REPRODUCTION AND CULTIVATION OF FISH

A RESEARCH PROGRAM
1994 - 1998

Academy of Finland

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FOREWORD

The Research Council for Agriculture and Forestry decided on May 25, 1992 to start to prepare a research program entitled "Reproduction and Cultivation of Fish."

A working group was appointed by the Research Council to outline the program. Dr Antti Soivio, Special Researcher and Council member, acted as Chairman, and the members of the group were Professor Malcolm Jobling, University of Tromso, Docent Mikko Nikinmaa, University of Helsinki, Professor Pekka Tuunainen, Finnish Game and Fisheries Research Institute, and Docent Erkki Virtanen, Cultor.

At the meeting on May 27, 1993, the program was approved by the Research Council for Agriculture and Forestry to be submitted to the Central Board of Research Councils. The Central Board of Research Councils approved the program on June 8, 1993.

1. The background of the research program

Intensive fish farming to produce fish for food and stocking started in Finland in the 1960's. At the beginning rainbow trout was mainly produced for food and the eggs of natural trout and salmon stocks were reared for stocking. On both lines an almost exponential development continued till 1989, when the food fish production reached 23.000 metric tons per annum. About 4.5 millions salmon smolts were released, giving a catch of approximately 2,000 metric tons to Finnish fishermen. After that the production of rainbow trout has decreased by about 30 % and the yearly number of salmon smolts released has settled down to about 2.8 million. To protect the natural stocks, international allocations have diminished the catch. Depending on political will, the catches can be increased to the levels corresponding the stocking. This could be a step towards practical sea ranching in the Baltic sea.

The rainbow trout is produced for food from farmed broodstocks because the rainbow trout does not reproduce naturally in Finnish waters. The rivers important to the reproduction of salmon and brown trout are either heavily polluted or they have been built for electricity production. Fish is released to sea and inwaters to ensure continuous fishing. To prevent the distribution of fish diseases, the fish farming industry produces the eggs needed from farmed brood stocks. No serious fish diseases have been detected in Finland.

The diet, possibilities to move, lighting conditions, light rhythm and annual temperature changes of the farmed brood fish differ from those prevailing in regions were the naturally reproducing salmon and brown trout live. When living in ponds or tanks the fish have to depend on a diet recommended and introduced, while the naturally living fish can feed according to their need and will. While moving freely the fish maintain their natural light rhythm even during wintertime and are able to select temperatures higher than 4 oC according to their needs.

Especially in the northern parts of Finland the outdoor ponds are covered with ice and snow before Christmas. From this time onwards the fish live in total darkness which often continues till late April. When the ice melts the fish are directly moved to a long-day light rhythm with the water temperature often still staying below 1 °C.

The development and effectiveness of Finnish foodfish industry is mainly due to the large range of adaptability of the rainbow trout. Farming routines have been adapted and modified, even from totally different circumstances, e.g. those in Denmark, and still a reasonable economic result has been reached in spite of the rather low level of national research on fish farming industry. Since 1989, both the export and consumption have decreased.

The quality of salmon smolts produced for stocking has reached a reasonably high level due to a governmental and some private research programs. The eggs produced by farmed broodstocks have been somewhat problematic both in quantity and quality. The reasons are probably to be found in the differences in living conditions described above. On the other hand, the eggs collected from wild brood fish in 1991 gave notably low fry production (in 1992 the result was even worse) in all Baltic countries. The reason for this is obviously the M74 syndrome, described by the Swedes for the first time in 1974 from River Mörrum. The syndrome, leading to the death of the fish before the swim up stage, is most probably due to some ecotoxicological catastrophe. The situation ought to encourage the research on salmonid reproduction and brood stock maintenance.

From other well valued fish in Finland only whitefish and grayling are farmed. There is an increasing need to introduce pike-pearch to farming, but there exist unsolved difficulties in its startfeeding and reproduction.

