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BREEDING OF MIGRATORY ARCTIC CHAR (SALVELINUS ALPINUS) IN BRACKISH AND SALT WATER

by

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INTRODUCTION

Domestication of different species of fishes is today an important research-field. Domestication of Arctic char is of special interest for fish breeding in the most northern and southern area of the world. It looks like migratory Arctic char which is the most northern species of the salmonids, has quite high growth rate even at low temperatures.

In order to study the behaviour and growth of this species in a domestic environment the experiment reported here was started.

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Norway.

MATERIAL AND METHODS

Mature migratory Arctic chars were caught in Storevatnet, a lake in Hammerfest (70° 39'N), in the northern part of Norway. The fishes weighed 700-1200 grams. When stripped, the egg from several females were pooled, and incubated in a hatchery at Hammerfest. The eggs were transported at the eyed stage to Fisk og Forsøk, Matredal (60° 52'N), 24th of January 1974. The fry hatched 7th of February 1974.

Table 1. An account of the material of migratory Arctic char from eggs to fingerlings.

Number of eggs		8700
Dead eggs	1962	2227
Dead yolk fry	265	
Transferred to the feeding hall, 5th of March 1974		6473
Dead during start feeding period *		3056
Fingerlings alive, 27th of August 1974		3417

* Because of using brackish water (ca. 5 °/oo S), an attack of Vibrio anguillarum swept out some hundreds Arctic char medio August 1974.

In the feeding hall the migratory Arctic char were kept in a square basin (1.5 m x 1.5 m, water depth 0.25 m) for start feeding. Reaching fingerling size, they were transported to 1 meter high sylindrical tanks (diam. 1.5 m, volume 1.8 m^3) with lids which had a square feeding- and observation-hole (0.2 m x 0.2 m). In the last part of the experimental period the groups of Arctic char were kept in a net-pen, 3 m x 3 m x 1.7 m, in brackish water. Water flow outside of the net-pens was 0.3 - 0.5 m/sec.

The experiment fishes were fed on Tess dry food (T. Skretting A/S, Stavanger), except colour dry food (EWOS, Norsk Landbrukskjemi A/S, Lørenskog). Colour dry food feeding started in the net-pen 21st of July 1976.

In the feeding hall all groups were fed by automats between 6 a.m. and 10 p.m. Fishes in the net-pen were fed twice in the winter period and three times in the summer period.

The total population was graded in three groups during autumn 1974. From 14th of February 1975 all the biggest size fishes and some of the smallest size fishes got special light treatment before being moved to a net-pen in brackish water. 300 of the biggest size group and 300 of the smallest size group stayed in "normal" light in the feeding hall (6 a.m. - 10 p.m.) while two similar groups stayed in continuous light. This special experimental period lasted from 14th of February 1975 until 20th of April 1975 when the groups were transported to a net-pen in brackish water.

Because of great quantities of Calanus finmarchicus in the fjord the migratory Arctic char got red fins, specially the smallest fishes. It was, however, too little to pigmentate the fish meat.

Specially June 1975 there was considerable mortality caused by Vibrio anguillarum which killed a greater part of the smallest fishes than of the biggest fishes. Besides of this mink and grey heron have taken their share.

The middle size group and the fishes left in the smallest size group stayed in the feeding hall until spring 1976. These fishes were used for salt water experiments and "stand by" freshwater controls. The freshwater controls were measured and weighed when they might be a help to understand the results of other experiments.

The middle size freshwater control group was acclimated to salt water during Christmas 1975 in order to cheque if the mature male fishes could survive in salt water (7-9° C). Besides fishes from two groups of migratory Arctic char non-migratory chars of the same age from two different lakes outside Bergen participated in the salt water experiment.

Extreme total length is always used, also when calculating condition factor $\left(C = \frac{\text{Weight (gram)} \times 100}{\text{Length}^3 \text{ (cm)}}\right)$.

Table 2: Growth of migratory Arctic char. Smallest size group with "normal" light.

