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T. G. Reinsnes and J. C. Wallace

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THE ARCTIC CHAR AS A FARMED FISH

Trend Geir Reinsnes
and
Jeff C. Wallace

Institute of the Fisheries Industry
University of Tromso

The Fisheries Technological Research Institute

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REPORT OF THE FISHERIES TECHNOLOGICAL RESEARCH INSTITUTE, No. U 41

THE ARCTIC CHAR AS A FARMED FISH Date : February 1988

T.G. Reinsnes

The report discusses the life cycle and distribution of the Arctic char and the factors that seem to be important in its farming; various forms of farming, and experiences from the seawater phase of the Arctic Char Project at University of Tromso.

Key concepts : Arctic char farming
Production models
Combination farming

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1. INTRODUCTION

Fish-farming activities In Norway have concentrated mainly on trout and salmon farming. However, the low sea temperatures in North Norway make trout production little profitable, especially in the northernmost regions.

Therefore, great interest has been expressed in recent years in testing the Arctic char for farming. The Arctic char has a circumpolar distribution with its southern boundary in Norway at the 65th latitude (the border between Nordland and Trondelag). Thus, it has to be considered an Arctic species which should be able to tolerate low temperatures.

The Arctic char can be of an exceptionally high quality when growing under natural conditions. Experiments carried out by University of Tromso have shown that the Arctic char is an ideal fish for farming in cold waters. However, it seems to have its limitations, which have to be considered as veil. This applies particularly to marine aquiculture.

This Report aims to discuss the experiences, both positive and negative, that we gained from an Arctic char farming project.

Thanks are due to Kjell Nilssen, scientist at the FTFI, for his constructive criticism and guidance during the writing of the report.

The experiences discussed in the report are based on the work comprised within the Arctic Char Project at University of Tromso (1982 - 1986). The report was written mainly during a 5-month period of work at the Fisheries Technological Research Institute in Tromso in 1986.

A .

2. GENERAL INFORMATION; THE ARCTIC CHAR AND AQUACULTURE

This chapter is largely taken from Report No. 2 of the The Arctic Char Project; Transplantation Stage" by Trend Geir Reinsnes and Jeff Wallace.

How to tell apart the different char types has been s complex issue both taxonomically and ecologically, because the char occurs in two or three coexistent forms. In the southern parts of its area of distribution, the char occurs in its three forms only in freshwater and is called respectively dwarf, normal, or large char. In rivers carrying the char, its forms are characterized either as stationary (small) or anadromous (sea-migrating).

The different forms may vary with regard to :

1. Age at sexual maturation
2. Sex distribution
3. Spawning color
4. Time and area of spawning
5. Feeding habitat
6. Morphological characters (appearance)
7. Migration

The above circumstances may be explained by that the different char stocks have the same genetic background but that their external form adapts to the environment. According to another theory, the Arctic char and the freshwater char have evolved from the same form, but the Ice Age created one environment for the freshwater char and another one that made migration to the sea possible.

Consequently, two char stocks evolved, with different hereditary qualities. Fish representing both populations then migrated to the same areas but stayed away from each other. (This is explained by that "Hardy Weinberg's equilibrium" can be found in both populations.)

Most scientists seem to agree that the different Arctic char forms are geographically separate with regard to reproduction. However, no agreement exists about the degree of relationship between the individual populations. This has resulted in differences in naming. Today, the char is placed under Salvelinus. Earlier, it has been named Salmo rossi, S. alpinus, and S. nitidus. The name Salmo is used today for the Atlantic salmon.

Hans Nordengen, associate professor at the University of Oslo, believes that the three coexistent char forms have the same inheritance. Furthermore, he thinks that parr of each form can produce all three char types (see Fig. 1).

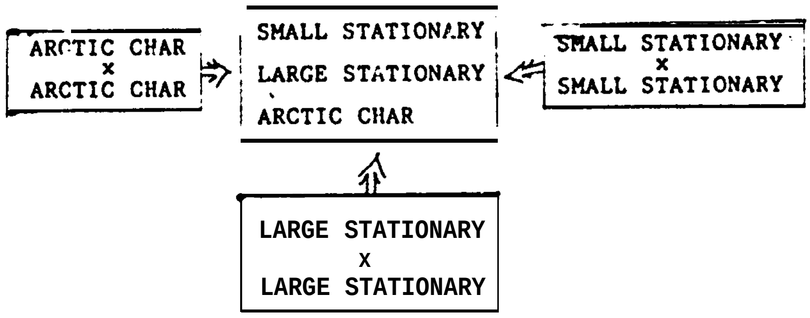

Fig. 1 illustrates how the individual “pure” char types can produce all three char types.

Experience gained from the University’s Arctic Char Project seems to indicate that a crossing of Arctic chars results in a greater proportion of anadromous offspring than a crossing of stationary forms. Therefore, a regular crossing of Arctic chars can be carried out in an attempt to reduce the input of fish not developing anadromous characteristics. In view of this, an organized breeding effort seems to constitute an important prerequisite for developing further the farming of the Arctic char.

One and the same age class of young chars will contain fish smoltifying at different ages. Some Individuals will never smoltify. As far as char farming is concerned, only fish smoltifying within the first 2 years is of interest. The fish that smoltify only at an age of 3 years or later will, in terms of farming, be considered a freshwater char, because in sea-farming it will probably not be profitable to take care of fish smoltifying after 3 years. See Fig. 2.

The freshwater char becomes sexually mature at an age of 2 - 4 years, while the Arctic char matures only after 4 - 6 years. According to Hans Noreng's registrations in Salangen River, South Troms County, the fish we define as freshwater char has a sexual maturation distribution that results in three males per female, while the opposite applies to the Arctic char.

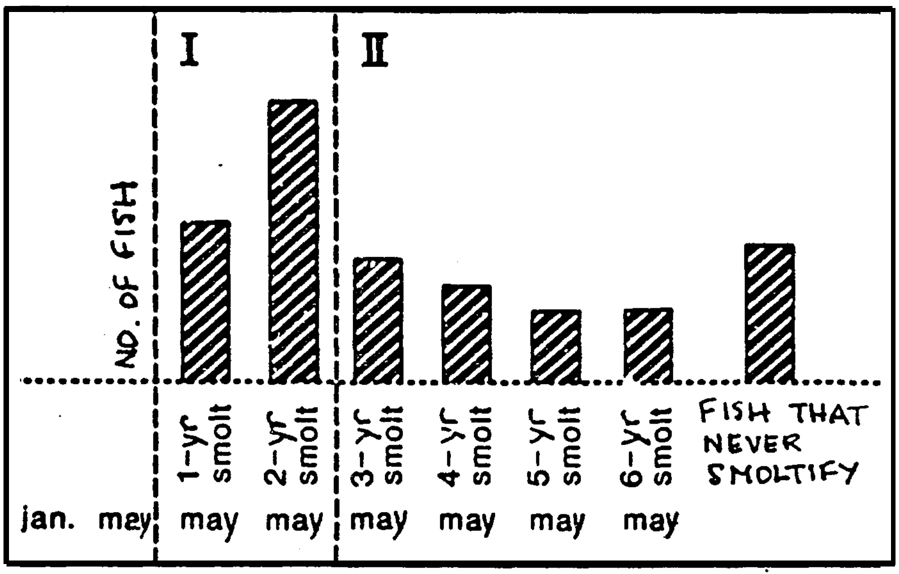

Fig. 2 Char undergoing smoltification at 1 - 2 years is considered Arctic char (I), while char smoltifying at greater ages is counted as freshwater char (II).

