US FISH AND WILDLIFE SERVICE
COLUMBIA RIVER BASIN HATCHERY REVIEW TEAM

Principles[1]

October 15, 2005

Principle 1: Well-Defined Goals

Goals for all affected stocks must be well-defined. These goals should be quantified, where possible and expressed in terms of values to the community (harvest, conservation, education, research, employment, recreation, etc.). Goals should also have short-term (10 years) and long-term (50 years) time frames. Hatcheries can then be managed as tools to help meet those goals.

Harvest and conservation are the most common stock goals. They can be defined as follows:

- Harvest goals promote or allow commercial, subsistence, ceremonial and recreational fishing;
- Conservation goals promote or allow the conservation of indigenous salmonid resources. They include endangered species protection and recovery, gene banking, maintaining native stocks as genetic repositories, particularly where natural spawning habitat is lost or limited, and restoring stocks to streams where they have been extirpated.

Hatcheries can also have research, education, and cultural goals.

To be successful, hatcheries should be used as part of an integrated strategy where habitat, hatchery management and harvest are coordinated to best meet resource management goals defined for each stock in the watershed. Hatcheries are, by their very nature, a compromise that represents a balance between benefits and risks to the target stock, other stocks and the environment affected by the hatchery program. The use of a hatchery program is defensible when benefits significantly outweigh the risks, and when the use of a hatchery program is more favorable than the benefits and risks associated with non-hatchery strategies for meeting the same goals, including situations where non-hatchery strategies cannot meet the desired goals.

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[1] These scientific principles will underlie and inform the Review Team's review and recommendations for US Fish and Wildlife Service-owned or –affiliated hatchery programs in the Columbia River Basin. These principles are based on similar principles developed as part of the Puget Sound and Coastal Washington Hatchery Reform Project's Hatchery Scientific Review Group (HSRG), the Northwest Power and Conservation Council's Artificial Production Review and Evaluation (APRE), and the Service's Pacific Region Hatchery Review Working Group (see references at the end of this document).

The following **sub-principles** are designed to help ensure a comprehensive goal setting process.

Set Goals for all Stocks and Manage Hatchery Programs on a Regional Scale

Hatchery programs must be evaluated in the context of the regions and watersheds in which they operate and the goals set by the co-managers. Reviews of hatcheries and their programs as a whole lead to broad generalities not suited to regional differences in stock and habitat status. Similarly, hatchery-by-hatchery reviews do not allow for evaluation in the context of each region's current and future habitat, harvest goals, the status of all anadromous salmonid stocks within a region, and the cumulative effects of all regional hatchery programs. Implementation of hatchery reform recommendations should also be coordinated by regional technical groups to ensure that goals for the resource, including the role of each hatchery program in achieving those goals, are tracked.

Measure Success in Terms of Contribution to Harvest, Conservation and Other Goals

It was not uncommon in the past for the direct hatchery output (i.e., numbers or pounds of juveniles released) to be cited as the goal by which a program's success was measured. More appropriate measures of success include:

- The number of returning adults and their ability to reproduce and sustain the stock, either in a hatchery, in the wild, or both.
- The scale and availability of harvest provided.
- The relative risks and benefits of each hatchery program.
- Alternative strategies for meeting similar goals.
- Whether the program is part of a comprehensive strategy to meet a stated resource goal.

Have Clear Goals for Educational Programs

Educational programs conducted at, or supported by, hatchery facilities are valuable for educating the public on the biology of salmon, the importance of maintaining healthy salmon habitat, and sustainable fisheries. A clear understanding of a program's specific educational goals needs to be articulated along with methods for determining if those goals are being met and for reporting educational benefits. It is incumbent upon the fisheries co-managers, as the professional partners of these often volunteer-driven programs, to ensure that such goal statements are developed for these programs and understood by participants. It is also essential that these programs be operated consistent with the conservation and education principles they are intended to promote. These principles may be particularly important for cooperative projects with elementary schools and vocational training programs.