Date of measuring	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m³)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Jan. 24, 1974	eyeroe								
Febr. 7, 1974	-	1.5	0.0	-	-	-	-	7.7	0.0
Mar. 5, 1974	-	-	0.0	-	-	-	-	7.2	0.0
Aug. 27, 1974	125	6.0	1.6	0.70	-	0.0224	0.0080	7 - 14	ca. 5
Oct. 30, 1974	100	8.5	5.6	0.88	-	0.0391	0.0625	9.5	0.0
Jan. 7, 1975	100	10.4	9.7	0.79	-	0.0275	0.0594	5.1	0.0
Feb. 11, 1975	100	11.7	15.3	0.89	108.07	0.0371	0.1600	5.1	6.7
Apr. 20, 1975	53	14.2	26.4	0.86	4.76	0.0373	0.1657	3.2	1.9
Jun. 17, 1975	96	17.0	44.0	0.84	-	0.0483	0.3034	0m: 6.7 1m: 7.0 2m: 7.3	11.3 14.6 19.2
Aug. 27, 1975	74	20.4	87.9	0.90	8.42	0.0479	0.6183	0m: 12.8 1m: 12.6 2m: 12.8	7.0 10.6 15.7
Dec. 9, 1975	63	26.3	194.7	0.93	17.72	0.0567	1.0269	0m: 9.7 1m: 10.1 2m: 10.7	8.8 11.9 14.9
Jun. 11, 1976	52	33.9	377.6	0.92	23.42	0.0411	0.9886	0m: 4.4 1m: 4.7 2m: 5.2	11.9 14.4 17.5
Aug. 16, 1976	71	36.1	481	0.97	29.77	0.0333	1.5666	0m: 12.1 1m: 12.2 2m: 14.1	8.7 11.1 15.6

Table 3: Growth of migratory Arctic char. Biggest size group with "normal" light.

Dato of measuring	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Jan. 24, 1974	eyeroe								
Feb. 7, 1974	-	1.5	0.0	-	-	-	-	7.7	0.0
Mar. 5, 1974	-	-	0.0	-	-	-	-	7.2	0.0
Aug. 27, 1974	102	8.5	5.1	0.80	-	0.0299	0.0254	7 - 14	ca. 5
Oct. 29, 1974	100	13.6	24.2	0.92	-	0.0810	0.3132	9.9	5.9
Jan. 7, 1975	100	17.6	48.1	0.86	-	0.0500	0.2988	6.1	7.7
Feb. 14, 1975	100	18.9	65.5	0.94	-	0.0464	0.6214	4.4	7.1
Apr. 20, 1975	55	21.9	99.9	0.93	4.76	0.0462	0.5292	4.2	12.2
Jun. 17, 1975	96	24.7	134.8	0.88	-	0.0483	0.6017	0m: 6.7 1m: 7.0 2m: 7.3	11.3 14.6 19.2
Aug. 27, 1975	74	28.3	240.8	1.02	8.42	0.0507	1.4930	0m: 12.8 1m: 12.6 2m: 12.8	7.0 10.6 15.7
Dec. 9, 1975	63	35.4	475.3	1.01	17.72	0.0683	2.2548	0m: 9.7 1m: 10.1 2m: 10.7	8.8 11.9 14.9
Jun. 11, 1976	52	39.9	660.1	0.99	23.42	0.0243	0.9989	0m: 4.4 1m: 4.7 2m: 5.2	11.9 14.4 17.5
Aug. 16, 1976	71	42.5	878	1.09	29.77	0.0394	3.3015	0m: 12.1 1m: 12.2 2m: 14.1	8.7 11.1 15.6

Table 4: Growth of migratory Arctic char. Smallest size group with continuous light.

Dato of measuring	Number of fishes measured	Average- Length (cm)	Average- Weight (gram)	Average- Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Daily growth Weight (gram)	Average in the period Temperature (°C)	Average in the period Salinity (°/oo)
Jan. 24, 1974	eyeroe								
Feb. 7, 1974	-	1.5	0.0	-	-	-	-	7.7	0.0
Mar. 5, 1974	-	-	0.0	-	-	-	-	7.2	0.0
Aug. 27, 1974	125	6.0	1.6	0.70	-	0.0224	0.0080	7 - 14	ca. 5
Oct. 30, 1974	100	8.5	5.6	0.88	-	0.0391	0.0625	9.5	0.0
Jan. 7, 1975	100	10.4	9.7	0.79	-	0.0275	0.0594	5.1	0.0
Feb. 11, 1975	100	11.7	15.3	0.89	108.07	0.0371	0.1600	5.1	6.7
Apr. 20, 1975	54	14.9	28.9	0.84	4.76	0.0478	0.2030	3.2	1.9
Jun. 17, 1975	81	17.8	51.1	0.85	-	0.0500	0.3828	0m: 6.7 1m: 7.0 2m: 7.3	11.3 14.6 19.2
Aug. 27, 1975	51	20.5	90.2	0.91	8.42	0.0380	0.5507	0m: 12.8 1m: 12.6 2m: 12.8	7.0 10.6 15.7
Dec. 9, 1975	47	29.7	294.6	0.99	17.72	0.0885	1.9654	0m: 9.7 1m: 10.1 2m: 10.7	8.8 11.9 14.9
Jun. 11, 1976	46	35.9	453.5	0.95	23.42	0.0335	0.8589	0m: 4.4 1m: 4.7 2m: 5.2	11.9 14.4 17.5
Aug. 16, 1976	77	38.4	610	1.02	29.77	0.0379	2.3712	0m: 12.1 1m: 12.2 2m: 14.1	8.7 11.1 15.6

Table 5: Growth of migratory Arctic char. Biggest size group with continuous light.