2.1 DISTRIBUTION

The Arctic char represents an Arctic species with distribution in North Norway, at Greenland, Svalbard, Bear Island, Novaya Zemlya, Iceland, Siberia,* Alaska, and Canada (Fig. 3). In Norway,. the Arctic char occurs north of Namdalen (boundary between Nordland and Trondelag). Towards the north, the fish becomes increasingly common in rivers, which indicates that it should be well suited for living in low temperatures. Based on this expectation, University of Tromso began to study the Arctic char's qualities as a farmed fish.

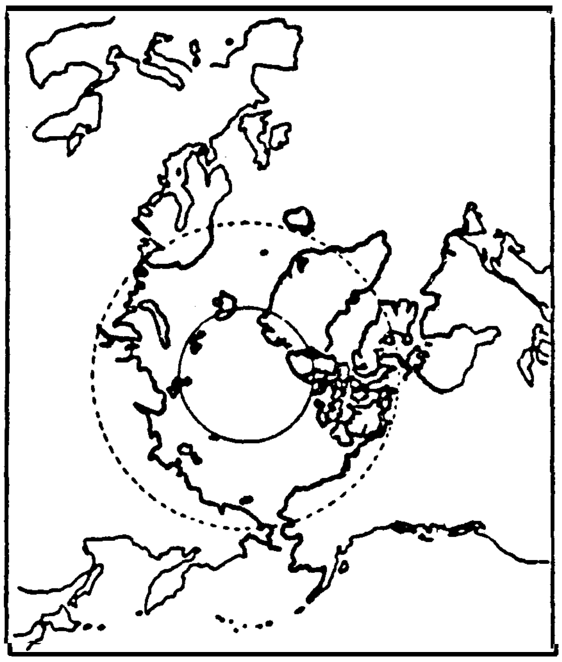

Fig . 3 Geographical distribution of the Arctic char.

2.2 LIFE CYCLE

A knowledge of how the Arctic char lives in nature is important for a fish farmer facing the problems connected with its farming.

Spawning takes place in fresh water. After the first 2 - 3 years in fresh water, the Arctic char migrates to the sea. The migration takes place early in the spring, when the river ice melts. The char stays in the sea for 1 - 2 months and rarely wanders further than 10 - 80 km from the mouth of its river. The purpose of the sea migration is to feed, in order to become large and strong and be able to produce as much roe and milt as possible. The Arctic char undertakes 4 - 5 seasonal migrations before it becomes sexually mature. This is how the Arctic char's life pattern differs from that of salmon which migrates to the sea to stay there for 3 - 5 years before spawning. This difference means that the salmon farming methods can not be directly applied to the Arctic char.

The spawning season of the Arctic char varies from river to river. In Storvannet, Hammerfest, it spawns in September/October, while in Strandvatnet, at Bogen in Ofoten, it has been recorded to spawn as late as at the end of December.

2.3 FARMING THE ARCTIC CHAR

The char differs from the salmon already at the egg stage in that its eggs are significantly smaller. The salmon egg diameter is 6.0 - 6.6 mm, while the char egg diameter is 4.7 - 5.4 mm.

A water temperature of 4 - 5° C seems to be favorable for the development of the eggs and the fry at the yolk-sac stage. Feeding is usually initiated when 2/3 of the yolk sac is used up.

It can be recommended, based on previous experience, that the water temperature be raised gradually to 8 - 9° C in the course of the initial feeding period. No excess feeding must be carried out during the initial feeding, because the fry easily develop gill inflammation If the water temperature is 7-8° C, it is recommended that feed O is used for the first 2 weeks, followed by a mixture of feeds O and 1 for the next 3 weeks and then a gradual change-over to feed 1.

Normally, the mortality of the Arctic char during the initial feeding period is about 20 %, which is similar to that of the salmon.

2.3.1 Importance of temperature

The growth of the fish is dependent on the water temperature. Fig. 4 shows growth at different water temperatures. It is seen that a char weighing 4 - 5 g can increase in weight to 19 - 20 g within 200 days at a temperature of 3° C. If the temperature is increased to 6, 9, or 12° C, the weight increases respectively to 40 - 45 g, 95 - 100 g, and 180 - 200 g. Compared with the salmon's growth, this can be considered a very good growth rate. The choice of the farming temperature is, however, an economic question to be evaluated separately for each individual locality.

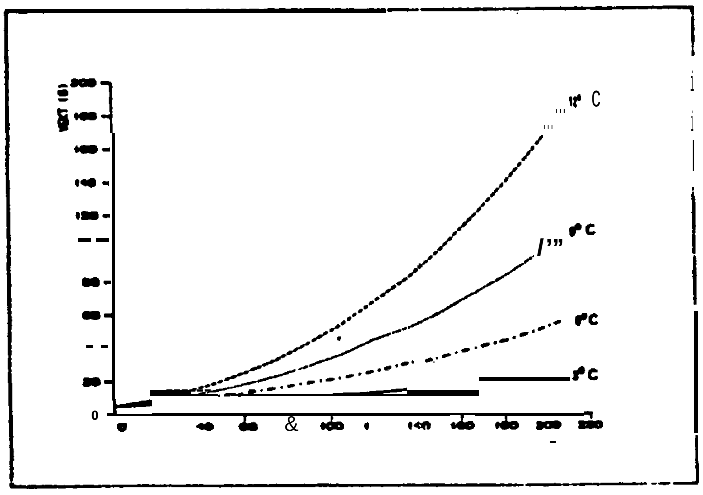

Fig. 4 Growth of the Arctic char at different water temperatures.

