

Genetic Considerations in Recovery Efforts for Pacific Salmon

The last few years have provided abundant indications that populations of all species of Pacific salmon (*Oncorhynchus* spp.) are in decline. Nehlsen et al. (1991) identified over 200 stocks they considered to be at some risk of extinction and over 100 already believed to be extinct. Major federal stock restoration programs are under way in the Columbia and Klamath River basins, and several populations of Pacific salmon have recently been listed as threatened or endangered under the U.S. Endangered Species Act (ESA).

Although there is widespread agreement that recovery programs are needed for Pacific salmon, there is less agreement over what constitutes recovery. Recovery is commonly perceived as simply increasing overall abundance to a level commensurate with the needs of society. Here, the term recovery will be used to refer to restoration of viable, self-sustaining populations in their natural habitats. If this type of recovery is to be successful in the long run, it is essential to conserve the genetic resources which are the foundation of natural production. Notably, the Northwest Power Planning Council has recently modified its original goal of doubling overall run sizes in the Columbia River basin to the dual goal

of increasing production while allowing no irreversible loss of genetic resources.

How then to best conserve genetic resources during salmon recovery efforts? Although considerable advances have been made in the conservation genetics of salmonids during the last two decades, there is still much to be learned. For example, the genetic basis for most phenotypic and life history variation—including traits that are likely to be among the most important in determining fitness—is complex and poorly understood, and there is little prospect for major advances in our understanding in the near future.

Fortunately, it is not necessary to achieve a complete understanding of genetics to make substantial progress toward restoration of salmon populations. Recovery can be accomplished most effectively through comprehensive and timely measures to address the factors that may be impeding natural recovery, such as habitat destruction, blockage of migratory routes, overharvesting, and artificial propagation. If these factors are addressed properly, most stocks should recover naturally, and the major genetic issues will largely take care of themselves. Furthermore, if the root causes of decline of salmon

populations are not addressed, even the best-informed genetic principles cannot ensure long term viable populations.

The factors responsible for the decline are deeply ingrained in our culture. Substantial progress toward saving salmon may require rethinking society's priorities. For example, population growth and urbanization invariably entail some degradation of riparian habitat, and hydroelectric dams that block or impede salmon migration play major roles in power production, irrigation, and flood control that affect the lives of virtually everyone in a particular region. At best, therefore, progress will come slowly. While society wrestles with the question of how serious it wants to be about restoring natural ecosystems upon which salmon depend, efforts to conserve genetic resources should focus on three issues: (1) identifying the appropriate units for conservation; (2) minimizing genetic risks to natural populations caused by fishery enhancement programs; and (3) judiciously using intensive management measures for high-risk populations.

Units of Conservation

Failure of salmon management plans to adequately account for stock structure can lead to losses of diversity. Recent ESA listings of Snake River sockeye salmon, Snake River fall chinook salmon, and Sacramento River winter chinook salmon as threatened or endangered species can all be attributed, at least in part, to a common oversight: management attention directed at more abundant nearby stocks. Identifying the appropriate units for conservation is a challenging effort that requires integrated analysis of diverse types of genetic, phenotypic, life history, and environmental information.

One approach, adopted by the National Marine Fisheries Service (NMFS) in its policy for considering Pacific salmon populations under the ESA (56FR 58612; Nov. 20, 1991; see also Waples 1991), is to focus on units that are reproductively isolated and that contribute substantially to the ecological and genetic diversity of the biological species. Emphasis is thus on conservation of genetic resources which allows the dynamic process of evolution to continue largely unconstrained by human factors. The ESA, however, is a last resort. It is not a general tool for managing salmon populations. Proper management requires a broader-based effort, and these efforts might focus on conservation units defined somewhat differently than they are under the ESA. However, if additional ESA listings are to be avoided, it is essential that managers focus on a scale at least as fine as that mandated under the ESA.

Fishery Enhancement Programs

For many decades salmon hatcheries have been seen as a means of enhancing fisheries to mitigate declines in

natural populations. Unfortunately, this view has also provided a convenient rationale for ignoring the causes of decline. Although fisheries enhancement may in some cases be compatible with sustained natural production, large-scale, artificial propagation programs pose a number of genetic risks for natural populations. These include direct effects (which result from hybridization due to straying or stock transfers), indirect effects (which result from factors such as competition, predation, altered selective regimes, and mixed-stock fisheries), and genetic changes in hatcheries (which magnify the consequences of direct and indirect genetic effects). Current enhancement programs for Pacific salmon need to be re-evaluated for compatibility with long-term conservation of genetic diversity.

One of the more difficult questions regarding the use of artificial propagation is the relative importance of inbreeding depression and outbreeding depression. These phenomena can be viewed as extremes on a continuum of breeding systems (Fig. 1). On one hand, high homing fidelity (and perhaps reduced population size) might generally lead to inbreeding depression in salmon populations, and this might be alleviated by judicious use of stock transfers. Alternatively, natural straying may be sufficient to alleviate most problems associated with inbreeding, in which case increased levels of outcrossing could be expected to disrupt local adaptation. More research is needed in this key area. However, considering that major fitness consequences may result from disruption of even a single link in the complex life history of Pacific salmon, any factors that increase the possibilities for outbreeding depression should be scrutinized closely.

High-Risk Populations

The absence of a body of empirical data demonstrating the ability of artificial propagation to enhance the viability of natural populations argues for recovery by natural means as the preferred alternative. However, there are situations in which the short-term risk of a population's extinction outweighs concern regarding the genetic and ecological consequences of fish culture. Aggressive actions, including the use of captive brood-

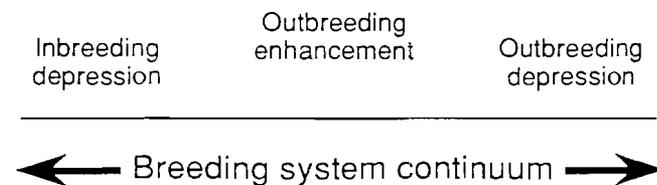


Figure 1. Continuum of breeding systems that, at opposite extremes, can lead to inbreeding depression or outbreeding depression. (Modified from Waples, *in press*).

stocks or other forms of artificial propagation, should be considered for high-risk populations, but only in conjunction with efforts to resolve root causes of decline. The risk of extinction can be evaluated using population vulnerability analysis (PVA) or other related methods. Genetic parameters such as effective population size are important in risk assessment, but it is difficult to formally integrate them into existing PVA models, which typically focus on the effects of demographic and environmental variability.

Literature Cited

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