Dato of measuring	Number of fishes measured	Average-- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Jan. 24, 1974	eyeroe								
Feb. 7, 1974	-	1.5	0.0	-	-	-	-	7.7	0.0
Mar. 5, 1974	-	-	0.0	-	-	-	-	7.2	0.0
Aug. 27, 1974	102	8.5	5.1	0.80	-	0.0299	0.0254	7 - 14	ca. 5
Oct. 29, 1974	100	13.6	24.2	0.92	-	0.0810	0.3132	9.9	5.9
Jan. 7, 1975	100	17.6	48.1	0.86	-	0.0500	0.2988	6.1	7.7
Feb. 14, 1975	100	18.9	65.5	0.94	-	0.0464	0.6214	4.4	7.1
Apr. 20, 1975	79	21.6	94.1	0.89	4.76	0.0415	0.4400	4.2	12.2
Jun. 17, 1975	103	24.4	135.7	0.91	-	0.0483	0.7172	0m: 6.7 1m: 7.0 2m: 7.3	11.3 14.6 19.2
Aug. 27, 1975	76	28.1	231.4	1.01	8.42	0.0521	1.3479	0m: 12.8 1m: 12.6 2m: 12.8	7.0 10.6 15.7
Dec. 9, 1975	123	35.1	506.7	1.03	17.72	0.0673	2.6471	0m: 9.7 1m: 10.1 2m: 10.7	8.8 11.9 14.9
Jun. 11, 1976	163	39.8	695.5	0.99	23.42	0.0254	1.0205	0m: 4.4 1m: 4.7 2m: 5.2	11.9 14.4 17.5
Aug. 16, 1976	233	42.2	857	1.08	29.77	0.0364	2.4470	0m: 12.1 1m: 12.2 2m: 14.1	8.7 11.1 15.6

Table 6: Maturity, size of mature males and not mature fishes among 1½ years old domesticated migratory Arctic char (9th of December, 1975).

MATURE FISHES:

Groups	Fish density (kg/m^3)	Mature males	Total group	%mature males	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor
Smallest size, "normal" light	17.72	1	94	1.1	1	24.2	120.5	0.85
Biggest size, "normal" light	17.72	24	181	13.3	15	30.4	254.9	0.90
Smallest size, continuous light	17.72	2	93	2.2	1	26.2	157.9	0.88
Biggest size, continuous light	17.72	26	225	11.6	14	31.2	229.8	0.88
Smallest size, freshwater control	41.96	111	639	17.4	28	21.6	98.5	0.95
Middle size, freshwater control	44.27	58	373	15.5	16	25.5	151.9	0.90

NOT MATURE FISHES:

Groups	Fish density (kg/m^3)	Mature males	Total group	%mature males	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor
Smallest size, "normal" light	17.72	-	-	-	62	26.3	195.9	0.93
Biggest size, "normal" light	17.72	-	-	-	87	36.3	513.3	1.03
Smallest size, continuous light	17.72	-	-	-	46	29.8	297.6	0.99
Biggest size, continous light	17.72	-	-	-	109	35.8	542.3	1.05
Smallest size, freshwater control	41.96	-	-	-	78	23.4	122.3	0.91
Middle size, freshwater control	44.27	-	-	-	78	29.3	227.6	0.89

RESULTS AND DISCUSSION

Growth rate and influence of different photoperiod

Table 2, 3, 4 and 5 show the growth from hatching (2nd of Feb. 1974) until ca. $2\frac{1}{2}$ years old (16th of Aug. 1976) and the corresponding temperatures and salinities.

The 9th of December 1975 the biggest Arctic char was found in the biggest size group with normal light:

Extreme total length (cm)	:	45.5
Weight (gram)	:	1125.7
Condition factor	:	1.21

At the same time matured males were registered; no matured females were found (table 6).