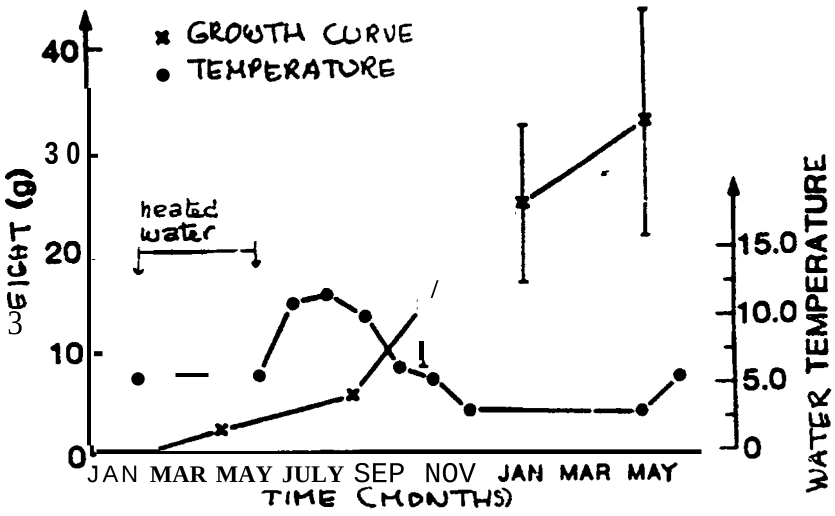

Fig. 5 Growth of the char in a 15-month period. During the initial feeding, the fresh water was heated to 7° C.

Fig. 5 shows the growth of the char during a period of 15 months. During the initial feeding period and until June, the water was heated to 7° C. The average weight was 31.5 g on May 6. When the water warmed up naturally, the heating was stopped. Thus, by the first half of August, the water temperature had increased to 12° C, to drop again to about 3°C in the course of November and to fluctuate at around 3° C throughout the winter.

These results mean that even a shortterm heating of the water (during the initial feeding period) can yield Arctic chars that weigh a minimum of 50 - 70 g already as 1-year old smolts in June.

2.3.2 Importance of density

The Arctic char has been shown to be able to tolerate farming at great densities without suffering or becoming diseased. This is connected with the fact that the Arctic char is a shoal fish, which is economically very important for the individual producer.

Fig. 6 illustrates growth m 3 groups consisting of different quantities of char . Fig. 7 shows appurtenant density changes.

A study of the figures shows what the Arctic char's growth is like at different densities. At the beginning of the trial, the fish weighed an average of 5.5 g. When they were measured the second time, the fish farmed at greater densities already showed a greater increase in growth that those living at lesser densities. At all subsequent measurings, the greatest densities had bigger fish than the lesser ones. In the course of the trial, which lasted 74 days, average weight at the greatest density had increased to 13.4 g, while at the medium density this weight was 12.9 g and at the smallest density 10.8 g. At the time of the last measurement, the densities were 90, 37, and 10 kg/m^3 in tanks with 700, 300, and 100 fish, respectively.

Fig. 8 shows the growth of some bigger fish after the relevant density was changed over a period of 95 days. The fish grew from 16 to 33 g when the density changed from 110 kg/m^3 to 225 kg/m^3. In connection with the last measurement, all fish were inspected, and none were found with worn fins or blemished skin. The condition factor varied between 0.8 and 1.0 for all groups during the trial period..

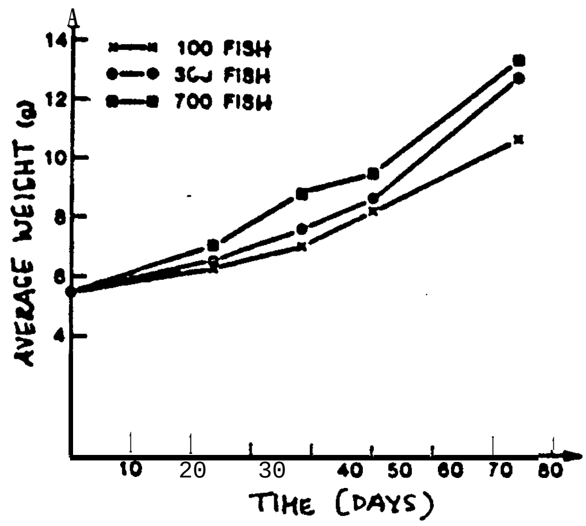

Fig. 6 Growth and appurtenant density over a period of 95 days.

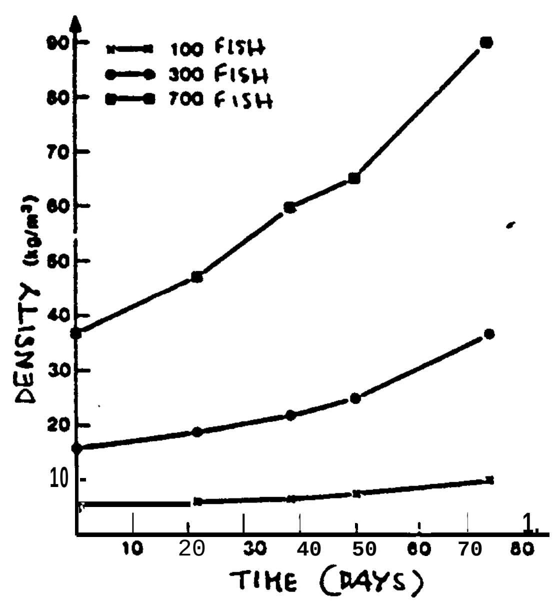

Fig. 7 Density changes in 3 groups of Arctic char, with different fish quantities and initial densities.

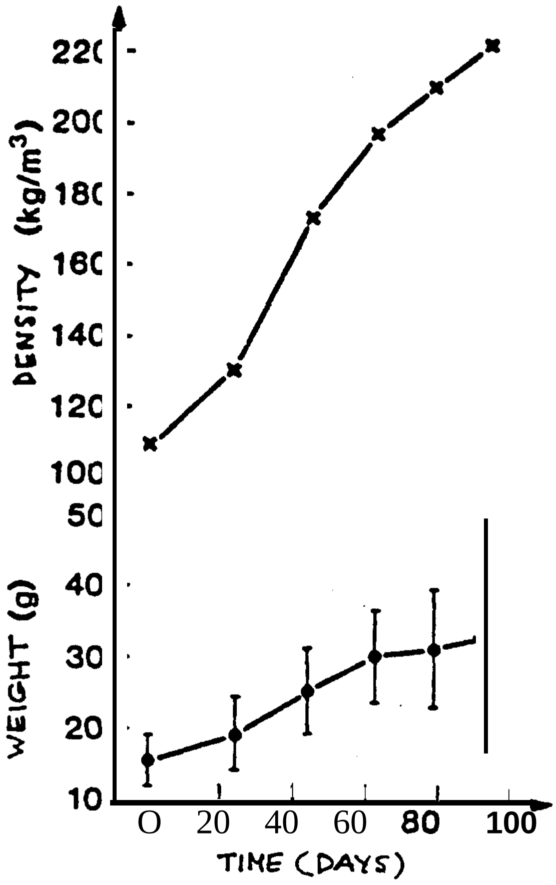

Fig. 8 The lower part of the Figure shows the growth and the upper part the matching densities for 700 Arctic chars in 104 L of water over 95 days.

The trial indicated that the Arctic char thrive in tanks with high densities, because at lower densities the fish crowd together and make poor use of the tank volume. At the greatest densities, the chars were evenly distributed throughout the water mass.

