COMPARISON OF STRAINS OF ARCTIC CHARR *(Salvelinus alpinus)* IN ICELAND FOR BODY WEIGHT AND AGE AT SEXUAL MATURITY

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SUMMARY

Comparison was made of 13 strains of Arctic charr *(Salvelinus alpinus)* from lakes and rivers in Iceland. The first part of the experiment involved the period from hatching to individual tagging at approximately one year of age and was carried out at two hatching stations. The second part involved rearing of charr for 18 months under eight different environmental conditions at commercial fish farms.

The results showed substantial variation between strains in growth rate, final body weight and time of sexual maturation. Genotype-environment interaction was significant but low in magnitude. Variation due to strains and strain-environment interaction accounted for 27 and 6 percent, respectively, of the random variation in final body weight after adjustment for effects of fish farm and hatching station. The study confirmed that careful selection of strains for rearing is important for successful aquaculture of Arctic charr.

INTRODUCTION

Aquaculture of Arctic charr is rather new and the worldwide production does not exceed 2000 tons (Pálsson, 1993). Arctic charr has been reared on a small scale in Iceland in the last few years with variable success, as producers have experienced great variations in growth rate and periods with complete stagnation of growth. The choice of strains for rearing has been more or less arbitrary and no information has been available on the suitability of different strains for rearing in captivity.

The present study was undertaken to evaluate some of the available strains of Arctic charr in Iceland in terms of performance in aquaculture and to identify suitable stock to form a basis for a future rearing and breeding program.

MATERIALS AND METHODS

Broodstock of 11 strains of Arctic charr were caught in the wild in the autumn of 1989, stripped for eggs and milt and fertilized eggs hatched at two stations; the Agricultural Research Institute at Keldnaholt and the Agricultural School at Holar in North Iceland. Additional two strains which had been reared in captivity for one and three generations were included in the comparison. The latter was reared in two groups throughout the experiment. Fertilized eggs from the other domestic strain were treated with heat shock to produce triploid charr and included as a separate group.

The fry and fingerlings were reared at the two hatching stations, each strain in a separate tank, until approximately one year of age, when the fish were individually tagged and randomly divided into eight groups. Six groups including fish from both hatching stations were sent to commercial fish farms and two groups were retained at the original hatching stations. The groups were reared for a test period of 18 months or until the age of 30 months. The fish farms had different water sources and water temperatures varied from 6 °C to 17 °C in the summer and from 0 °C to 8 °C in the winter. One fish farm reared the charr in brackish water. All fish were reared together in the same tank at all fish farms. Four test farms received around 2200 fish each, two received approximately 1000 fish, a large group of 2500 was retained at Holar and a small group of 380 fish was kept at the Agricultural Research Institute at Keldnaholt.

The young were sorted according to size twice during the first part of the experiment and the smallest fish from each group discarded. At tagging all fish were individually weighed and the length measured. A

total of 13726 fingerlings were tagged. A more detailed description of the first part of the experiment is reported by Aðalsteinsson et al. (1992).

Two of the test farms lost all their fish due to disruptions in water supply after 6 and 9 months of rearing and a third farm lost approximately half of the charr after three months. Tag losses were also substantial. Total mortality and tag losses were close to 40 % of all fish that entered the test period.

During the test period a sample of fish from each farm were slaughtered at three months intervals, weighed and the length measured, scores were given for colour of body and fins, the gonads disected out and weighed and sex of the fish recorded. A gonadosomatic index (GSI) was calculated as the weight of gonads divided by body weight. Fish were classified as sexually maturing if GSI exceeded 0.015 or 1.5 % of body weight. In addition all fish were individually weighed alive after 9 and 18 months at the fish farms and scores given for visual signs of sexual maturation.