The 16th of August 1976 the biggest Arctic char was a male found in the biggest size group with normal light:

Extreme total length (cm)	:	53.0
Weight (gram)	:	1950
Condition factor	:	1.31

The 16th of August 1976 13 fishes were killed, 9 of them still had white meat while 4 of them had pink meat. That means that after a month with colour dry food about one third of the fishes got pink meat.

In order to get a true picture of breeding of migratory Arctic char in brackish water, the experiment lasted until the first maturity period of the females. Tables 2, 3, 4 and 5 show growth rate of the four different experimental groups and the corresponding temperatures and salinities.

The smallest size groups never reached the size of the biggest size groups. Table 2, 3, 4 and 5 show that in February 1975 average

length and weight of the smaller size groups were 11.7 cm and 15.3 gram and for the bigger size groups 18.9 cm and 65.5 gram. The results from August 1975 show that the smaller groups were 36.1 cm and 38.4 cm long (mean) and weighed 481 grams and 610 grams (mean) while the corresponding mean of the bigger size groups were 42.5 cm and 42.2 cm long and they weighed 878 grams and 857 grams respectively.

No great difference between the groups correlated with difference in photoperiod before transport to the net-pen was found. The condition factor was reduced more in continuous light than "normal" light. Fish in "normal" light, however, continued to decrease the condition factor in the first period in the net-pen while the fish in continuous light recovered sooner.

Summer and autumn 1975 show a high growth rate. The density of fish, however, had reached 17.72 kg/m^3 the 9th of Dec. 1975.

Autumn 1975 gave just matured males (tab. 6) 1-2% in the smallest size groups and 11-13% in the biggest size groups. Table 6 shows that the matured males from the biggest size groups had just half the average weight of the rest of the groups they belonged to. The smallest size groups also had a similar tendency that average weight of mature males was lower than average weight of not mature fishes. The mature males in the bigger size groups seem to have stopped growing in August 1975 (Table 6).

It looks like size and maturity of males are closely connected. The size of the fishes must reach a certain level before maturity occur. The two freshwater control groups, however, show a higher percent of mature males than the fishes from the net-pen.

The reason for this difference is not easy to explain, but it may be connected with differences in densities, photoperiods or other environmental factors. Possibly also the mortality caused by vibriosis or predators may be different for immature and maturing fishes in the net-pen.

We must suppose that in commercial breeding of migratory Arctic char 10-15% of the population will mature at an age of $1\frac{1}{2}$ year (mainly males).

The fishes continued to grow in 1976. The growth rate, however, slows down and was not so high as in 1975. The reasons may be the high fish density together with starting maturity in both males and females (16th of Aug. 1976: stage IV).

From June 1976 to August 1976 the condition factor increased 0.05 - 0.10 in the different groups (Table 2, 3, 4 and 5). This happen when the fish density increased from 23.42 kg/m^3 to 29.77 kg/m^3. Several fishes were bigger than their parent fishes. Daily growth show that in periods with 3-4° C the growth rate is quite high.

Brackish water makes no visible salt water stress problems. Breeding of migratory Arctic char in brackish water can be recommended as long as water temperature do not exceed the values observed in the present experiment.

Salt water tolerance

Experiment with salt water tolerance of Arctic char was started 22nd of Aug. 1975.

4 groups of Arctic char participated in the experiment:
Migratory Arctic char from Hammerfest (average size: 23.7 cm and 132.4 g)
Migratory Arctic char from Hammerfest (18.1 cm and 59.9 g)
Freshwater Arctic char from Skogseidsvatnet, Hålandsdalen (21.5 cm and 119.6 g)
Freshwater Arctic char from Tveitevatnet, Lindås (18.6 cm and 70.1 g).

The 4 groups were taken directly from freshwater (13-14° C and 0.0 °/oo S) to salt water (15-16° C and 30.4 °/oo S). Already next day (23rd of Aug. 1975) 36% of the smaller size group from

Hammerfest died while ca. 20% from the other groups died. Salinity immediately was reduced to 13.3 °/oo (13° C). The groups were restocked and acclimated to salt water. In order not to stress the fishes, they were undisturbed until 10th of Oct. 1975. No fishes died during this period.

Temperatures and salinities during the acclimatisation period:

23rd of Aug. 1975 - 10th of Sept. 1975	:	13.5° C and 11.7 °/oo S
10th of Sept. 1975 - 21st of Sept. 1975	:	15.2° C and 26.0 °/oo S
21st of Sept. 1975 - 29th of Sept. 1975	:	9.2° C and 0.0 °/oo S *
29th of Sept. 1975 - 10th of Oct. 1975	:	13.2° C and 21.2 °/oo S
10th of Oct. 1975 - 5th of Dec. 1975	:	12.5° C and 30.3 °/oo S

* problems with salt water supply.