If the final measurements carried out at the different densities are compared, the coefficient of variation is the same for groups with 100 and 300 fish as it is for those with 700 fish. This means that the number of small fish does not increase with increasing density. It is also remarkable that fish weighing 30 g can be farmed at 200 kg/m^3 for a month without occurrence of worn-out fins or disease. Therefore, preventive treatments with formalin and malachite green are probably needed less in char farming than they are today used in salmon farming.

However, at higher densities, measures have to taken against leaving the fish in darkness (emergency power unit). The Arctic char has a tendency to lie on the bottom when the lights are turned off, which can lead to a blockage of the drainages of the tanks and a flooding of the water over the edges.

In the first place, the density trials confirmed that as a shoal fish, the Arctic char has characteristics indicative of good possibilities for fish farming.

Commercial fish farming will favor the use of large tank volumes. With sufficiently large water supplies, it seems tobe recommendable to produce Arctic char at densities of up to 100 - 150 kg/m^3.

Note : This applies to farming in tanks on land, with lots of fresh water. We have no figures indicating ideal densities for net cages in the sea.

3. SEAWATER PHASE - Experiences from the Arctic Char Project

Introduction

It was planned to transplant Arctic char representing different stocks in five localities along the northern Norwegian coast. This planting took place at the following establishments : Faks A/S, Hammerfest; Voldenfiske-oppdrett A/S, Alta; Kaldfjord Fiskefarm A/S, Tromso; Sjofisk A/S, Grovjord; Blokken Sjoroyeoppdrett A/S, Sortland.

Warm thanks are extended to the fish-farmers for their willing cooperation. A special thank-you goes to Leonhard Hansen, Kaldfjord Fiskefarm A/S, who was the employer of the project leader.

The project aimed to compare the growth and survival rates in seawater of different Arctic char stocks in view of the idea that some Arctic char stocks are more suited for farming than some others. It proved difficult, however, to obtain sufficient quantities of parent fish and roe in the various rivers to sustain this approach to the question. A comparison of different char stocks requires a great number of fish of the parent generation, so that the assortment of parent fish covers the genetic diversity in the population. However, we chose to continue the project with intent to increase the general knowledge about the farming of the Arctic char.

Subsequently, it turned out that this was a correct decision. Besides gaining increased knowledge about Arctic char farming, we lay a foundation for roe production by letting the project fish stay in the sea until they were sexually mature. Thus, producers of fish for stocking will have a supply of Arctic char roe originating in the Arctic Char Project.

EXPERIENCES FROM THE FIRST TEAR IN THE SEA

The Arctic char were placed in the sea at the beginning of July 1984, at an age of 1 year and average weight of 28 - 34 g. In the summer, some of the fish grew satisfactorily, while 40 - 50 % of them grew very little.

It turned out afterwards that we carried out initial feeding of the Arctic char fry at a temperature that was too low, which resulted in that the fish were too small for l-year old fish for transplantation. Had we sorted the fish and transplanted only those bigger than 50 g, the results would have been much better. If the temperature had been higher during the initial feeding period, the fish would have been ready for transplantation in May/June, with an average weight of 50 - 60 g. This conclusion is based on experiences gained in 1985 and 1986.

Those Arctic chars that were willing to eat, grew fast and maintained a good appetite all the way til September.

In the course of the fall, the chars' appetites began to wane, and they started to die. The mortality increased towards the turn of the year, to decline around the approach of April. In the period April - September, almost no mortality was recorded (Fig. 9).

The fish that died were essentially those that had showed poor growth already in the summer.

In summer 1984, quantities of fish were weighed, and their origin was recorded. The most uniform numerical material was obtained from Blokken and Tromso. Therefore, only these results are presented in this report.

Table 1 shows that in the locality "Blokken", Hammerfest Tam (roe from farmed fish) had 2 - 3 times better survival that Hammerfest-Vill (roe from wild fish). This indicates that breeding is unimportant factor in improving the survival of the Arctic char in seawater in the winter. Hammerfest Tam yielded the best results in the locality "Tromso" as well.

It turned out later that the Arctic char was too small at the time of the transplantation and that better survival can not be expected with fish this small. The Table also indicates that in the first year, growth is too low to make roe production interesting. However, this low growth was attributed to the small size of the transplanted fish. Fig. 10 indicates much better growth, with an average transplantation weight of 48 g, which indicates a significantly better growth capacity than what the Table promises.

EXPERIENCES FROM THE SECOND TEAR IN THE SEA

Some unpredictable production-related factors made the numerical information on the 2nd-year mortality in the sea unreliable, but a weighing of the remaining fish at the Tromso localities in August 1986 yielded the following growth figures for a 14-month period :

Arctic char stock	June 1985	August 1986
Hammerfest-Tam	306 g	1188 g ± 473 (377)*
Jægervannet	154 g	582 g ± 188 (17)
Svolvær	160 g	461 g ± 270 (116)
Island	213 g	1137 g ± 610 (110)

Table 2 shows growth from June 1985 to August 1986 for fish placed in the sea in June 1984.

*) Parenthesized figures indicate numbers of fish weighed.

Table 1 Growth of Arctic char from June 1984 to June 1985.

STOCK	No. of fish planted in 1984	Weight June 1984	No. of registr. in 1985	Weight May/ June 1985	Survival in % 1986-1985
From Blokken					
Lakselv	226	33,9222	19	126±91,4 (9)*	8,9
Hammerfest-Vill	371	28,3±10,1	73	91257,8 (30)	19,7
Hammerfest-Tam	1054	28,6±11,1	4 8 3	124±66,4 (30)	45,8
Eiby	192	34,1215,1	28	178±110,0(30)	14,6
Oksfjord	682	32,8220	9	46±39 (9)	1,3
Ringvannet + Jægervannet	332	25,3±7,9	46	55±30,1(30)	13,9
Bogen	988	32,2?12,2	125	76$51,4(30)	12,7
Å-vannet	257	30,1±11,1	38	37±12 (30)	14,8
Svolvær	1278	26,5216,5	203	73±40,2(30)	15,9
Island	737	43,7214,0	160	84±72,6(30)	21,7
Jægervannet	741	35,2s14,1	29	48±25,8(29)	3,9
From Tromsø					
H-1%	2283	28,3s10,1	1307	306±184 (30)	57,2
Jægervannet	108	35,2±14,1	33	154± 69 (30)	30,6
Svolvær	2301	26,5±16,5	426	160± 96 (30)	18,5
Island	951	43,7214,5	457	213±120 (30)	48,1

*) parenthesized figure shows number of fish weighed.