2. The present status of research

2.1 Finland

In addition to the Finnish Game and Fisheries Research Institute, integrated research on fish farming is carried out in the National Veterinary and Food Research Institute (NVFI) and the Universities of Oulu, Jyväskylä, Kuopio, Joensuu and Helsinki as well as Åbo Akademi University. The physiology of Salmonid smoltification and the environmental dependence of reproduction cycles of rainbow trout have been the main research interests among the investigations in NVFI and the Department of Zoology in the University of Helsinki. The close relationship between these two institutes has made it possible to produce several master and doctoral theses as well as other publications giving new light to the basics of fish farming routines. The reliability of roe

production in rainbow trout and the even internationally high standard of big sized food fish are mostly due to this long lasting collaboration, which has made it possible to market fish products to Japan. Also the farming routine of salmon smolts, giving an internationally high recapture rate of more than 15 % is a nice result of the joint research between these institutes. However, the stocking material of brown trout is still a big problem; the catch is often smaller than the mass of released material. The possibility to combine the biological, technical and economic knowledge to the same projects is by far the most encouraging feature of the close co-operation between research and private fish farming. The way of combining the resources of governmental and private fish farms to research gives a good basis on which we can continue.

2.2 Scandinavian countries

Denmark is the pioneer of fish farming in Fennoscandia, especially in the field of rainbow trout farming in ponds. At the moment, their main research interests concern the problems of netpen farming in sea, and are very close to the Norwegian research projects. In the field of basic fish physiology Finns have research contacts to the University of Odense. The expansion of rainbow trout and salmon production in Norway in the early 1980's draw the biological and veterinarian research attention towards the problems of intensive fish farming in sea. However, the research interests in Norway do not solve our problems, which are far away from the ordinary problems of farming food fish in the ocean.

The production of one-year-old salmon smolts in geothermal water, to be released in the Atlantic ocean is the main goal of Icelandic fish farming. The economic target is to catch 4 % of the released fish from the site of stocking after a 2 - 3 year- long sea migration. At the moment they lack about half of the catch and the industry is in failure. A need to make sea harvesting more effective is, however, commonly felt in Iceland, Sweden and Finland. The differences are to be found in the methods of producing fish for stocking and in the seas to be exploited (the Atlantic Ocean/the Baltic Sea).

The routines used to produce salmon for stocking purposes are basically similar in Sweden and Finland. So are the goals, because these two countries release about 80 % of the salmon in the Baltic Sea. The main difference comes from the variety of Swedish stocks, which are farmed at the mouth of the river

they originate from. In Finland we have only three original salmon stocks left (in addition to one imported from the River Neva) and the farming has been spread all over the country. As a result of this dispersion there is a need to transport fish long distances to the sites of releasing. When this is done the fish must be moved from one light and temperature regime to a different one. However, the catch in both countries is satisfying, about 15 % of the fish are caught during or after their feeding migration. Fish farming in Sweden and Finland has one big problem in common: the catch of released brown and sea trout is intolerably low. In both countries there is a need to begin the farming of new species.

Consequently, the problems are basically the same. The concentration of fish farming into the northern parts of Finland gives us, however, additional problems due to the long, dark and exceptionally cold farming environment.

2.3 Europe

In the rest of Europe the basic research of fish reproduction and farming is on a high level both in the United Kingdom (e.g. University College of North Wales, University of Stirling, Institute of Freshwater Ecology, Windermere, and in other institutes of Ministry of Agriculture, Fisheries and Food) and France (IFREMER and Laboratoire d'Ichtyologie Générale et Appliquée, Paris). Finland's links to the scientific world of these countries are strong and especially in these laboratories Finnish scientists have developed several warm contacts on a personal level. The research of fish farming is on an advanced level also in Spain, which can be observed in the programs of several Spanish congresses. Other parts of Europe are mainly potential targets for marketing.

3. Focal centers of the research program

The following list shows the variety of research needed in the main areas of aquaculture:

Reproduction is by far the most critical stage in the maintenance of a species. In addition to the transfer of the genetic material from one generation to

the next and the birth of a new individual it must also fulfil the condition for the next generation to be able to reproduce. Reproduction is the main strategy in an individual´s life.

The reproduction of fishes is one of the major problems of our aquaculture.

