

**HSRG/WDFW/NWIFC Technical Discussion Paper #1:
Integrated Hatchery Programs
June 21, 2004**

Genetic and ecological interactions have been at the center of the debate over benefits and risks of hatchery programs (e.g., NRC 1993; HSRG 2004; Williams et al. 2003). The two options for managing these risks are either to minimize interaction through segregation (isolation) of the hatchery population from the natural population or to manage the hatchery population as an integral, benign component of a composite hatchery-natural population. All salmon and steelhead hatchery programs must be classified either as integrated or segregated by intent. These classifications lead directly to a series of genetic and ecological management guidelines for each of the two types of programs. How well programs meet this intent will vary; this variation provides an important measure for evaluating the biological risks posed by hatchery programs on natural populations.

The purpose of this summary is to provide a definition of an integrated hatchery program, describe operational guidelines for implementation, and identify some of the implications and constraints imposed by the guidelines.

Definition of an Integrated Hatchery Program

The terms integrated and segregated describe the intended reproductive relationship of hatchery populations to naturally spawning populations. An integrated hatchery program is associated with a specified natural population from which gene flow occurs. The goal of an integrated program is to demographically increase the abundance of fish representing a natural population (two environments, one gene pool).

*Formal Definition: A hatchery program is an **Integrated Type** if the intent is for the natural environment to drive the adaptation and fitness of a composite population of fish that spawns both in a hatchery and in the wild.*

Theoretical Premise for Integrated Programs

For a natural/hatchery composite population at equilibrium (Ford 2002), the influence of the hatchery and natural environments on the adaptation of the composite population is determined by the proportion of natural-origin broodstock in the hatchery (pNOB¹) and the proportion of hatchery-origin fish in the natural spawning escapement (pHOS). The larger the ratio $pNOB/(pHOS+pNOB)$, the greater the strength of selection in the natural environment relative to that of the hatchery environment (Figure 1). In order for the natural environment to dominate selection, this ratio must exceed 0.5 (Campton, Busack and Currens, personal communication). Furthermore, the greater the difference between the hatchery and natural stock components (e.g., in run timing) and the "less natural" the hatchery environment (e.g., longer hatchery rearing), the larger the ratio must be to reduce the effects of hatchery selection.

¹ Terminology: NOR = Natural Origin Return, HOR = Hatchery Origin Return, NOB = Natural Origin fish included in hatchery Broodstock, and HOS = Hatchery Origin fish in the natural Spawning escapement.

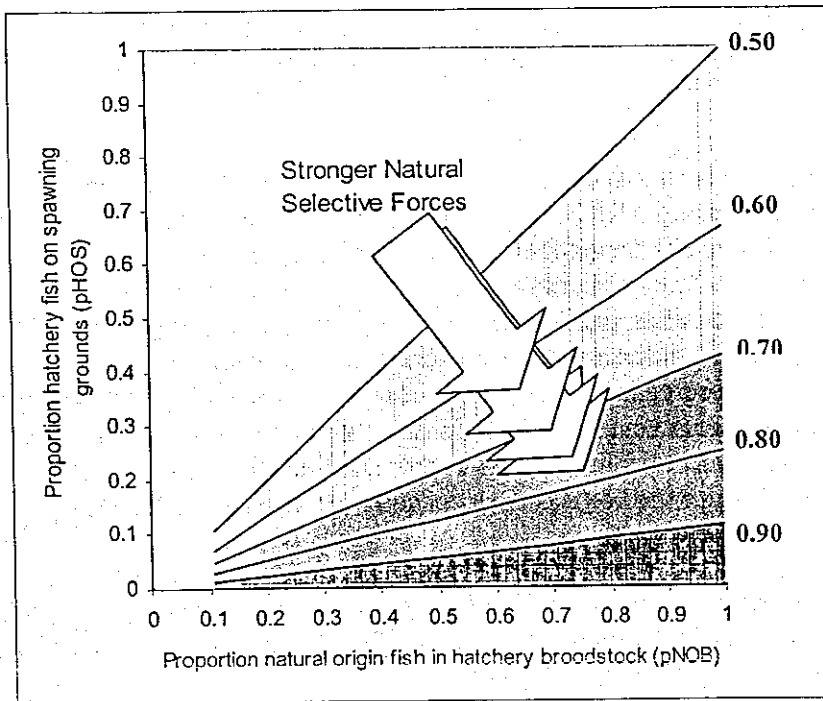


Figure 1. Proportionate effects of natural selective forces in integrated hatchery programs at equilibrium; values to the right indicate the ratio $pNOB/(pHOS+pNOB)$; pNOB must be >0.1 to account for genetic drift.