Principle 2: Scientifically Defensible Programs

Once the goals for the resource have been established (see above), the scientific rationale for a hatchery program—in terms of benefits and risks—must be described to explain how the hatchery program is expected to contribute to those goals. The purpose, operation and management of each hatchery program must be scientifically defensible. The strategy and specific protocols chosen must be consistent with current scientific knowledge. Hypotheses and assumptions should be articulated to clarify uncertainties. 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 cite the scientific literature, including conceptual or theoretical models that take into account scientific uncertainty associated with various benefit and risk factors (e.g., predation assumptions, cumulative effects, productivity of naturally spawning populations, etc.).

The following **sub-principles are designed** to help ensure a scientifically-defensible hatchery program.

Operate Hatchery Programs within the Context of Their Ecosystems

The benefits and risks of hatchery programs can only be properly evaluated in the context of their ecosystems. Hatchery management requires understanding genetic and ecological interactions between species and among stocks (e.g., predation, competition, interbreeding). This requires knowing the status of the hatchery stocks and of other stocks, understanding the interactions between the stocks, and how well the habitat can support these stocks under current conditions and in the future.

Each ecosystem is unique with respect to recent history, natural events, human development, and the strategies and goals developed by resource managers. The status and expectation for naturally-spawning stocks, and the environments on which they depend, prescribe the potential for success and the limitations on any hatchery program. Therefore, in making decisions about current and future hatchery programs, decision makers should have current and future habitat assessments available to make informed decisions about short-term and long-term goals for all stocks.

Operate Hatchery Programs as either Genetically Integrated or Segregated Broodstocks Relative to Naturally-Spawning Populations

Hatchery broodstocks should be managed as either genetically integrated with, or genetically segregated from, natural populations. Hatchery programs are classified as *segregated* if the intent is to manage for two separate gene pools (one adapted to the hatchery, the other to the natural environment). Under this strategy, only hatchery-origin fish are used for broodstock, and hatchery-origin fish mush have a very low probability of spawning successfully in the wild. In contrast, hatchery programs are classified as *integrated* if the intent is for the genetic make-up of hatchery-origin fish to be the same as that of the underlying natural population, with the goal that natural selection in the wild drives the mean fitness of both components of the population. This requires that natural-origin fish be included systematically in the hatchery broodstock each year (or each generation) and that natural spawning of hatchery-origin fish be minimized to allow the goals of genetic integration to be achieved.

The concepts of genetic integration and segregation of hatchery broodstocks lead to a different set of well-defined operational guidelines and objectives for: 1) achieving the respective broodstock management goals; and 2) minimizing risks to naturally spawning populations. Each concept provides a template for broodstock management and operations. The greater the deviation from one of these templates (e.g., natural spawning by hatchery-origin fish from a segregated broodstock), the greater are the risks to naturally spawning populations with increased likelihood that the benefits of a hatchery program will not outweigh the risks. Consequently, from the outset, each hatchery program must identify one of the two broodstock strategies, and follow that strategy as closely as possible, to achieve the desired purpose of the program.[2]

Size Hatchery Programs Consistent with Stock Goals

Fisheries managers should determine the proper size (number of adult fish trapped and spawned, and number of fish released) of a hatchery program based on clearly defined goals for the stock. The size of a hatchery program must reflect two parameters: 1) the number of returning adult fish needed to meet the purpose of the program; and 2) the number of adult spawners necessary to meet *both* the purpose of the program *and* the genetic management goals for the broodstock. In general, the number of juvenile fish released should be the smallest number considered necessary to meet the management goals of the program. Similarly, the number of adults spawned should be the smallest number necessary to meet the genetic management goals for the broodstock and the production goals for the program. In addition, the number and composition (hatchery- or natural-origin) of adults used for broodstock must meet genetic guidelines and constraints consistent with maintaining a viable population, either as a genetically integrated or segregated broodstock.