Results presented here are limited to the analysis of body weight and sexual maturity when the live measurments were taken of all the fish. Weight data were transformed to natural logarithms before statistical analysis because of a very skewed distribution. Data were analyzed using the REML algorithm available in GENSTAT. The model included fixed effects of hatching station and fish farm together with random effects of strains and strain-farm interaction. Growth rate in the test period was evaluated after including body weight at tagging (transformed) as a linear covariate. Sex and sexual maturity were added to the models as fixed effects in some of the analysis. Predictions of strain effects for growth and body weight are reported after back-transformation to the original scale and standardization relative to the strain that had been reared in captivity for three generations (strain 12). Incidence of sexual maturation was analyzed by the same model as an all or none character.

RESULTS

Performance of charr was highly variable between farms and seemed closely related to water temperatures. Low temperatures in winter had clearly the most adverse effects on growth in the test period. Growth in brackish water was also very poor, but financial problems at this particular farm may also have played a role in that result. Mean body weight of charr at the end of the experiment varied from 340 to 1060 g depending on the environmental conditions.

Mean values for body weight at tagging are shown in Table 1 together with predicted values for body weight and growth rate of the strains at 9 and 18 months from tagging. Great variation was observed in body weight of fingerlings at the time of tagging. Strain 13 was hatched 50-60 days earlier than the other strains which is reflected in heavy weight at tagging. This advantage was lost during the test period when this strain showed relatively poor growth rate. Strain 9 had a very high growth rate at all times and ranked highest in final body weight with a mean of 1200 g at the end of the experiment while the slowest growing strains (1 and 4) weighed only about 200 g. Most of the other groups weighed on average between 600 and 900 g at 30 months of age. Triploid charr showed good growth rate during the test period but ranked fifth in final body weight because of the superiority of the other groups at the beginning of the test period. Generally the rank of the strains with respect to body weight seemed to change little after tagging, except for strain 13 and the triploid group.

Variance components for strains and the interaction of strain and environment from analysis of body weight and growth rate are shown in Table 2. The variance components for strains are similar for both periods but the residual variation is increased in the later instance when the effect of sexual maturation had become evident. Including stage of sexual maturation in October in the model for body weight in July reduced residual variation and increased the variance component due to strains. Results for body weight in October did not change by including stage of maturation. Analysis of body weight of sampled fish after 9 months of rearing did not show a significant difference between males and females.

Table 1. Mean body weight (g) of young Arctic charr at tagging and predicted values for body weight and growth rate in the period from tagging to 9 and 18 months of rearing at test farms, expressed relative to strain 12 (mean of a and b) which is set equal to 100. Predictions are adjusted for effects of hatching station and test farm.

Strain	Jan. '91 Tagging		Oct. '91 9 months rearing			July '92 18 months rearing		
	N	Mean wt.	N	Pred. wt.	Pred. growth	N	Pred. wt.	Pred. growth
1	630	47.8	200	37.2	39.2	74	33.2	34.9
2	1049	50.7	520	109.8	103.2	214	104.4	96.8
3	1291	63.0	602	109.8	95.6	269	102.0	91.3
4	630	40.8	176	32.4	37.9	64	36.3	40.1
5	1170	48.8	549	84.3	84.8	249	77.7	76.8
6	780	49.8	376	72.1	74.0	163	65.5	66.2
7	630	76.6	221	133.9	102.0	67	124.0	101.3
8	1140	47.3	547	108.1	113.1	246	100.4	102.3
9	1804	90.1	737	169.0	115.5	345	159.5	118.2
10	835	73.1	299	132.3	102.1	136	124.6	98.2
11	840	75.9	346	127.7	96.0	162	123.0	98.0
12a	631	50.3	239	99.6	100.3	81	95.3	96.2
12b	630	51.0	219	100.4	99.7	62	104.7	103.8
13	810	122.7	361	120.3	67.5	145	97.9	61.7
Triploid	856	52.2	398	128.1	122.5	185	119.0	111.4
Total/mean	13726	64.4	5790			2462		
RSD/SED		0.27[1)]		0.0936[2)]	0.0966[2)]		0.1385[2)]	0.1419[2)]

1) Residual standard deviation on log scale 2) Standard error of difference on log scale

The variance component for interaction of strains and fish farms was significant in all models but of rather low magnitude, or 4 to 6 percent of the random variation.

