should be articulated.

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. 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 goals for a population 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 goals for biological significance (Primary or Contributing) and viability (productivity, abundance, diversity and spatial structure) of a population. 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.

In the past, the 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 clear, 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 goals

Once population goals have been defined and the purpose(s) of a hatchery program (harvest, conservation, or both) have been established, the scientific rationale for the program must be documented. The scientific rationale 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.) [4]. 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 segregated from, the natural populations they most directly influence (Appendix A, Implementing and Transitioning Hatchery Programs). 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

[4] For example, the HSRG 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 (personal communication with D. Campton). The specific assumptions used in these calculations were entered into the AHA spreadsheet. An example of assumptions used and their expected outcome is shown in Table D-2 of Appendix D. The biological specifications document prepared by Yakima/Klickitat Fisheries Program (Hager and Costello 1999) is another example of how scientific accountability can be documented.

a demographic safety net to vulnerable natural populations. An integrated program is intended to maintain the genetic characteristics of a locally adapted natural population and minimize the potential genetic effect of domestication. To achieve this, at a minimum, the proportion of hatchery broodstock comprised of natural-origin fish (pNOB) has to be greater than the proportion of the natural spawning population that is made up of hatchery-origin fish (pHOS).

For segregated hatchery programs, the intent is to maintain a genetically distinct hatchery population that is isolated 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 the 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.[5] 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

[5] For more information on the integrated/segregated concept, standards and implementation methods, see Section B-3 (Management Goals for Hatchery Broodstocks: Genetic Integration Versus Segregation) of the HSRG April 2004 report, and the technical discussion papers on integrated and segregated hatchery programs, all available at the HSRG's website, www.hatcheryreform.us.

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. This, in turn, determines 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 assuring 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[6].

It is not uncommon within the Columbia River Basin for excessive adult surpluses to return to a hatchery. These surpluses— the consequence of incorrectly sized programs and/or under-harvesting of hatchery fish—have led to lost economic benefit, unneeded expenditure for production, and increased conservation concerns. The HSRG recommends that managers size their hatchery and harvest programs to reduce these surpluses and use some of the surplus fish to provide ecological benefit through nutrient enhancement of streams and rivers (Appendix A, Nutrient Enhancement of Freshwater Streams to Increase Production of Pacific Salmon). Specific program recommendations to rectify excessive surpluses are identified in the population reports (Appendix E).

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

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 proportion of natural-origin spawners made up of hatchery-origin fish (pHOS), 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 and pNOB.

The designation of a population as Primary, Contributing or Stabilizing is a policy decision; however, for its analysis, the HSRG made assumptions based on the status of each population and manager's objectives. Standards used by the HSRG for broodstock management are as follows:

HSRG criteria for hatchery influence on Primary populations

- The proportion of effective hatchery-origin spawners (pHOS) 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 by at least a factor of two, corresponding to a PNI (proportionate natural influence) value of 0.67 or greater and pHOS should be less than 0.30.

[6] The proposed Klickitat coho harvest program, for example, is designed to maximize survival through local adaptation, and reduce straying and ecological interactions by reducing the number of fish released and acclimating the fish downstream of the current release site.

HSRG criteria for hatchery influence on Contributing populations

- The proportion of effective hatchery-origin spawners (pHOS) 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 pHOS, corresponding to a PNI value of 0.50 or greater and pHOS should be less than 0.30.

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) 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 most populations to meet conservation goals for abundance.

The HSRG's analysis showed that both conservation goals and harvest goals could 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, pNOB and PNI.[7]

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

[7] The HSRG's review of the Lower Columbia River Chinook ESU (see Part 3 of this report) 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.

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 assessed for use in the Columbia River Basin. Additionally, the HSRG recommends that more hatchery fish be transferred to and acclimated in terminal fishing locales, where they can be harvested in known stock fisheries with little mortality to other populations.[8]

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 outplanting locations also contributes to the loss of genetic diversity within and among populations. Use of local broodstock and in-basin rearing promotes selection for traits favorable to survival in the local environment and improves homing fidelity, thereby reducing straying risks to other populations.[9] 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).

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

Columbia River Basin fish production needs to be regionally coordinated if system-wide 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 production on naturally

[8] One example of the HSRG's suggested solution is for Youngs Bay coho (see Part 3.2 of this report). 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.

[9] 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.

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 into the Columbia River Basin 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 in the Columbia River Basin. The result of this type of coordination could be invaluable in achieving conservation, while maintaining or increasing harvest.

Basin-wide coordination would require that regional 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—by population, ESU and species—for the entire Columbia River Basin.[10]

Recommendation 12: Assure 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

[10] The AHA tool described in Appendix C is a good starting point for developing this capability. The implementation recommendations described in Section 2.2 would also help support a coordinated decision-making process that is responsive to information feedback.

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. The release of 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, the release of 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.[11]

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.

[11] Many of the HSRG solutions provided in Appendix E for upper Columbia Basin releases (such as Wenatchee coho) encourage local adaptation. This should produce higher survival and allow managers to meet their conservation and harvest goals with lower release numbers. Increasing the release size of spring Chinook in the Grande Ronde subbasin provides another example that should lead to higher survival and accelerate recovery.

Principle: 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 the 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 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 the managers' 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 2008e) requires periodic reviews at five and ten year intervals, to monitor progress toward implementing actions and assessing progress towards 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.[12]

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.

[12] To facilitate these regional reviews, all HSRG data sets and reports, as well as the AHA tools, are available through the publically accessible Hatchery Reform web site, www.hatcheryreform.us.

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 available 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 needed changes can be implemented. This responsive process should be structured to allow for innovation and experimentation, so 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 assure 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.[13]

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 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 between 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.

[13] Specific monitoring recommendations are provided in the population reports (Appendix E). A proposed framework for monitoring is outlined in Appendix A (Framework for Monitoring and Evaluating Hatchery Programs).

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 in the Columbia River Basin. 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 (Appendix A, Global Climate Change and its Effects on the Columbia River Basin).

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

Many of the Columbia River Basin 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, especially in much of the Columbia River Basin. 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.

2.3 Next Steps in Hatchery Reform

Hatchery design, programming and reform often occur simultaneously within the Columbia River Basin due to the myriad funding, regulatory and management entities and forums. These activities are complicated by the large number of Basin hatchery programs (178) and populations (351) across multiple political jurisdictions. If hatchery benefits and risks are to be scientifically assessed, a common language and framework is needed within the Basin 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 in the Columbia River Basin. 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 in the Columbia River Basin, 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 assessment of hatchery programs by applying the HSRG standards, tools and data in development of the Hatchery and Genetic Management Plans (HGMPs). HGMPs should also address how each hatchery program incorporates the HSRG's system-wide recommendations (Section 2.2). 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 individual population reports (Appendix E) in its reviews with each hatchery operator.

- The HSRG encourages the regional hatchery funding entities (utilities, BPA, Army Corps of Engineers, Bureau of Reclamation, NOAA 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 the 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 set is 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 for 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 Provincial level and scheduled so that hatchery programs in each Province 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.