Hatchery programs that are sized incorrectly can present ecological, economic, or genetic risks. For example, fish from large hatchery releases may interact through competition and predation with natural stocks, and via other ecological processes, in a way that substantially reduces the survival and productivity of natural population in freshwater. "Extra" fish may also impact the survival of other populations once they enter the ocean, particularly during periods of low marine productivity. The potential economic benefits of hatcheries will be reduced or minimal if returning adults cannot be harvested and/or large numbers of unharvested fish overwhelm hatchery personnel. Determining the optimum size of a particular hatchery program in a particular watershed can be a scientific challenge unto itself, but it should be considered an integral component of hatchery management.

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[2] Detailed descriptions of the theory behind—and guidelines for properly implementing—integrated and segregated hatchery programs are contained in technical discussion papers on this topic produced as part of the Puget Sound and Coastal Washington Hatchery Reform Project (see reference list).

Consider the Dynamic Nature of Freshwater and Marine Carrying Capacities in Sizing Hatchery Programs

Interannual variations in freshwater and marine trophic conditions, including carrying capacity, may limit the ability of a program to contribute to a resource goal.[3] Overall, the managers should maintain a repertoire of release strategies that can be adjusted in response to changing environmental or trophic conditions. There must be a defensible rationale for any given level of hatchery production, leading to sustainability and cost effectiveness. In short, hatchery programs should be considered dynamic.

Factors that should be considered in sizing a hatchery program may include (but not be limited to) the following:

1. potential for ecological interactions with natural populations;
2. physical capacity of the individual hatchery;
3. carrying capacity of receiving waters in terms of both juveniles and adults (see recommendations above);
4. cycles in ocean productivity; and
5. ability to control the contribution of hatchery-origin fish to the natural spawning escapement.

Ensure Productive Habitat for Hatchery Programs

Productive habitat, in which a salmon population conducts the various phases of its life cycle, is necessary to the success of any hatchery program. The fitness of the naturally-spawning population, its productivity, and the number of adult salmon (artificially or naturally produced) returning to the watershed ultimately depend on the natural habitat to support those fish following release, not on the output of the hatchery. Silt free incubation gravels and cool, stable incubating water are necessary for the survival of salmon embryos. Flowing streams with complex structure, riparian vegetation, seasonal flow stability, and productive estuaries are necessary to the survival of juvenile salmon. Flowing streams are also necessary for the successful passage and spawning of returning adults.

Habitat is particularly essential to the success of integrated hatchery programs, because the hatchery broodstock is directly supported genetically by the naturally spawning component.[4] Integrated hatchery programs will be limited in scope by the productivity of the natural habitat and the number of natural origin adults returning to a watershed. Natural populations are expected to increase in fitness, productivity, and viability as habitats improve.

Emphasize Quality, Not Quantity, in Fish Releases

Hatcheries, as an indicator of success, should strive for fish quality as measured by adult returns and fitness, not quantity as measured by the number of fish released or reared. The lowest number of fish (consistent with goals for the resource) with the highest quality should be

[3] See HSRG 2004, Emerging Issues chapter, section on marine carrying capacity.
[4] See sub-principle on integrated and segregated broodstock management

released to maximize potential benefits while minimizing risks to naturally spawning populations. Conservation programs may further try to match a "wild salmon template" in terms of the physiological, morphological and behavioral traits that affect smolt-to-adult survival and performance. Measures of quality can include affects on physiological, morphological and behavioral fitness, including competency of juvenile fish to migrate, adapt behaviorally and feed in natural environments, and ultimately survive to adulthood.[5] These fitness characteristics clearly have both genetic and environmental components (nature vs. nurture).