Operational Guidelines for Integrated Programs

1. The targeted value of $pNOB/(pHOS+pNOB)$ should be based upon the current status of the stock, the goals for the stock, and involves a benefit versus risk judgment. For any fixed pNOB, the smaller the pHOS, the stronger the selective forces for the natural environment (see Figure 1).
2. The proportion of natural-origin fish in the broodstock must exceed the proportion of hatchery-origin fish on the spawning grounds ($pNOB > pHOS$) for the natural environment to drive adaptation, which is equivalent to $pNOB/(pHOS+pNOB) > 0.50$.
3. $pNOB/(pHOS+pNOB)$ for integrated programs with stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock) should be greater than 0.7 (see Figure 1) to ensure high levels of natural dominance.
4. pNOB should be a minimum of 10% to avoid divergence of the hatchery population from the natural component, even when pHOS is zero.
5. A general rule of thumb is that the total number of adults (hatchery- and natural-origin) used for broodstock cannot exceed the total number of natural-origin escapement.

6. Hatchery fish should be reared under conditions that deviate as little as possible from those experienced by the natural population component, to minimize the effects of selective forces in the hatchery:
 - a) Rear in a hatchery environment that allows synchronization of adult maturation, incubation and emergence, and out-migration with natural populations.
 - b) Use rearing protocols that produce juvenile fish similar to natural populations in growth rate and size, to reduce competition with and predation on natural stocks, and to maintain the age structure of the natural population.
 - c) Rear fish at reduced densities in enriched environments, to produce a fish with cryptic coloration, territorial fidelity and behavior similar to naturally-produced fish.
 - d) Release fish volitionally during the out-migration timing of the natural stock.
7. The size of the program should take into account the quantity and quality of habitat available for juveniles and adult spawners, and the effect of the hatchery program on natural stocks.
8. Use marks, tags or other methods to distinguish natural- and hatchery-origin fish among natural spawners, in hatchery broodstocks and in harvests.
9. Take into consideration the potential selective impacts of harvest (for example, size selectivity) on the long-term viability of integrated programs.

Implications/Constraints of Broodstock Management Guidelines for Integrated Hatchery Programs

Broodstock management guidelines for an integrated hatchery program impose limitations on the size of that program. These limitations depend on the ability to control the mix of hatchery- and natural-origin fish both on the spawning grounds and in the hatchery. They also depend on factors affecting the number of natural spawners available for hatchery broodstock (i.e., the productivity of the natural environment and the harvest rate on natural fish). Identification of the options available to implement integrated programs (i.e., changing the ratio of pNOB to pHOS, and/or the size of the hatchery program) requires case-by-case analyses.

Implementing an Integrated Hatchery Program

Currently, few hatchery programs are meeting the broodstock guidelines recently developed for programs where integration is a goal. Assuming that it has been determined that an integrated program is appropriate to meet resource goals, how should the transition occur? The answer depends in large part on the genetic make-up of the current hatchery and natural

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 harvest and/or conservation (e.g., RASP, 1991). The key question for supplementation programs is whether the hatchery fish spawning in the wild indeed confer a net benefit. The HSRG has concluded that this may be possible in some circumstances and that such programs should always be accompanied by comprehensive monitoring and evaluation efforts. Supplementation programs may be either integrated or segregated.

population components. It also depends on a tolerance to risk that varies depending on the viability of, and goals for, the natural population. For example, in a recovery program, it may be necessary to rely on hatchery propagation to secure genetic resources, until the habitat is capable of supporting a fully integrated program. Initially, this type of program may have to be developed from one where the composite population is highly influenced by the hatchery environment, but where a detailed management plan has been developed to eventually have the natural environment dominate. Similarly, integrated harvest programs with goals to maintain or improve the biological significance of the stock should be operated to ensure that selective forces in the natural environment dominate.