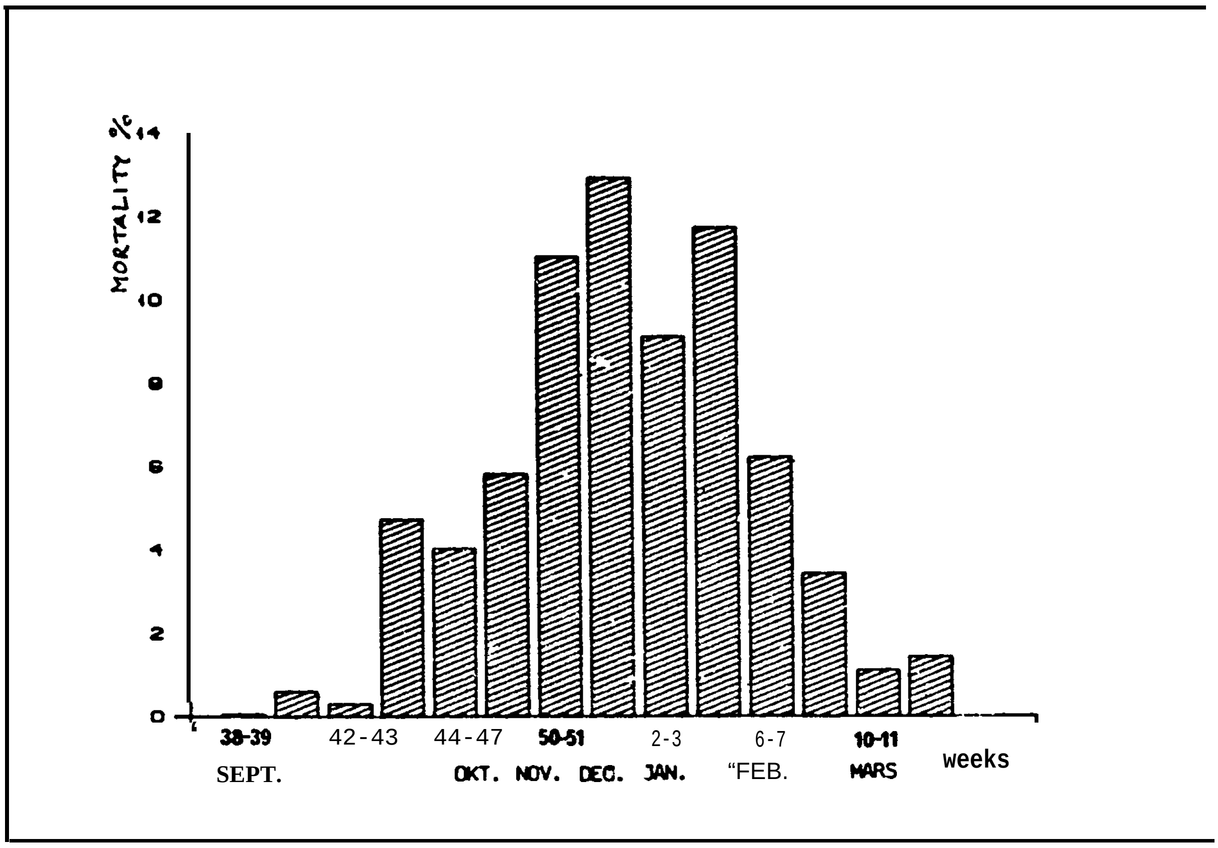

Fig. 9 Mortality of Arctic char during winter 1983/84.

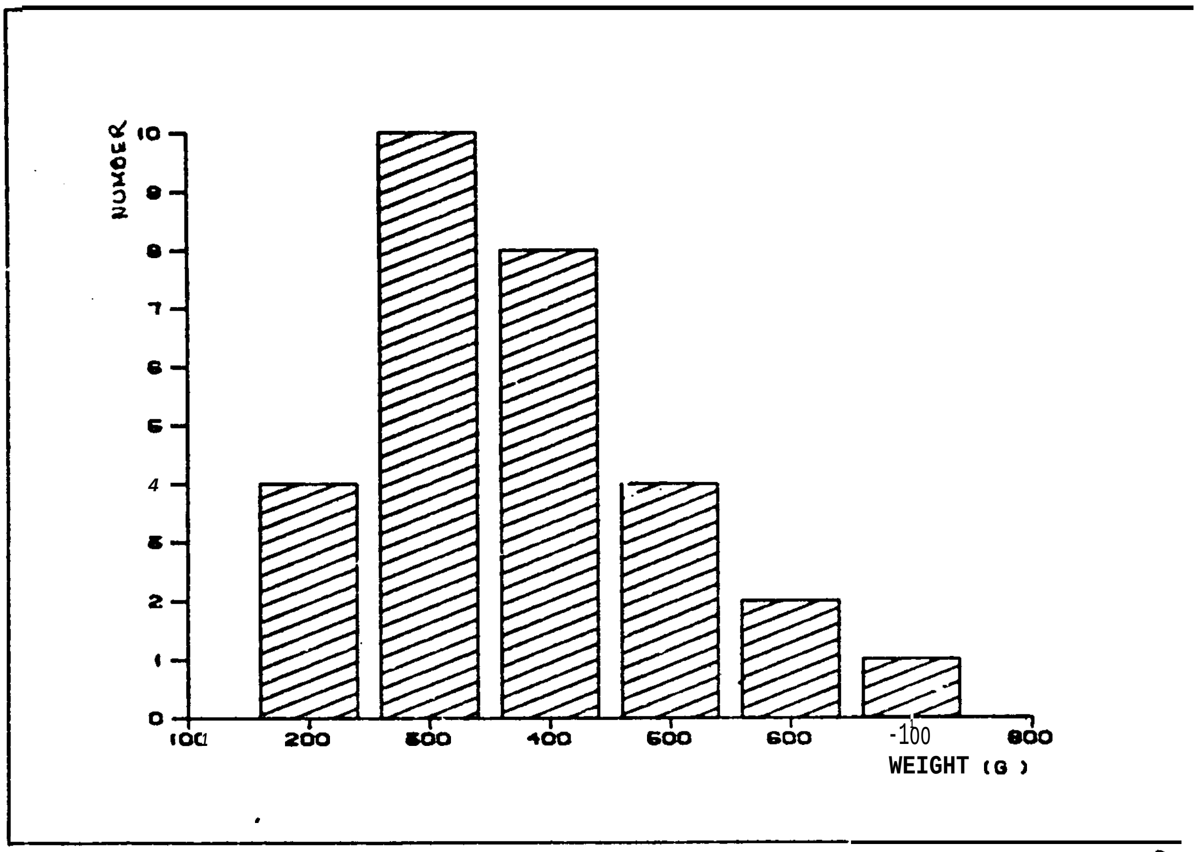

Fig. 10 Weight of Arctic char, measured May 20 1984. Average weight 405 g. Placed in seawater in June 1983 with an average weight of 48 g.

FEED UPTAKE

During the dark winter months, the Arctic char eats almost nothing. Its feed uptake increases in April when the water temperature rises, and in the beginning of September, its appetite begins to gradually decline again.

However, not all fish reduce or stop their feed uptake in the winter. About 15 - 25 % of the fish continue to take up feed and put on weight in the winter as well.