It is important that some measure of the quality, rather than simply the quantity, of fish released from hatcheries be measured and evaluated. In the past, performance has been measured by numbers of juvenile released. As discussed in the recommendation to "Size Hatchery Programs Consistent with Stock Goals," releasing too many fish may have ecological risks and economic costs. In the future, performance should be measured by the level of post-release survival, the rate of adult returns, and the extent to which short-term and long-term goals are achieved, all of which depend on the quality of fish released.

Use In-Basin Rearing and Locally-Adapted Broodstocks

Some hatchery programs, for lack of adequate facilities and/or proper escapement management, transfer eggs and/or juveniles between facilities and among watersheds/regions. This "backfilling" of broodstock shortages should be terminated because it specifically counteracts genetic adaptation to local watersheds and hydrology, thus circumventing the biological and evolutionary benefits of natural homing. These biological attributes are common to both hatchery and natural origin fish, and the same management principles should be applied to both groups. Managers should use in-basin rearing and locally adapted broodstocks[6] to increase the productivity of hatchery programs and minimize risks. Failure to follow these simple guidelines promotes loss of local genetic adaptability, increased potential for disease transfer, and lowered productivity of hatchery stocks.

Spawn Adults Randomly throughout the Natural Period of Adult Return

To assure long-term sustainability, managers should adopt and implement policies that conserve or recover natural history and life history traits of the various hatchery stocks that are temporally and spatially adapted to the watersheds where adults are trapped for broodstock and juvenile fish are released. For example, the shift in spawn timing that often results from selective breeding for early adult return is expected to reduce the mean fitness of the stock. On the other hand, some segregated hatchery programs may be able to justify such selective breeding to intentionally shift run timing, and/or other characteristics, to achieve temporal separation of hatchery and natural-origin fish. In such exceptions, the relative benefits and risks of selective breeding need to be carefully evaluated, particularly if hatchery-origin fish are capable of spawning naturally and reproducing successfully.

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[5] See HSRG 2004, Emerging Issues paper on Hatchery Smolt Quality and Achieving the Wild Salmon Template.
[6] For integrated programs, this means adaptation to the natural environment; for segregated programs, it means adaptation to the hatchery environment. In both cases, "backfilling" can reduce the level of adaptation.

Use Genetically-Benign Spawning Protocols that Maximize Effective Population Size

The selection, mating and artificial spawning of fish in a hatchery should be designed to achieve two principal objectives: 1) maximizing the genetic effective number of breeders; and 2) ensuring that every selected adult has an equal opportunity to produce progeny (i.e., to avoid selective breeding and artificial selection in the hatchery environment). This is particularly critical in conservation programs or hatchery stocks intended to represent a genetic repository for future recovery actions where natural populations are small or have experienced significant declines.

To achieve these objectives, male and female hatchery fish can be mated following pairwise (one male to one female), nested (e.g., one male to three females), or factorial (e.g., three-by-three spawning matrix) designs. Mixed milt spawning (where eggs are fertilized by the simultaneous or sequential addition of sperm) should be avoided because of unequal genetic contributions among male spawners and consequential reductions in effective population size. Single family and modified factorial mating[7] are feasible and effective (up to 94% fertilization), even in very large programs.

Hatchery spawning protocols should typically incorporate gametes from all age classes, including jacks (males that return one year earlier, and at a substantially reduced size, relative to the youngest-returning females), to maintain genetic continuity or gene flow among brood years within populations. A past approach was to use jacks for two percent of the adult male spawning population. This rate is probably lower than what occurs among natural spawning populations, based on the best available scientific information. Therefore, jacks should be spawned according to their occurrence among returning adults, up to a maximum of 10%, with the exception of coho salmon where a *minimum* of 10% jacks among male spawners should be used. The inclusion of jacks to maintain genetic continuity among brood years of coho salmon is especially important because they mature primarily at three years of age.[8]