The tables below are intended to provide guidance in developing an action plan to implement an integrated program based on the initial condition (Scenarios 1-3). There may be circumstances where one or more elements of these approaches are not applicable.

Scenario 1: New Integrated Program No hatchery program exists Natural population has had little influence from hatchery fish	
Recommended approach for initiating a new integrated program	Considerations
<ul style="list-style-type: none"> • Initiate hatchery program by collecting representative sample of natural fish. • Collect a number of brood that allows for an effective population size of the composite population (natural plus hatchery) in excess of 500 fish. • If a long-term goal of the hatchery program is to provide a conservation benefit, or if the natural spawning of hatchery-origin fish will be difficult to control, then the effective population size of the hatchery component should also be greater than 500 fish. • Incorporate a minimum of 10% NORs into hatchery broodstock each year. • Ensure that gene flow from the natural to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • For stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock), $p_{NOB}/(p_{HOS}+p_{NOB})$ should be greater than 0.7. • Size program consistent with goals, the ability of the natural population to support hatchery broodstock requirements, and gene flow limitations to the natural population. 	<p>Likelihood of achieving natural adaptation: High likelihood of attaining stock goals (developing a program where the natural environment drives the adaptation of the composite hatchery and natural population), as long as broodstock collection is feasible and gene flow is maintained within recommended guidelines for the goals of the stock.</p> <p>Cost: Additional program cost compared to segregated programs, primarily for natural broodstock collection.</p> <p>Effect on Harvest: Changes in harvest contribution are dependent on productivity of the natural component of the population, as well as productivity of the hatchery component.</p>

Scenario 2: Transition from a segregated program to an integrated program Hatchery broodstock has had no systematic gene flow from the natural population Natural spawning population has had little influence from hatchery fish	
<p>Approach #1 - Not recommended because of low likelihood of attaining stock goals</p> <ul style="list-style-type: none"> • Incorporate a minimum of 10% NORs into hatchery broodstock each year. • Ensure that gene flow from the natural to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • Size program consistent with goals, the ability of the natural population to support hatchery broodstock requirements, and gene flow limitations to the natural population. 	<p>Considerations</p> <p>Likelihood of achieving natural adaptation: Low likelihood of attaining stock goals in the immediate future. Likelihood increases as additional NORs are incorporated into the hatchery population through time, or as the proportion of NORs in the hatchery broodstock is increased. Composite population is likely to have low to intermediate fitness in the natural environment.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches.</p> <p>Effect on Harvest: Effect on harvest appears similar under all approaches other than Approach #2 in this and the next scenario, where the segregated harvest program is terminated or suspended to allow some level of adaptation of the hatchery stock.</p>
<p>Approach #2 - Recommended approach if attaining harvest goal can be interrupted during transition to integrated program</p> <ul style="list-style-type: none"> • Initiate a new hatchery program by collecting a representative sample of natural fish. • Collect a number of brood that allows for an effective population size of the composite population (natural plus hatchery) in excess of 500 fish. • If a long-term goal of the hatchery program is to provide a conservation benefit, or if the natural spawning of hatchery-origin fish will be difficult to control, then the effective population size of the hatchery component should also be greater than 500 fish. • Incorporate a minimum of 10% NORs into hatchery broodstock each year. • Ensure that gene flow from the natural population to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • For stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock), $p_{NOB}/(p_{HOS}+p_{NOB})$ should be greater than 0.70. • Size program consistent with goals and the ability of the natural population to support hatchery broodstock requirements and gene flow limitations to the natural population. • Terminate segregated harvest program. 	<p>Considerations</p> <p>Likelihood of achieving natural adaptation: High likelihood of attaining stock goals as long as broodstock collection is feasible and gene flow is maintained within recommended guidelines.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches.</p> <p>Effect on Harvest: A loss of contribution to harvest would be expected between termination of the segregated program and achieving the final size of the new integrated program.</p>