A random sample consisting of 47 fish was taken in February from a net cage in the sea, where fish had been staying for 20 months. Fig. 11 shows that the fish that weighed more than 700 g had, to a considerable extent, food in their stomach and intestines. Photo A shows a fish that obviously had not behaved very modestly at "the dinner table".

Fig. 11 also shows that 13 of the 14 fishes with food in their stomachs were female, and that the largest fishes were female. Besides, it is important to note that as much as 52 % of the Arctic char had unpigmented meat (Fig. 12). Only fish that had been feeding had pigmented meat.

Those fishes that ate during the winter had abundant abdominal fat deposits. This is a common phenomenon in Arctic animals. Different energy strategies in the different seasons among the Arctic char perhaps demand a different feed composition in the summer than in the winter.

Photo A A concrete proof of that part of the Arctic char population feeds all winter in seawater. This fish was re-moved from a net cage in February.

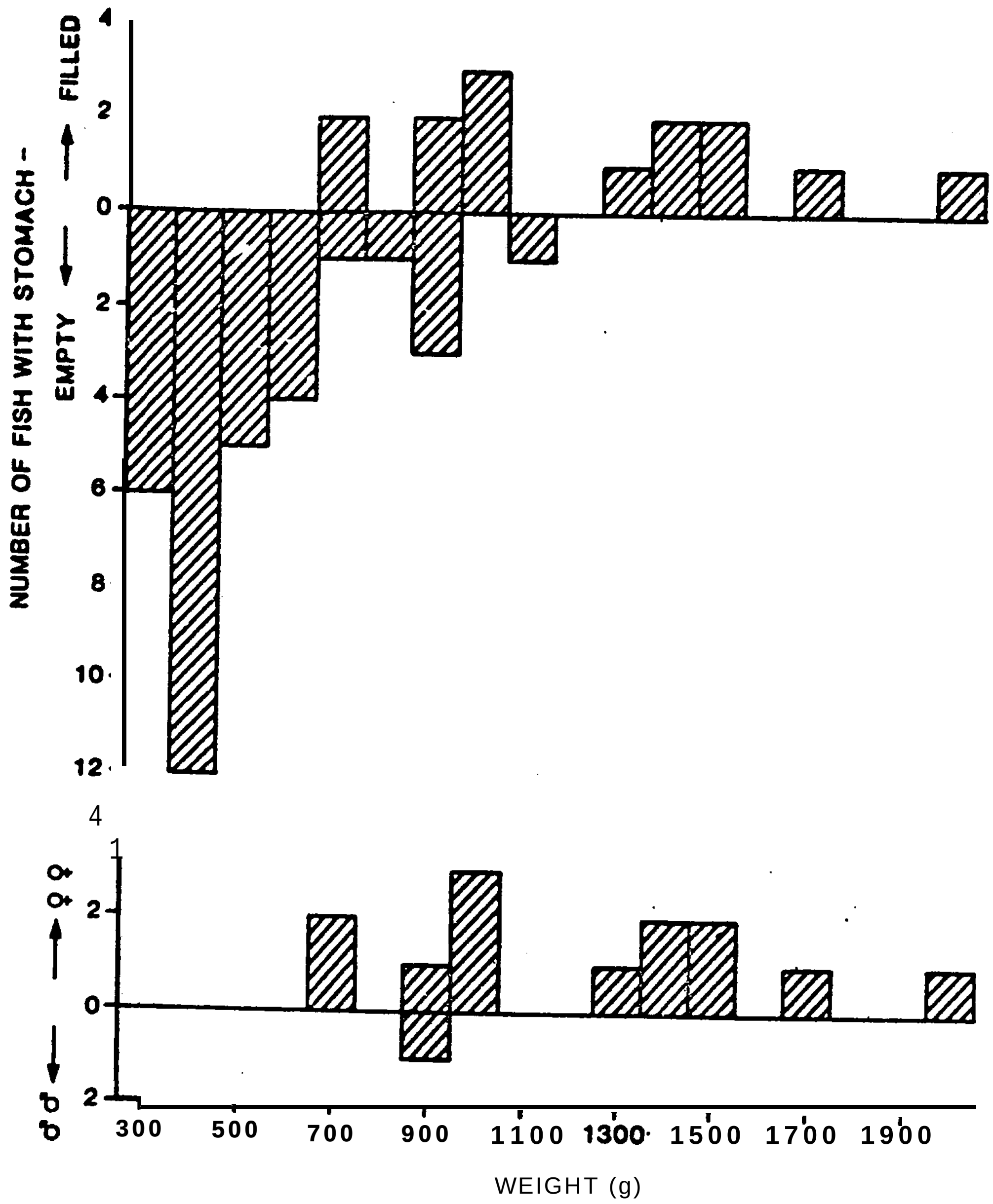

Fig. 11 Number of fish with residue of food/no food in the stomach among a random sample of 48 fish in February. The lower figure shows sex of the fish with food in the stomach.