Reduce Risks Associated with Outplanting and Net Pen Releases

Releasing smolts in streams geographically removed from a hatchery or adult collection facility is commonly called outplanting. This practice may pose significant genetic and ecological risks by promoting stray rates, often exceeding natural levels, to freshwater areas where interbreeding and ecological competition with naturally spawning populations are undesirable. Steelhead programs have often used outplanting to support sport fisheries in a large number of small streams. Similarly, floating net pens are often used to acclimate and release salmon smolts in estuarine areas where a targeted fishery on returning adults is desired. A common feature of these programs is that they release fish where no facilities exist to trap returning adults that escape target fisheries. Outplanting and net-pen releases from segregated hatchery programs[9] are especially problematic because of the potentially high level of genetic divergence between the hatchery stock and natural populations, including the potential for “ecological swamping” by hatchery fish, where straying and natural spawning may occur.

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[7] See Currens, etal 1998.
[8] See Van Doornik, etal 2002.
[9] See sub-principle above on operating integrated and segregated hatchery programs.

Managers should reduce risks associated with outplanting and net-pen releases by reducing the number and/or size of such programs. Risks can also be reduced by:

1) intense, selective harvest and/or the use of adult traps;
2) reducing the geographic range of outplanting;
3) restricting release to areas where adult collection facilities are available or can be easily developed;
4) using locally-adapted and genetically integrated broodstocks[10] where natural spawning is difficult to control so that strays have less of a deleterious effect on natural populations;
5) evaluating the benefits and risks of each program every two or three years, and reducing or terminating programs that impose significant risks relative to benefits;
6) monitoring and evaluating high risk programs to ensure that adverse effects to naturally-spawning populations are minimal, straying risks are appropriately managed, and off-station releases are appropriately located; and
7) developing basin-wide, risk management guidelines and protocols for outplanting and net-pen programs to account for cumulative risks over large geographic regions.[11]

Use Hatchery Salmon Carcasses for Nutrification of Freshwater Ecosystems, while Reducing Associated Fish Health Risks[12]

Returning adult salmon are a unique vector for the delivery of marine nutrients into the freshwater ecosystem. The importance of these nutrients to all trophic levels, including terrestrial mammals and birds, has been recognized for some time. Recent research also suggests that a significant portion of nitrogen in plants and animals in streams where adult salmon are abundant is derived from those returning adults. Marine-derived nutrients from returning adult salmon have been found to make a significant contribution to riparian vegetation and even old-growth forests. In streams in interior British Columbia, up to 60% of the nitrogen in benthic insects was derived from the carcasses in streams where salmon were abundant. Those studies also indicated that juvenile salmon show higher growth rates in streams where adult salmon spawn than in streams without spawning adults. Use of hatchery salmon carcasses as a source of these marine-derived nutrients was found to increase the density of age 0+ coho and age 0+ and 1+ steelhead in small, southwestern Washington streams.

The deliberate distribution of hatchery salmon carcasses into watersheds for purposes of nutrification can have a positive ecological benefit to natural salmonid stocks. This practice may, however, also pose a fish health risk to these stocks if those carcasses carry live pathogens and are not properly treated or managed prior to distribution. It is well recognized that disease organisms present in salmon carcasses can be transmitted to other salmonids following the release of these organisms into water or through their direct consumption, unless appropriate

[10] Ibid.
[11] See HSRG 2004, Emerging Issues paper on out-planting and net pens.
[12] See HSRG 2004, Emerging Issue paper nutrification and fish health risks for more detail, including references.

disease risk-aversive measures such as pathogen-free certification are followed. Another concern that must be taken into account is the potential to transfer contaminants such PCBs and heavy metals. Hence, carcasses should be certified pathogen and contaminant-free (i.e. within acceptable, established guidelines) when used for nutrient enhancement of salmon streams.

Principle 3: Informed Decision Making

Assuming that goals for the resource have been established (see Principle 1), and the scientific rationale and defensibility for a particular hatchery program have been developed into a comprehensive *management and operational plan,* decisions about hatcheries then need to be informed and modified by continuous evaluations of existing programs and by new scientific information. Such an approach may require a substantial increase in scientific oversight of hatchery operations, particularly in the areas of genetic and ecological monitoring.