Scenario 2 (continued): Transition from a segregated program to an integrated program Hatchery broodstock has had no systematic gene flow from the natural population Natural spawning population has had little influence from hatchery fish	
Approach #3 - Recommended approach if attaining harvest goal cannot be interrupted during transition to integrated program	Considerations
<ul style="list-style-type: none"> • Initiate new hatchery program by collecting representative sample of natural fish. • Collect a number of brood that allows for an effective population size of the composite population (natural plus hatchery) to be in excess of 500 fish. • If a long-term goal of the hatchery program is to provide a conservation benefit, or if the natural spawning of hatchery-origin fish will be difficult to control, then the effective population size of the hatchery component should also be greater than 500 fish. • Differentially mark and release offspring of old/new broodstock. Preferentially use returns that represent the NOS broodstock. Phase out use of old broodstock as new broodstock returns. • Incorporate a minimum of 10% NORs into hatchery broodstock each year once new broodstock returns. • Ensure that gene flow from the natural population to the hatchery population is greater than gene flow from the hatchery to the natural population ($pNOB > pHOS$). • For stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock) $pNOB / (pHOS + pNOB)$ should be greater than 0.70. • Size program consistent with goals and the ability of the natural population to support hatchery broodstock requirements and gene flow limitations to the natural population. 	<p>Likelihood of achieving natural adaptation: High likelihood of attaining stock goals, as long as broodstock collection is feasible and gene flow is maintained within recommended guidelines.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches. An additional cost for differentially marking the two hatchery broodstocks would be incurred. Cost in terms of operational complexity is higher than all other approaches except the final approach, but should be no greater than rearing an additional species.</p> <p>Effect on Harvest: The loss of contribution to harvest in Scenario 2, Approach #2, above, could be avoided during transition with additional marking cost.</p>

<p>Scenario 3: Transition from an incompletely segregated program to an integrated program. (Most common scenario). Hatchery broodstock has had no systematic gene flow from the natural population Natural spawning population has had significant influence from hatchery fish</p>	
<p>Approach #1 - Not recommended because of low likelihood of attaining stock goals</p>	<p>Considerations</p>
<ul style="list-style-type: none"> • Incorporate a minimum of 10% NORs into hatchery broodstock each year. • Ensure that gene flow from the natural population to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • Size program consistent with goals and the ability of the natural population to support hatchery broodstock requirements and gene flow limitations to the natural population • Restrict natural spawning by HORs. 	<p>Likelihood of achieving natural adaptation: Lowest likelihood of all options in attaining stock goals in the immediate future since NORs incorporated into hatchery broodstock may themselves have suffered loss of productivity as a result of past hatchery influence. Likelihood of reaching stock goals increases as additional NORs are incorporated into the hatchery population through time or as proportion of NORs in hatchery broodstock is increased. Composite population is likely to have the lowest fitness in the natural environment of all the approaches.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches.</p> <p>Effect on Harvest: Effect on harvest appears similar under all approaches other than Approach #2 in Scenarios 2 and 3.</p>
<p>Approach #2 - Recommended approach if attaining harvest goal can be interrupted during transition to integrated program.</p>	<p>Considerations:</p>
<ul style="list-style-type: none"> • Take steps to reduce the number of hatchery fish in the natural population to less than five percent of the natural population. (Reduce hatchery program, selective harvest to limit strays, weir, other measures to control straying) • Allow a minimum of three to four generations to promote adaptation to the natural environment. • Initiate a new hatchery program by collecting representative sample of natural fish. • Collect a number of brood that allows for an effective population size of the composite population (natural plus hatchery) to be in excess of 500 fish. • If a long-term goal of the hatchery program is to provide a conservation benefit, or if the natural spawning of hatchery-origin fish will be difficult to control, then the effective population size of the hatchery component should also be greater than 500 fish. • Incorporate a minimum of 10% NORs into hatchery broodstock each year. • Ensure that gene flow from the natural population to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • For stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock) $p_{NOB}/(p_{HOS}+p_{NOB})$ should be greater than 0.70. • Size program consistent with goals and the ability of the natural population to support hatchery broodstock requirements and gene flow limitations to the natural population. • Terminate segregated harvest program. 	<p>Likelihood of achieving natural adaptation: Intermediate likelihood of attaining stock goals because of the uncertainty of adaptation to the natural environment after three to four generations. The likelihood of meeting stock goals increases with the amount of time allowed before initiating new program and lower contribution of hatchery fish in the natural population.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches.</p> <p>Effect on Harvest: Highest likelihood of loss of contribution to harvest of all the approaches since the segregated program would likely be reduced to allow adaptation of the natural stock and the segregated program would be terminated to initiate a new integrated program.</p>