10th of Oct. 1975 and accidental stop in the water flow swept out most of the fishes. The few survivers were not disturbed until 5th of Dec. 1975. All except the group with the smallest migratory Arctic char had survivers.

Table 7 show the winter growth in salt water. The 6 surviving migratory Arctic chars increased their weight more than twice. The non migratory Arctic char from Hålandsdalen had a similar growth rate but some of them died during the winter, while non migratory char from Lindås showed very little growth and high death rate.

These results clearly show that both migratory and non migratory Arctic char may survive and grow in salt water during winter, but differences between populations seem to occur both concerning growth rate and ability to tolerate salt water.

The results are somewhat different from Gjedrems (1975) results concerning survival of migratory Arctic char in the sea during fall and winter. In his experiment all the migratory Arctic chars from Hammerfest died while in the present experiment they survived and showed a high growth rate. The reason may be that the salt water

in his floating nets had a lower temperature than in my circular tanks or his fishes might have been sexual mature.

In the middle size, freshwater control group which was acclimatized to salt water during Christmas 1975, 27.9% (31 out of 111) of the males became very thin and died in the period 9th of Febr. 1975 to 28th of March 1975 (water temperature 7-9° C). In the smallest size freshwater control which was kept in freshwater the whole actual period, not a single fish died.

Not mature migratory Arctic char, however, had no visible problems in salt water. If the main reason is that all the migratory Arctic chars go up in freshwater during winter because of too low salt water temperatur, net-pens under sea level, in the layer of high temperature salt water, could solve the problem for fish farming in the sea. Besides of this the winter growth may be quite good too. At least the growth rate in salt water is as good as the growth rate in brackish water.

In practical fish farming the mature males ($1\frac{1}{2}$ years old) should be graded away in August and sold as portion size fishes.

Table 7: Growth in salt water, migratory and nonmigratory Arctic char.

MIGRATORY ARCTIC CHAR, Hammerfest:

Dato of measuring	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Dec. 5, 1975	6	30.2	294.9	0.95	3.23				
Feb. 5, 1976	6	33.6	396.3	0.96	3.53	0.0548	1.6355	9.4	29.2
Apr. 6, 1976	6	36.6	556.9	1.08	4.19	0.0492	2.6328	7.2	31.6
Jun. 3, 1976	6	39.4	761.4	1.22	5.15	0.0483	3.5259	7.4	29.1

NONMIGRATORY ARCTIC CHAR, Hålandsdalen:

Dato of measuring	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Dec. 5, 1975	10	26.6	215.4	1.00	3.23				
Fib. 5, 1976	8	30.1	328.8	1.03	3.53	0.0564	1.8290	9.4	29.2
Apr. 6, 1976	8	31.4	360.0	0.97	4.19	0.0213	0.5114	7.2	31.6
Jun. 3, 1976	6	33.8	568.9	1.14	5.15	0.0414	3.6017	7.4	29.1

NONMIGRATORY ARCTIC CHAR, Lindås:

Dato of measuring	Number of fishes measured	Average- Length (cm)	Weight (gram)	Condition factor	Fish density (kg/m^3)	Daily growth Length (cm)	Weight (gram)	Average in the period Temperature (°C)	Salinity (°/oo)
Dec. 5, 1975	24	20.0	78.8	0.90	3.23				
Feb. 5, 1976	12	22.2	112.5	0.93	3.53	0.0355	0.5435	9.4	29.2
Apr. 6, 1976	12	22.4	109.3	0.85	4.19	0.0033	-0.0525	7.2	31.6
Jun. 3, 1976	10	23.7	128.4	0.88	5.15	0.0224	0.3293	7.4	29.1

CONCLUSIONS

1. Migratory Arctic char is well fitted for fish breeding in brackish water (salinity not higher than 20-25 °/oo).

2. Growth rate is high down to 3-4° C.

3. Maximum size at an age of $1\frac{1}{2}$ year was 45.5 cm (extreme total length) and 1125 grams. Maximum size at an age of $2\frac{1}{2}$ year was 53 cm (extreme total length) and 1950 grams (a male).

4. Fish density higher than about 18 kg/m^3 seemed to reduce the growth rate.

5. Maturity occur in males first time at an age of $1\frac{1}{2}$ year (11-13% of the whole population), female first time at an age of $2\frac{1}{2}$ year.

6. The Arctic char survive in salt water during winter at 7-13° C.

7. Growth rates in brackish and salt water were similar.

REFERENCE

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