AN ILLUSTRATION OF DOMESTICATION SELECTION IN A HATCHERY PROGRAM FOR STEELHEAD

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Introduction

Clear understanding of both the benefits and hazards is necessary for effective management of artificial production programs. Several studies with sea-ranched anadromous salmonids (released to grow in the natural environment after a period of artificial rearing) show genetic differences in behavior, growth, physiology, and survival between hatchery and wild fish (reviewed by Rubin and Reisenbichler 1999). Data further indicate that such genetic change (domestication) is accompanied by loss of fitness for natural rearing (Reisenbichler and McIntyre 1977; Leider et al. 1990; USGS, unpublished data). Domestication in a hatchery population can be problematic when hatchery fish interbreed with wild fish either accidentally or as the intended result of Asupplementation@ programs (Waples 1999). These data and theoretical arguments are sometimes rejected, however, because the substantial selective mortality necessary to effect significant domestication has not been apparent. Mortality typically is low in hatcheries and the animals spend most (typically > 2/3) of their lives in the natural environment.

The purpose of this study was to elucidate domestication in steelhead (*Oncorhynchus mykiss*).

Methods

We tested for genetic differences in survival, growth, and downstream migration between hatchery and wild steelhead in the Clearwater River, Idaho. The progeny from hatchery and wild fish were reared together in the hatchery so that any observed differences resulted from genetic differences (or maternal effects) rather than environmental differences. We included hybrid crosses of hatchery females and wild males to account for maternal effects. Four hundred fish from each set were measured, weighed, and injected with a uniquely coded PIT tag (Prentice et al. 1990) one month before release. Detections of PIT-tagged fish at four downstream dams on the Snake and Columbia Rivers were used to compare the size at release and the cross of fish surviving and successfully migrating downstream.

Results

Survival in the hatchery was similarly high for the three crosses ($P > 0.25$; Table 1). HxH fish, however, grew better and were 30% larger at release than WxW fish ($P < 0.001$) and 10% larger than HxW fish ($P < 0.001$; Figure 1). Detection rate for HxH fish was at least 7x that for WxW fish ($P < 0.001$) and 40% greater than for HxW fish ($P < 0.001$; Table 1). Median times to detection differed marginally ($0.05 < P < 0.10$): 13 d for HxH ($n = 146$), 18 d for HxW ($n = 95$), and 22 d for WxW ($n = 16$).

Differences in length explained much of the variation in detection rate. Few steelhead <180 mm FL were detected, and larger proportions of the HxW and WxW groups were below this threshold (Figure 1). Differences in size among crosses, however, did not explain all of the discrepancies in detection rate. When compared within size classes, detection rates for HxH fish remained approximately 2x those for WxW fish ($P < 0.001$), and marginally higher than for HxW ($0.05 < P < 0.10$). Equal size did not result in equal performance among the crosses after release.

