

**ENRICHED REARING HABITATS MODIFY COMPETITIVE  
BEHAVIOR OF HATCHERY-REARED STEELHEAD**

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**EXTENDED ABSTRACT ONLY – DO NOT CITE**

Conservation hatcheries for Pacific salmonids in the Pacific Northwest aim to produce fish which are behaviorally, physiologically, and morphologically similar to natural fish, in part by providing a more natural rearing environment. Enriched rearing habitat that includes overhead cover, in-water structure, underwater feed delivery and other features added to conventional rearing vessels affects external body coloration and improves the post-release survival of chinook salmon (*Oncorhynchus tshawytscha*) smolts (Maynard et al. 1996). Berejikian et al. (2000 and 2001) conducted studies on steelhead (*O. mykiss*) designed to answer three questions related to interactions of released fish with wild fish in streams. First, do enriched hatchery rearing environments affect the development of aggressive behavior and competitive ability? Second, does territorial behavior (i.e., territory size and overlap) differ between fish reared in enriched, conventional hatchery environments and fish reared in a natural

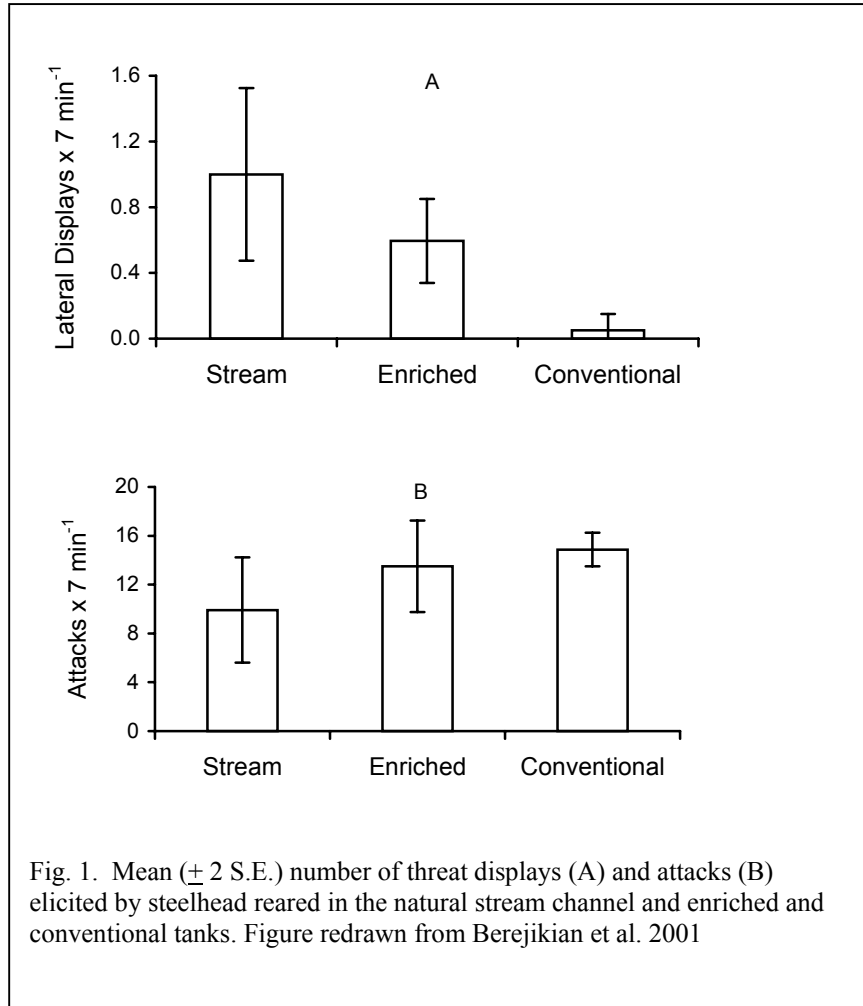
stream? Third, do fish reared in enriched and conventional environments impart different competitive pressures on naturally reared fish?

In those studies, emergent steelhead from a single population were allocated to three treatments: 1) enriched hatchery rearing (EN) and 2) conventional hatchery rearing (CO) tanks, and 3) a section of natural stream (NR). Three EN tanks contained the tops of two commercially grown Douglas fir (*Pseudotsuga menziesii*) trees that were submerged to provide in-water structure. A double layer of brown and green camouflage netting provided shade cover. Underwater feeders delivered food at the mid-water depth at two locations on opposite sides of the tanks. Three CO tanks contained no overhead cover or in-water structure, and the fish were hand-fed by scattering the food across the surface of the water.