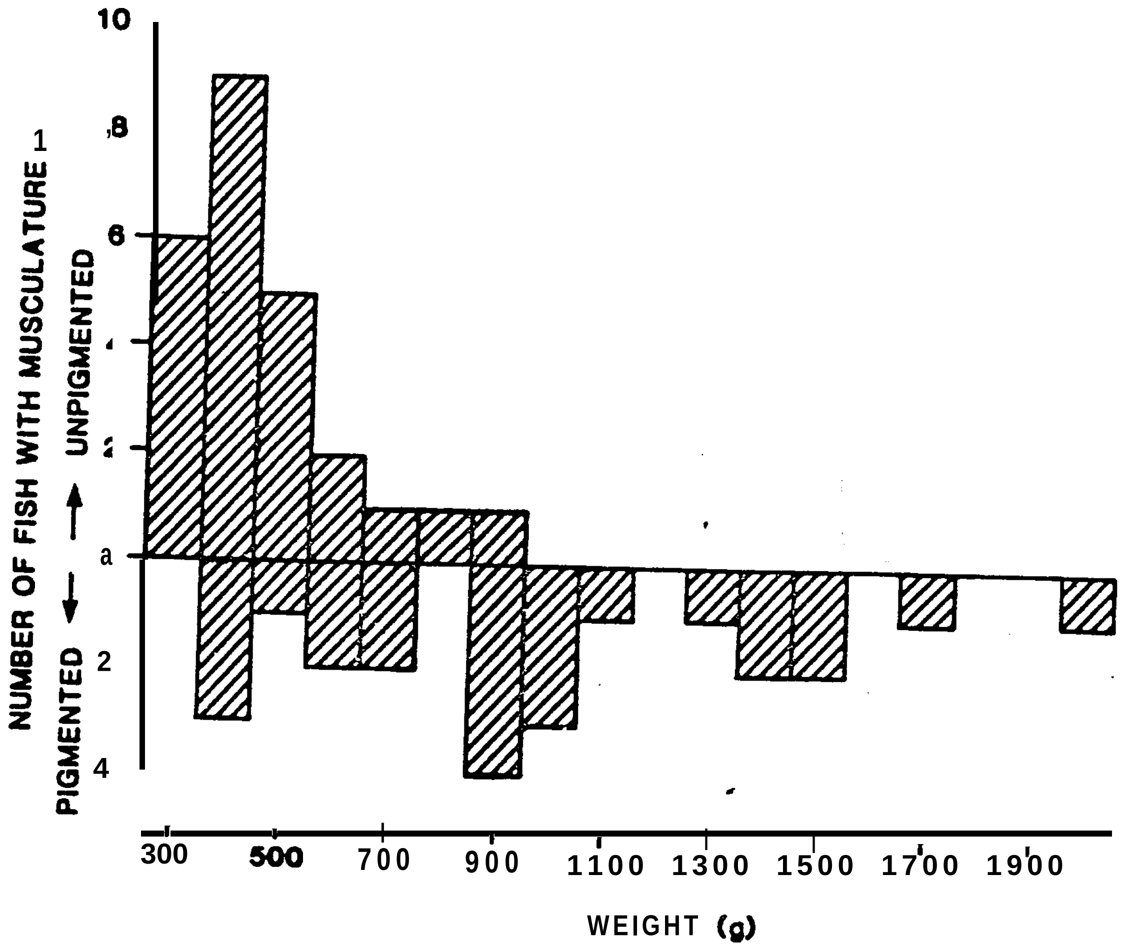

Fig. 12 Distribution of fish with pigment/without pigment in musculature, in relation to size.

CONCLUSION

Keeping Arctic char in seawater (30 - 35 %) in the winter resulted in high mortality. This mortality can be avoided to a considerable degree, however, by planting out only fish weighing more than 50 - 60 g.

Even then, a fair proportion of transplanted Arctic char will grow poorly in seawater. It is recommended that the Arctic char be kept in fresh water for 2 years before placement in the sea (2-year fish for transplantation). It is reasonable to have the fish weigh 250 - 400 g at the time of the transplantation. In the beginning of September, the average weight should approach 0.7 - 1.3 kg, and the fish can be either slaughtered or taken back to fresh water or brackish water ($< 17^{o}/oo$). See also Chapter 6 which outlines different production models. Which production model is chosen depends on the supply of fresh water in the locality in question.

The Arctic char is an ideal fish to be farmed in fresh water. Therefore, plants not having access to fresh water should not attempt Arctic char production. However, there are a number of locations along the coast of Norway, excellently suited for farming the Arctic char.

Purely marine farms will hardly develop any profitability before growing 2 - 3 generations of char, based on the Hammerfest-Tam breed from the Arctic Char Project.

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4. ARCTIC CHAR FARMING - POSSIBILITIES AND LIMITATIONS

The Arctic char is a hardy fish which does not require the same production conditions as salmon does. Therefore, simple and inexpensive production equipment can be used, and it is also relatively easy to acquire the knowledge required for a successful Arctic char farming.

Simple production conditions mean that no heat pump is needed to produce fish for transplantation. A heat pump sets high demands for construction as well as maintenance and inspection by persons with relevant technical knowledge. When the Arctic char is farmed, heat is supplied only during the initial feeding period, and this can be done by heating cables which are simple to operate and inexpensive to purchase.

The Arctic char tolerates high densities at the fingerling stage, without developing diseases. Besides, it distributes favorably in the water column and grows fast at low temperatures. Thus, few and big tanks can be used.

The requirements concerning locality are modest, if the intention is to produce 40 - 50 000 transplantable fish intended for domestic food fish production (see Ch. 6). Only hatching and initial feeding have to be done indoors. As early as in July, 6 - 7 months after hatching, production can take place in tanks outdoors.

For further minimization of the investments, it is recommended that the roe be kept at natural water temperatures and that the fry be given their initial feeding in the spring when the water temperature reaches 5 - 9° C. This way, investments in heating systems are avoided.

As the Arctic char is a shoal fish, only two outdoors tanks (40 - 50 m^3) are needed to produce 40 000 2-year old fish for transplantation.

If a suitable marine locality is available, the fish (2-year old) can be placed in the sea in May and slaughtered in September. Normally, this practice results in fish weighing 0.7 - 1.3 kg.

On bigger farms, the char can be brought from the seawater back to fresh water in the fall, which results in a supply of slaughter fish all year round.

We can see no conflicts between small and big farms, because the market can absorb the quantity that can be produced in Norway. It requires only good quality and good marketing.

Bigger farms can be expected to carry out continuous marketing and sales of the Arctic char. This should stabilize the demand for the product and result in favorable prices.

5. THE TRANOY PROJECT

North Norway has a settlement pattern character zed by long distances between densely populated places and areas with primary production. People living in such remore areas often have difficulties with finding profitable employment. Arctic char farming should be an activity ideally suited for keeping these areas on their feet, because it can be carried out in small units, in combination with agriculture and fjord fishery. Also, its need for capital is small compared with other activities.

Tranoy represents a poorly industrialized municipality in Senja. We wished to cooperate with such a municipality, to develop, if possible, a form of fish-farming that would suit such a district. This was the beginning of the Tranoy Project.

Based on information gained from such a project, we wanted to formulate a guidance activity for char farming in several localities, with intent to give a fish-farmer an opportunity to choose a farming method best suited for his individual locality.

The Gjovik Arctic Char Farm in Senja is an example of such an inexpensive and simple form of operation. About 120 000 chars were hatched and given their initial feeding during a winter in a closed-down. cowhouse. This was done at an investment cost of NOK 30 000. The future costs will amount to NOK 35 000 which will be spent to purchase an outdoor tank of 50 m^3. The example shows that it is possible to start production with small investments.

6. PRODUCTION MODELS

Arctic char farming has taught us that a majority of the population grows poorly in the sea during the summer. Also, we know that many fishes die in the winter season, if they stay in seawater. The reason for the fish mortality during a winter spent in the sea has been documented by the Fisheries Technological Research Institute (FTFI), and instructions for avoiding this problem are available.

The FTFI is attempting, with the Tranoy Project (see Ch. 5), to prepare conditions for the best possible farming practices. By trying different models, a production form will be found that gives, at the lowest possible cost, a product well adapted to the market.

6.1 Various production models

Basic pr :Separation of Arctic chars from freshwater chars during freshwater phase

This aims to separate as early as possible chars which will smoltify from those that will not.

It is known that smoltification reduces the growth in salmon. It has been registered that the Arctic char, at an age of 18 months, divides in 2 growth groups. Thus, it can be assumed that one of the growth groups represents fish which will smoltify. If this is true, it may be possible to separate Arctic chars from freshwater chars already during the joint freshwater phase.

The FTFI has documented recently that a great proportion of freshwater chars die while the Arctic char thrives well during a summer in the sea. However, FTFI's work also indicates chat the Arctic char has problems with surviving a winter in the sea. This is assumed to be associated with its freshwater-related winter ecology.