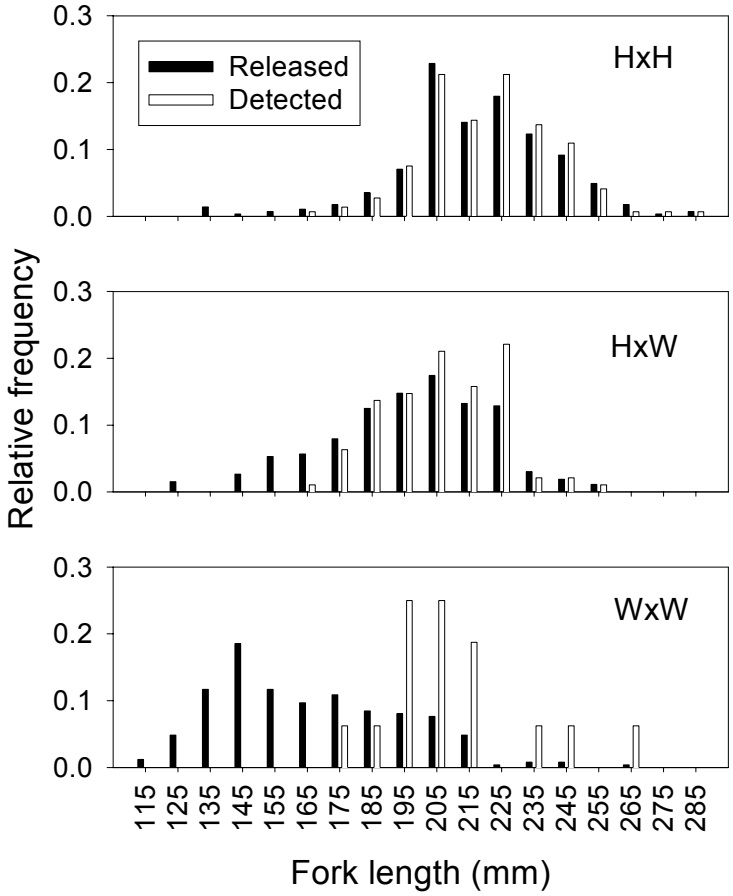

Figure 1. Fork length of experimental fish when they were injected with PIT tags in March 1997. The fish were released into the Crooked River one month after being tagged. Relative frequencies for released fish in each cross sum to one; likewise for detected fish. Solid bars show the lengths at tagging for the fish released into Crooked River; open bars show the lengths at tagging for only those fish that were detected at dams downstream in the Snake or Columbia Rivers. HxH, HxW, and WxW denote the crosses among hatchery (H) and wild (W) fish.

Table 1. Performance of experimental fish in the hatchery and after release. Mortality was measured over the 22 months in the hatchery after fish reached the button-up stage. Length was measured when the fish were PIT-tagged (March 1997), a month before they were transported to Crooked River for release. Detection rate was the proportion of PIT-tagged fish observed at downstream dams on the Snake and Columbia rivers in 1997. One additional fish of unknown cross was detected in 1998.

Set	Cross	Number of button-up fry	Survival to release (%)	Number PIT-tagged	Fork length (mm; SD)	Detection rate (%)
I	HxH	3,991	83.7	143	218 (26)	57.3
	HxW	4,007	75.2	145	198 (26)	40.7
	WxW	4,066	76.6	108	164 (28)	5.6
	Total	12,064	78.5	396[a]	196 (34)	37.1
II	HxH	3,822	82.3	141	217 (22)	45.4
	HxW	3,780	89.5	119	198 (23)	30.3
	WxW	3,735	74.1	140	170 (28)	7.1
	Total	11,337	82.0	400	195 (31)	27.5
Total	HxH	7,813	83.0	284	218 (24)	51.4
	HxW	7,787	82.1	264	198 (25)	36.0
	WxW	7,801	75.4	248	168 (28)	6.5
	Total	23,401	80.2	796	195 (33)	32.3

[a] Four additional fish were PIT-tagged but are not included here for lack of PEPA activity, (i.e., unknown cross).

Discussion

The intermediate performance of HxW fish confirms that the differences between HxH and WxW fish primarily resulted from genetic differences between hatchery and wild populations, not maternal effects. The seven-fold difference in migration and detection after release not only illustrates substantial genetic difference between hatchery and wild fish (i.e., domestication of hatchery fish), but also intense selection for Ahatchery-type@ fish.

Growth rate in the hatchery appears to be one trait subject to this intense selection because almost no fish < 180 mm were detected after release. Domestication was apparent because a much smaller proportion of HxH fish than WxW fish were below this threshold. Domestication selection (differential success), however, also seems to operate on traits other than growth because detections of WxW fish were lower than for HxH fish of the same length.

We considered downstream migration and detection as an index of fitness or expected return because hatchery steelhead must successfully migrate downstream and rear at sea to be included in the hatchery broodstock when they return as adults. No PIT-tagged fish from this study were recovered as adults; however, adult returns from a similar comparison of HxH, HxW, and WxW steelhead were consistent with predictions from the relative detection rates for downstream migrants (HxH > WxW; USGS, unpublished data).

The net consequences of supplementation, both short-term and long-term, depend on the balance between rates of domestication and naturalization (increasing fitness for natural reproduction after supplementation is halted). Currently these rates are unknown, as is the practicality of modifying hatchery environments or practices to substantially reduce domestication. These factors and the extent of domestication in hatchery programs will vary among species, and are becoming the focus of further research.

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