<p>Scenario 3 (continued): Transition from an incompletely segregated program to an integrated program. (Most common scenario). Hatchery broodstock has had no systematic gene flow from the natural population Natural spawning population has had significant influence from hatchery fish</p>	
<p>Approach # 2 Plus Differential Marking - Recommended approach if attaining harvest goal cannot be interrupted during transition to integrated program</p>	<p>Considerations</p>
<ul style="list-style-type: none"> • Take steps to reduce the number of hatchery fish in the natural population to less than five percent of the natural population (reduce hatchery program, selectively harvest to limit strays, use a weir or other measures to control straying). • Allow a minimum of three to four generations to promote adaptation to the natural environment. • Initiate a new hatchery program by collecting representative sample of natural fish. • Collect a number of brood that allows for an effective population size of the composite population (natural plus hatchery) in excess of 500 fish. • If a long-term goal of the hatchery program is to provide a conservation benefit, or if the natural spawning of hatchery-origin fish will be difficult to control, then the effective population size of the hatchery component should also be greater than 500 fish. • Differentially mark and release offspring of old/new broodstock. Preferentially use returns that represent the NOS broodstock. Phase out use of old broodstock as new broodstock returns. • Incorporate a minimum of 10% NORs into hatchery broodstock each year once new broodstock returns. • Ensure that gene flow from the natural to the hatchery population is greater than gene flow from the hatchery to the natural population ($p_{NOB} > p_{HOS}$). • For stocks of moderate or high biological significance and viability (or goals to maintain or improve the biological significance and viability of the stock), $p_{NOB}/(p_{HOS}+p_{NOB})$ should be greater than 0.70. • Size program consistent with goals and the ability of the natural population to support hatchery broodstock requirements and gene flow limitations to the natural population. 	<p>Likelihood of achieving natural adaptation: Intermediate likelihood of attaining stock goals because of the uncertainty of adaptation to the natural environment after three to four generations. The likelihood of meeting stock goals increases with the amount of time allowed before initiating a new program and a lower contribution of hatchery fish in the natural population.</p> <p>Cost: Increase in cost incurred for broodstock collection appears similar for all approaches. An additional cost for differentially marking the two hatchery broodstocks would be incurred. Cost in terms of operational complexity is higher than all other approaches except Approach #4, but should be no greater than rearing an additional species.</p> <p>Effect on Harvest: Reduces loss of contribution to harvest during transition from the previous approach.</p>

References:

Ford, M.J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. *Conservation Biology* 16: 815-825.

HSRG (Hatchery Scientific Review Group)—Lars Mobernd (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. April 2004. *Hatchery Reform: Principles and Recommendations of the HSRG. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101 (available from www.hatcheryreform.org).*

Mobernd, Lars. 1991. *Regional Assessment of Supplementation Program (RASP). Project #1985-06200 (BPA Report DOE/BP-01830-11). Bonneville Power Administration, PO Box 3621, Portland, OR 97208.*

National Research Council Committee on Protection and Management of Pacific Northwest Anadromous Salmonids (NRC). 1996. *Upstream: Salmon and Society in the Pacific Northwest, National Academy Press, Washington, DC.*

Williams, R. N., J. A. Lichatowich, P. R. Mundy, and M. Powell. 2003. *Integrating artificial production with salmonid life history, genetic, and ecosystem diversity: a landscape perspective. Issue Paper for Trout Unlimited, West Coast Conservation Office, Portland.*