REALIZED RESPONSES TO SELECTION IN ATLANTIC SALMON

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SUMMARY

Gains from selection have been observed in two experiments with Atlantic salmon. Mass selection for length in one study resulted in a realized heritability of .27. A multiple objective index selection for growth and development in both freshwater and saltwater stages was applied in a second study. Responses were demonstrated in the growth of fry. Information on later life stages is currently being collected for the index selection study.

INTRODUCTION

Reviews of the quantitative genetics of fish species that are commonly used in aquaculture, and forecasts of the gains which might be accrued through their controlled breeding, have been published by Gjerde (1986) and Gjedrem et al. (1988). For most economic traits, phenotypic variances, as reflected by coefficients of variation, are higher in fish than in terrestrial, agricultural species. Sizeable fractions of the phenotypic variance tend to be heritable in fish. This suggests that the gains expected from selection in fish should exceed those of most other domestic animals.

The results from two selection studies involving Atlantic salmon, Salmo salar, are reported herein. The first study reports the gains from one generation of mass selection for a single trait, fork length at grilse (sexual maturation after one sea-winter) age. The second experiment involved an index which included four growth and development traits. Throughout the manuscript, these are referred to as the M (for mass selection) and I (for index selection) studies, respectively.

MATERIALS AND METHODS

Details of the mating and selection procedures have been described in Friars et al. (1990a), Friars et al. (1990b) and Atlantic Salmon Federation (1986, 1987, 1988, 1989). Briefly, in the M study, a control group of fifty single-pair matings was established from a population of approximately 3,000 grilse. Mass selection was practiced on the remaining fish and was based on a single trait, length (measured from the tip of the nose to the fork in the tail). All matings avoided full-sib pairs, but were otherwise random in both the control and select lines. The minimum number of matings yielding information on any single trait was 39 in the control and 42 in the select line. A selection differential of 1.52 standard deviations were achieved among the parents that produced progeny.

The selection in the I study was applied to two-sea-winter fish of Saint John River origin. Early- and late-run samples were reared in domestication for one generation to yield progeny in 15 to 19 single-pair matings per control and select line in each subpopulation. Mating procedures were similar to those used in the M study. The selection index weights were based on estimates of genetic and phenotypic parameters and economic weights for each trait, as follows:

$$\text{Index value} = 1.0(P_1)+0.5(P_2)+6.9(P_3)+3.1(P_4)+0.5(P_5)$$

where: the P_i's are deviations of either family means from population means or individual values from family means, as appropriate. P_1, P_2 and P_3 represent family values for parr length, percent smolt and harvest length, respectively. P_4 and P_5 denote, in turn, individual and family mean mature length. The selection differentials on the index scale were 1.12 and 1.20 standard deviations in the early- and late-run subpopulations, respectively.

The stock used in the M study tended to produce about 60 percent grilse. Grilse are not desirable because they become sexually mature before they reach a market size of 6 to 9 lb. Growth rate slows and flesh quality deteriorates with the onset of maturation. The stock used in the I study tended to yield very low incidences of grilse.

RESULTS

The comparative data for the control and select lines are presented in Table 1 for the M study and in Table 2 for the I study.

Table 1. Least square means of control and selected lines for traits measured in the mass selection experiment (adapted from Friars *et al*. 1990a).

Trait	Control	Select	Trait	Control	Select
Eggs/female	4430	5744**	Fry weight (gm)		
			Uncorrected	2.07	1.99
Egg size (mm^3)	94.1	100.0**	Corrected[a]	1.98	2.06
Survival (%)			Smolt (%)	67.23	69.51
Eyed stage	35.6	48.6*			
Fry stage	22.7	32.1*	Length (cm)		
			Smolt	16.21	16.48**
Fry/family	1270	2135**	Parr	11.05	11.15**
			13 wks at sea	28.82	29.31**
Fry length (mm)			27 wks at sea	44.20	45.35**
Uncorrected	55.87	55.73	54 wks at sea	53.80	55.09**
Corrected[a]	55.14	56.28	70 wks at sea	66.65	68.49**

* Difference between control and select significant (P<.05)
** Difference between control and select significant (P<.01)
[a] Corrected for number of fry per tank

Table 2. Least square means of control and select lines for juvenile traits measured in the index experiment (adapted from Friars et al. 1990b).

	Early Run		Late Run	
Trait	Control	Select	Control	Select
Eggs/female	14594	15258	14343	15513
Egg size (mm^3)	102.7	107.3	106.8	108.8
Survival (%)				
Eyed stage	47.5	57.7	65.6	48.4
Fry stage	23.3	46.0	40.5	59.5
Fry length (cm)	6.34	6.49	6.46	6.80*
Fry weight (gm)	2.78	2.98	3.08	3.62*

* Difference between control and select significant ($P<.05$)

DISCUSSION

In both experiments, egg size and the number of eggs per female were larger in the select than the control females (Tables 1 and 2). A similar effect was noted between studies, where older and larger fish were used in the I study. The larger number of eggs per female, coupled with improved survival, yielded more progeny per dam in the select lines, except in the late-run component of the I study (Table 2).

The progeny of individual females were reared, to the fry stage, in separate tanks. Thus tanks containing families with more eggs and/or higher survival were more crowded and tended to yield smaller fish. A covariance correction, for the number of fish per tank, revealed that the select progeny were consistently larger than those of the control, in both studies. However, statistically significant ($P<.05$) differences were found only for the late-run progeny of the I study.

Tank densities were balanced when fry were transferred from the hatchery to the outdoor tanks. This removed the necessity for covariance corrections. The rate of S1 smolting was improved somewhat, though not significantly ($P>.05$), in the select line of the M study (Table 1). This was also accompanied by an increase in mean parr and smolt size ($P<.05$). At the time of writing, data for growth and development beyond the fry stage were not available for the I study.

The S1 smolt progeny in the M study were transferred from fresh to salt water at about 18 months post-fertilization. Populations were sampled after 13, 27, 54 and 70 weeks in sea water. The 70 weeks sample completed the generation cycle in the M study. After 70 weeks in sea water, the select progeny were, on average, 1.84 cm longer than the controls, yielding a realized heritability of 0.27. Using weight-length charts, formulated from fish reared under similar conditions, this represents a genetic gain of about .6 lb, among grilse which averaged approximately 6 lb.

Comparisons of the control and select fry weights in the I study show that there was a genetic gain of 7.2% in the progeny of the early-run fish and 17.5% in those of the late-run parents (Table 2). The corresponding selection differentials in the index values were 1.12 and 1.20. Although the early- and late-run components were separate gene pools, experimental error could have contributed an appreciable portion to the difference. Since the highest index weight was that associated with market size, genetic gains of this order on market value are not expected.

The M select line has had multiple objective, index selection, similar to that used in the first generation of the I line, applied in the second generation. At the time of writing, those eggs had not reached the eyed stage. Smoltification and saltwater growth data will be collected on samples of the control and select lines in the I study. Samples of the select line from the I study are being grown by multiplier growers, who will supply fertilized eggs to the Bay of Fundy sea cage aquaculture industry, where more than 2,000,000 smolts are placed in cages, annually.

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