When stocked together in simulated stream environments at the NMFS Manchester Research Station, steelhead reared in CO tanks achieved significantly lower dominance ranks than size-matched steelhead reared in EN tanks in 70% of trials ( $P < 0.05$ ), and lower ranks than NR fish in 66% of trials ( $P < 0.05$ ). Relative to NR steelhead, those reared in EN tanks achieved a higher dominance rank in just over half (55%) of trials ( $P = 0.27$ ), indicating similar competitive ability of the two groups.

Frequencies of certain aggressive behaviors also depended on rearing treatment. For example, NR and EN fish exhibited a higher frequency of threat displays than CO fish ( $P < 0.05$ ). Fish reared in the EN environments were intermediate between NR and CO fish in the frequency of attacks, although no significant differences were detected among treatments ( $P = 0.126$ ; Fig. 1). NR steelhead exhibited greater territorial overlap than fish reared in either hatchery environment ( $P = 0.020$ ); steelhead reared in the enriched hatchery environment were again intermediate between NR and CO fish.

Steelhead reared in the enriched tanks grew at a higher rate than conventionally reared fish under conditions of mutual competition in a quasi-natural stream channel ( $P = 0.02$ ). No differences in growth rate were found in the absence of mutual competition ( $P = 0.45$ ), indicating that growth differences in mutual competition were caused by interference competition and supporting results of the dominance experiment. The growth rates of NR fry did not differ depending on the hatchery rearing history of their competitors ( $P = 0.095$ ), nor did the combined biomass of hatchery and NR fry ( $P = 0.420$ ).



Competitive interactions between hatchery-reared and extant wild fish in streams are an important concern in the management of imperiled salmonid populations. The concept of stocking highly competitive fish from enriched hatchery environments, such as those evaluated in this study, could be perceived as potentially detrimental to the more valuable (from a conservation standpoint) wild/natural juveniles. Although steelhead reared in the EN environments were

more competitive than conventionally reared fish, they exhibited social behaviors that were more wild-like. Social interactions in the release environment are less likely to be disruptive to wild fish if the more natural development of social behavior observed in the laboratory for EN fish also occurs in the wild. To further minimize impacts on natural fish, however, hatchery-reared fish should also be: i) derived from locally adapted wild broodstock (Busack and Currens 1995); ii) restocked at densities within the carrying capacity of the target stream, and iii) released within the size range of wild fish to minimize size-related effects on competition (Flagg and Nash 1999). To clarify the risks and benefits of utilizing enriched rearing environments, future studies should evaluate the potential for differential impacts of EN and CO reared fish on growth and survival of wild fish in streams, as well as the their effects on the aggregate hatchery and wild productivity.

## References

- Berejikian, B. A., E. P. Tezak, A. LaRae, T. A. Flagg, and E. Kummerow, and C. V. W. Mahnken. 2000. Social dominance, growth and habitat use of age-0 steelhead (*Oncorhynchus mykiss*) grown in enriched and conventional hatchery rearing environments. *Can. J. Fish. Aquat. Sci.* 57: 628-636.
- Berejikian, B. A., E. P. Tezak, S. C. Riley, and A. L. LaRae. 2001. Social behavior and competitive ability of juvenile steelhead (*Oncorhynchus mykiss*) reared in enriched and conventional hatchery tanks and a stream environment. *J. Fish. Biol.* 59: 1600-1613.
- Busack, C. A., and Currens, K. P. 1995. Genetic risks and hazards in hatchery operations: fundamental concepts and issues. *Am. Fish. Soc. Symp.* 15: 71-80
- Flagg, T.A., and C.E Nash, (editors). 1999. A Conceptual Framework for Conservation Strategies for Pacific Salmonids. Dep. Commer., NOAA Tech. Memo. NMFS-NWFSC-38.
- Maynard, D. J., Flagg, T. A., Mahnken, C. V. W., and Schroder, S. L. 1996. Natural rearing technologies for increasing postrelease survival of hatchery-reared salmon. *Bull. Natl. Res. Inst. Aquacult., Suppl.* 2: 71-77.

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