NATURAL SELECTION ON JUVENILE BODY SIZE

IN AN ATLANTIC SALMON RESTORATION PROJECT

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EXTENDED ABSTRACT ONLY – DO NOT CITE

Transplants of non-native fish are often used when attempting to reintroduce salmon into river systems from which they have been extirpated. Immediate success in restoration efforts is rarely achieved, in part because introduced fish are not well adapted to the new system. When maladaptation is strong, the introduced population should be subject to strong selection for traits that improve survival in the new environment. Our goal was to quantify the strength and form of natural selection acting on juvenile body length and mass in an Atlantic salmon population recently introduced to the Connecticut River basin, Massachusetts.

Un-fed fry (progeny of wild adults returning to the Connecticut River) were stocked into a 1 km section of the Westbrook, a Connecticut River tributary, in spring 1996, 1997, and 1998. All fish in the section were collected by electroshocking and night-seining during the summer of their stocking year, measured for length and mass, and PIT-tagged. At monthly (summer) or tri-monthly (winter) intervals thereafter, all fish were recaptured and measured for length and mass. A smolt trap was used to collect fish leaving the section each spring. Additional information on the study is provided by Letcher et al. (this volume).

We analyzed selection on body length and mass over three-month intervals, including two winters and two summers. For each fish captured at the start of each interval, we determined whether it survived to the end of the interval (captured in the ending sample, or any sample thereafter) or died before the end of the interval (not captured in the ending sample, or thereafter). Fish that matured as parr were excluded from analyses.

Body length and mass (cube-root) were standardized (mean = 0 and SD = 1), and relative fitness was calculated by dividing each individual's absolute fitness (survived = 0, died = 1) by average absolute fitness during an interval. Selection was quantified using Lande and Arnold's (1983) linear regression methods and visualized using Schluter's (1988) cubic spline analysis.

Linear selection *differentials* represent combined effects of direct and indirect (i.e., total) selection acting to increase (when positive) or decrease (when negative) mean trait value. Linear differentials can be interpreted as the change in mean trait value owing to selection. Non-linear (*quadratic*) selection *differentials* represent total selection acting to increase (when postive) or decrease (when negative) trait variance. *Linear* selection *gradients* represent direct effects of selection acting to increase (when positive) or decrease (when negative) mean trait value. Gradients can be interpreted as the change in relative fitness with a given change in the trait, holding effects of other traits constant. Non-linear (*quadratic*) selection *gradients* represent direct effects of selection acting to increase (when positive) or decrease (when negative) trait variance. Brodie et al. (1995) further describes these measures of selection.

The strength and direction of selection on body length and mass varied between seasons (summer, winter), among cohorts (1996, 1997, 1998), and between age classes (1+, 2+). The only consistent pattern for total effects of selection (i.e., differentials and splines) was that larger individuals did not survive better than smaller individuals during the winter (Table 1; Fig. 1). Some interesting patterns were evident when considering direct effects of selection (i.e., gradients, which hold effects of the other trait constant). In most cases, gradients for length and mass were of opposite sign (Table 1), indicating that either longer/lighter or shorter/heavier individuals survived at higher rates. The most striking pattern was that length gradients were positive and mass gradients negative for all four samples of 1+ fish (highly significant during summers). This result indicates that longer/lighter fish survived at higher rates during their second year of life. Stabilizing selection acted on length and mass of 1+ fish during summers (highly significant in 1996). When differentials and gradients were non-significant, it was because of small effect sizes rather than small sample sizes (Table 1).

In the future, we intend to add data for additional stocking years, examine selection on growth rate, and evaluate likely evolutionary responses in the population. Assuming a heritability of juvenile body length of 0.11 and mass of 0.13 with a genetic correlation of 0.98 (Gjedrem, 1983; Jónasson, 1993), and considering only selection during summers (Table 1), evolutionary responses predicted by equation 5.14 in Roff (1997) are slight per-generation decreases in length (0.008 SD) and mass (0.010 SD). Quantifying natural selection and the genetic basis for phenotypic traits allows prediction of evolutionary responses during restoration. This predictive ability may facilitate consideration of alternative restoration strategies, and suggest time frames needed for recovery.

References

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Table 1. Results of tests for selection on body length and mass, including total selection (differentials) and direct selection (gradients), as well as directional selection (linear) and stabilizing or disruptive selection (quadratic). Positive linear differentials and gradients indicate directional selection for larger trait values. Negative quadratic differentials and gradients indicate stabilizing selection (a reduction of trait variance). [a] $P < 0.10$, [b] $P < 0.05$, [c] $P < 0.01$, [d] $P < 0.001$

	Winter				Summer	
Stock year	1997	1998	1996	1997	1996	1997
Fish age	1+	1+	2+	2+	1+	1+
Start day	Dec 10	Dec 01	Dec 10	Dec 01	Jun 17	Jun 22
End day	Mar 17	Mar 16	Mar 17	Mar 16	Sept 23	Sept 10
Starting N	231	748	121	96	139	78
Survival (%)	67.1	61.0	38.8	57.3	64.7	70.5
Linear selection differentials						
Length	-0.106	-0.010	-0.070	-0.109	-0.023	0.082
Mass	0.046	-0.015	-0.081	-0.109	-0.066	0.025
Linear selection gradients						
Length	0.331	0.141	-0.931[a]	0.023	0.835[d]	1.627[d]
Mass	-0.327	-0.153	0.907[a]	-0.133	-0.881[d]	-1.574[d]
Quadratic selection differentials						
Length	-0.015	-0.041	-0.116	-0.177	-0.044	-0.035
Mass	-0.037	-0.043	-0.101	-0.216	-0.013	-0.050
Quadratic selection gradients						
Length	-0.908	0.348	-0.166	-0.854	-4.894[c]	-1.576
Mass	-1.760	0.266	0.054[b]	-2.154	-4.110[b]	-1.776

Figure 1. Non-parametric cubic splines illustrating the form of total selection acting on body length in juvenile Atlantic salmon.