The frequency of early sexual maturation in the second year of life showed great variation between strains (Table 3). Some of the fast growing strains had a high frequency of maturation (strains 10 and 11) while a large proportion of the rather slow-growing strain 6 also had a high maturation frequency at this time. Other fast growing strains, such as strains 7 and 9, had very low frequencies of maturation at 21 months of age.

Table 2. Variance components from analysis of body weight and growth rate of strains of Arctic charr and percentage of variation explained by each component, after adjustment for fixed effects of hatching station and test farm. All analysis were made on logarithmic scale.

Weight						
Effect	Oct. '91 (9 mo)			July '92 (18 mo)		
	Var. comp.	S.E.	% of var.	Var. comp.	S.E.	% of var.
Strain	0.2173	0.08382	34.76	0.2050	0.08103	27.37
Strain x farm	0.02234	0.004565	4.00	0.03543	0.009287	5.70
Residual	0.2259	0.004236		0.2640	0.007650	
Growth from tagging						
Strain	0.1344	0.05264	26.16	0.1442	0.05839	21.0
Strain x farm	0.02519	0.004915	5.43	0.03971	0.009947	6.85
Residual	0.1957	0.003669		0.2472	0.007166	

Frequency of maturing fish increased markedly from 18 to 21 months age, indicating that the trait should be measured close to the spawning season in the autumn. At 30 months age, fish of all strains seemed to be

approaching maturity. Growth of early maturing charr (classified by visual score) was reduced by 30 % on average, compared to immature fish during the 18 months of rearing.

Table 3. Predicted values for the frequency (percent) of Arctic charr classified as sexually maturing after 6, 9 and 18 months of rearing (18, 21 and 30 months age), adjusted for effects of hatching station and fish farm. Classifications were made on the basis of weight of gonads in the first two measurements and as a subjective score in the last measurement.

Age	Strain														
	1	2	3	4	5	6	7	8	9	10	11	12	13	Tripl.	Mean (SED)
18 months (July '91)	5	8	14	11	12	42	7	9	1	29	22	13	4	4	12.8[1] (5.4)
21 months (Oct. '91)	11	17	29	8	36	58	6	15	17	65	43	20	12	13	24.8[2] (7.0)
30 months (July '92)	18	40	35	33	47	51	28	38	52	59	59	65	39	27	43.6[3] (8.4)
	1) N = 1093; 2) N = 842; 3) N = 2462														

DISCUSSION

The results of the study are in agreement with results reported for other salmonid species, in that choice of stock for rearing of a new species in aquaculture is of great importance for productivity of the species (e.g. Kinghorn, 1983; Gjerde, 1986). The strains selected for the comparison can be looked upon as a sample of available strains of Arctic charr in Iceland and a final selection of strains may include other stocks which were not included in the experiment. A few of the strains tested seem to be well suited for future rearing and selection, especially strains 9 and 7 with excellent growth rate and low incidence of early sexual maturity. The magnitude of genotype-environment interaction found indicates that the same stock may be used for rearing under different environmental conditions found at Icelandic fish farms without major problems. Further testing of performance in brackish water may though be necessary.

Growth rate of fingerlings in the first year of life seemed to be of major influence for for the final body weight of charr in the experiment. This may partly be be due to structure of the experiment since fish of different sizes were reared together throughout the test period and the largest fish are likely to have become dominant in the tank.

A breeding program for Arctic charr must clearly include both selection for increased growth rate and against early sexual maturity in the second year of life. Market weights above 1000 g seem to be attainable before sexual maturation in the third year of life and a breeding program may thus be operated with a three years generation interval. Due to the high incidence of early sexual maturity of the Arctic charr a selection program should be based on a combination of family and individual selection for optimum results.

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