When decision-making processes that can respond to new information are in place, hatcheries can be managed in a flexible and dynamic manner in response to changing environmental conditions, new scientific information, changing economic values, and other factors that can determine the most efficient use of limited resources. This model applied to hatcheries requires that performance standards and indicators be identified, so that monitoring activities focus on key uncertainties and effective evaluation of results can occur. Results of this monitoring and evaluation (M&E) must then be brought forward to a 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 be responsive to new goals and concepts in culture practice.

The following **sub-principles** are designed to help ensure the principle of informed decision making for hatchery programs is achieved.

Adaptively Manage Hatchery Programs

Adaptive management is particularly important in the context of hatchery operations. Adaptive management, as related to ecosystems, is defined as an “adaptive policy that is designed from the outset to test clearly formulated hypotheses about the behavior of the ecosystem being affected by human use.”[13] There is a significant amount of scientific uncertainty about the effects and proper uses of hatcheries, and a great need for flexibility and adaptation to changing goals, new scientific knowledge, and new information about the condition of stocks and habitat. A structured adaptive management program is a key component of a strategy for success in these circumstances.

A critical implication is the notion of responsive change—rather than the status quo—as the normal operating procedure. Put simply, adaptive management is learning by doing, assuming programs and operations will change regularly to reflect new information and better meet goals, and taking action in the face of scientific uncertainty. However, the actions taken through

[13] See Lee 1993.

adaptive management are not selected at random. Rather, action is prescribed through the thoughtful and disciplined application of the scientific method.

The scientific method and adaptive management require a scientific framework for organizing and understanding information and identifying uncertainties. The HSRG has developed such a framework for the context of anadromous salmonid hatcheries[14]. Equally important is a structured process that assures the right information is collected, analyzed, reported and brought forward in the decision making processes at all levels of hatchery operation. Such a system is currently under development under the title "Managing for Success and Accountability."[15]

Incorporate Flexibility into Hatchery Design and Operation

Hatchery facilities should be designed and operated in such a way that they are able to respond relatively easily to changes in harvest and conservation goals and priorities, ocean conditions, stock status, freshwater habitat conditions, and the myriad other factors that will alter current policies and programs. The goal of a hatchery or regional manager should *not* be to fill the hatchery facility to its biological capacity, but rather, to manage the facility to achieve programmatic goals.

Programs must also be able to respond to uncertainty and risk. For example, an empty raceway for six months out of a year may be the most efficient use of a facility and may be necessary to provide flexibility, both at the present time and in the future. The keys to flexibility are having sufficient supplies of land, water quality and quantity, and physical facilities, along with a planning mindset that takes the concepts of flexibility, managing change, and future needs into account.

Evaluate Hatchery Programs Regularly to Ensure Accountability for Success

Achieving successful hatchery programs (where benefits and risks are managed effectively) requires ongoing monitoring and evaluation (M&E), with some level of commonality and standardization across a basin. Monitoring should include not only expanded efforts to distinguish hatchery- and natural-origin fish on natural spawning grounds and in broodstocks, but it should also determine the fate of migrants in fresh and saltwater environments following release. An integrated, region-wide hatchery M&E system needs to be developed that includes the systematic and annual evaluation of the ecological co-mingling of hatchery and naturally-spawning fish.

Lastly, a modern centralized M&E database system, where information can be evaluated annually for adherence to regional and system-wide goals, needs to be institutionalized within and between regions to adaptively manage the entire hatchery system and its components. Individual hatcheries need to be equipped with computers and Internet access that allow them to use and share data from a record collection system.

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[14] See HSRG 2004, Scientific Framework for the Artificial Propagation of Salmon and Steelhead.
[15] Available in prototype at www.mobrand.com/mfs.

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