3.1. To guarantee the production of good quality eggs broodfish culture is to be promoted

The eggs needed to produce fishes for stocking purposes come from cultivated broodfishes. From the cultivation routine in use we must be able to point out factors hampering or helping the developing of fertile roe. The hormonal regulation of reproduction in even, reasonably high (10 °C) temperature is rather well known. But which are the effects of temperature on the production and secretion of hormones responsible for the reproductive cycle? Do we know and master the impact of low temperature on the homeoviscose adaptation affecting the function of steroids? Is it possible to modify the factors underlying these phenomena? Is it possible to generate vitellogenesis in the near-zero temperatures? What is the role of low temperature on the melatonin secretion of the pineal body and which mechanisms lead to sexual maturation? When we master these and several other problems, it will be possible to regulate the mechanisms involved in the reproduction by altering the external conditions (light, temperature, motion, nutrition), in which the fishes live.

3.2. Food and nutritional research

The fishes are able to select their nourishment in natural conditions. The quality of feed is evidently dependent on the age and developmental stage of the fish. What does ideal food consist of? New kinds of food compositions are almost yearly introduced to the market by industrial enterprises. The nutritional composition of proteins, fat and carbohydrates is altered, even without changing the name of the food. However, our knowledge of the effects of peroxidation on cell membranes and their functions is scanty or nonexistent. Can it be possible that the failure in brown trout smoltification is due to failures in food composition? A big question is the effect of food lipids on the homeoviscose adaptation and on the passive and active transport mechanisms in different temperatures.

Antioxidants have been shown to enhance the immunoresponse even in fishes. Which are the mechanisms and how do they depend on temperature? Which are the mechanisms behind the development of lower and upper mode parr resulting in the differentiation between one- and two-year-old smolts? Which are the regulatory mechanisms here? Can they be a consequence of the degree of dominance in the fish group? On what basis does the dominance develop? It is time to abandon the descriptive attitude of research and concentrate on answering the clear question: Why? The problems of environmental pollution can also be connected to nutritional research.

3.3 Timing of smoltification in cultivated fish to favor the beginning of migration after stocking

Smolting and especially its regulation in reared sea and brown trout has been a problem during recent years. This wrong timing has been one of the reasons for low catches from the released fish. To solve this problem, the regulatory mechanisms of trout smoltification must be thoroughly investigated in sea and lake forms of trout in different temperatures in all stages from the homeostatic regulation to the cellular level. Many questions concerning the bioenergetics of smolting remain to be answered. Which are the reasons for slow growth rates after release? The parr in fresh water does not drink but the smolt in sea water drinks to be able to osmoregulate. What is the situation in brackish water? What is the role of drinking in digestion and absorption? How is starvation related to the secretory and absorptive mechanisms of the alimentary canal in different temperatures?

3.4. Introduction of new species (pikeperch, white fish, lamprey) to fish farming

It is vital to develop new specific farming routines to each new species to be reared. A serious problem at present is the startfeeding of pikeperch. To solve the problems intensive research must be focused on the feeding habits and quality of food in natural conditions and the digestive functions in the alimentary

canal of a pikeperch fry. The same is partly true for whitefish farming. The farming routine of lamprey leaves a lot to be desired because the larval stages of lamprey are very badly documented.

3.5. Adopting new methods

Contacts abroad are beneficial for both research and the improvement of farming techniques. The investigation in the field of fish bioenergetics is on a high, advanced level in, e.g. the Universities of Tromsø and Aberdeen. Many research centers have made progress in the field of genemanipulation. Work done at, e.g. the University of Trondheim is ahead of the Finnish projects. In the field of nutritional research the University of Washington in Seattle, University College of North Wales in Bangor and University of Aberdeen in Scotland can be recommended as places of advanced research. In all these centers high-standard basic research is carried on, but the special problems of arctic fish farming in near zero temperatures we have to solve ourselves.

All fields of research mentioned above share the following problems:

The reasons of precocious sexual maturity

The early maturation of parr has been explained by the fact that a great amount of fat is usually stored in the tissues of cultivated fish. The exact mechanism of the phenomenon is not known. However, early sexual maturity tends to decrease the harvesting size of the fish and makes its economy weaker. If we knew the basic background of this phenomenon it could be possible to regulate the length of migration (and the size of the fertile fish).

The fight against parasites and sickness needs more knowledge on

- immunity
- vaccination
- effects of antibiotics

The effects of food and nutritional stage on

- flesh quality
- egg quality
- development of offspring
- environmental pollution

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