MODEL 1 Slaughter of fish at 21 months

A production program allowing the char to stay 15 - 16 months in fresh water after hatching and then 4 - 5 months in the sea yields portion-sized fish of 200 - 500 g. This size group is believed to have a significant demand in the market.

A timely separation of non-anadromous char can increase the profitability of this production model to a significant degree.

MODEL 2 Slaughter of 80 % of the fish (the smallest) at 21 months, with the rest put into the sea for the winter

Some farms have a restricted freshwater supply in the winter, which makes it difficult to farm bigger fish in freshwater tanks. In view of the negative experiences gained from survival in the sea in winter, as many fish as possible should be slaughtered in the fall.

Fish that have grown sufficiently during the summer season can tolerate overwintering in seawater. Therefore, this suggests a production model in which 80 % of the fish (the smallest) are slaughtered at 21 months after a summer in the sea , while the remaining 20 % can stay in the sea over the winter and the following summer until slaughter.

MODEL 3 Bringing in the smallest fish from seawater to fresh water in fall at 21 months, and letting the biggest stay in seawater over the winter and the following summer

This model is based on conditions similar to those of Model 2, but it is assumed in this case that the locality has sufficient supplies of fresh water. Thus, the smallest fish are moved back to freshwater tanks on land for the winter, to be set out in the sea the second time the following summer. The biggest fish stay in the sea all the time.

MODEL 4 Moving all fish into fresh water in fall

In this Model, all food fish is transferred from the sea back to fresh water after the first summer. The next spring, the fish is then transferred into the sea for another summer season before slaughter in the fall.

There are many localities in North Norway with abundant fresh water but unsuitable seawater locations. Model 4 can be of interest in such localities.

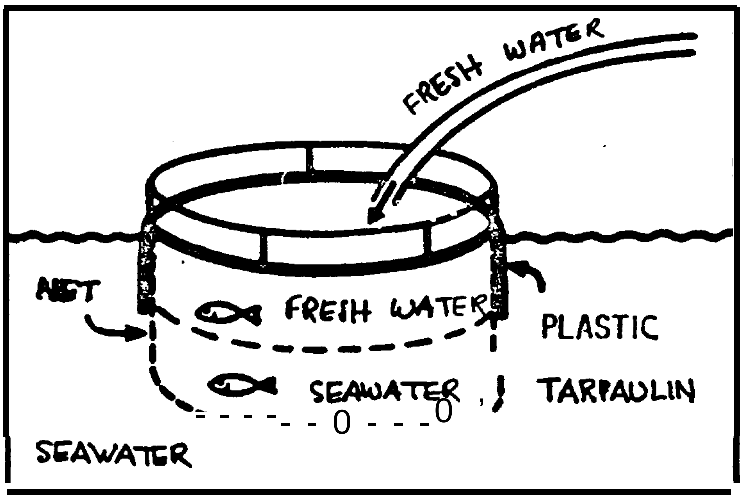
MODEL 5 Allowing Arctic char to stay in fresh water for two years followed by 5 months in seawater

The fish would stay for 24 months in fresh water before a final production phase of 5 months in the sea. This production form requires abundant freshwater supplies. In the freshwater period, the water can be heated to 8 - 9° C during the initial feeding period. As for the rest of the period, the water temperature is kept above 2.5° C in the winter and above 10° C in the summer, a great majority of the char achieve a weight of 250 - 400 g before being set out in the sea (2-year old fish for transplantation).

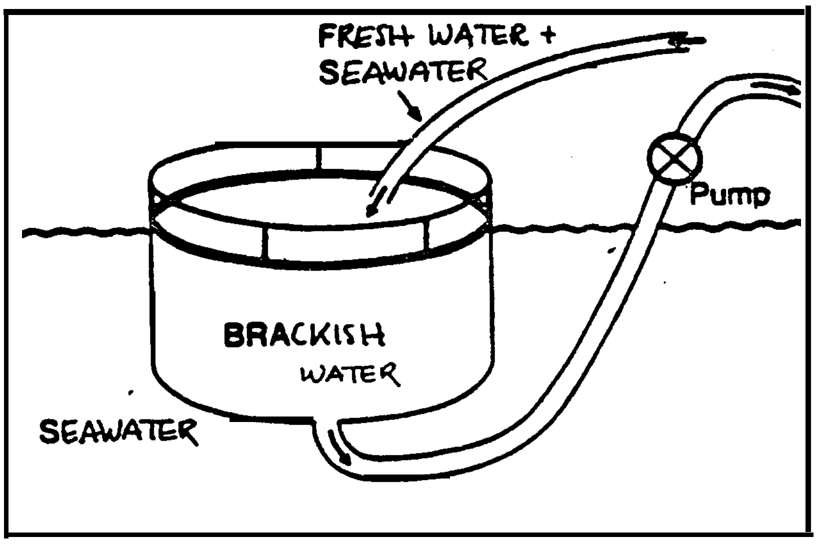
MODEL 6 **Bringing fresh water into cage**

The Arctic char is known to survive the winter in the sea, if the salt content of the water is reduced to 10 - 15 %. The Model is based on a reduction of the salt content in the cage. Thus, after being set out in the sea, the fish stay there until slaughter.

Alternative 1 : The net cage is wrapped in tarpaulin, which is 2.5 - 3 deep and welded at the seams. Fresh water is then brought into the cage. The salt content of the water in the cage will thus increase towards the bottom, and the Arctic char can choose the salinity at which it wants to stay.



Alternative 1 : Net cage with plastic tarpaulin and freshwater inlet, providing increasing salt content towards the bottom.



Alternative 2 : Net cage entirely wrapped in tarpaulin.

Alternative 2 : The second alternative is to cover the entire net cage with plastic tarpaulin and conduct a mixture of fresh water and saltwater into the cage. A discharge pump has to be installed as well. This alternative provides a better possibility for mixing the water and at the 'same time removing waste feed and excrement. The Model can use seawater from the bottom, which is warmer than the surface water in the winter. Also, this system can be installed in localities with little water flow.

MODEL 7 Use of brackish water areas

The Arctic char grows well in brackish water. It may therefore be possible to carry out the entire farming in such an area. However, brackish water farming may be made difficult by ice in the winter. Some technological re-thinking may have to be done before year-round fish farming in brackish water is started.

MODEL 8 Allowing the char to choose locality

When it is difficult to distinguish between Arctic char and freshwater char prior to transfer into seawater, it may be good to give the fish a chance to choose whether it wants to be in seawater or fresh water. A system can be constructed to conduct fresh water over an artificial dam with its bottom part equipped with an enclosure in the sea. The char can then choose where it wants to stay in each season of the year.

MODEL 9 Grazing in the sea

Under natural conditions, an anadromous char stays in the sea for 1 - 2 months, grazing mainly within a radius of 8 - 10 km from the river's mouth. It is known that the fish can double its weight during this stay. Therefore, it can be of interest to study a farming model based on marine grazing.