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Greetings from the Minister of Fisheries and Agriculture

I want to express my appreciation to all those attending the Conference on Cod Farming in Nordic Countries and welcome you to this event. Your contribution to research and development of this new industry is important and highly appreciated by the Icelandic Ministry of Fisheries and Agriculture.

Cod farming is growing slowly in Iceland, and this year the production is expected to reach nearly 2000 tons. Most of the production is capture-based farming, but interest is growing in using hatchery-reared fry. Now for the first time the demand for fry is greater than the supply.

The fisheries companies in Iceland have led the development of cod farming. Over the next several years further promotion of cod farming is needed, and the ministry will support this as much as possible.

In the Ministry of Fisheries and Agriculture, proposals are being prepared on how to support cod fry production, and they will soon be finished. Cod farming is a good addition to the economy in rural areas and is a good support for what already exists in this field.

The last annual 500-ton allocation of cod quota for on-growing will expire in 2010. In the near future a workgroup will be appointed to review the rules on on-growing. It is anticipated that the current arrangement will be changed so that on-growing of wild cod can be increased.

In recent years breeding efforts in cod farming have been greatly bolstered. Plans call for this to continue since breeding is an essential element in building up profitable full-cycle cod farming in the future.

Many research and development projects on cod farming are international, and cod is also competing in markets with other kinds of whitefish. It is therefore important for Nordic scientists and cod farmers to work jointly on solving the main problems to ensure competitive cod farming.

I thank all those who have helped in organizing this conference and I am certain that it will make a real contribution to the development of an important new part of our seafood sector.

Einar K. Guðfinnsson

Minister of Fisheries and Agriculture

Organizers of the conference

Nordic cod farming network

The Nordic Cod Farming Network is a cooperative project with representatives from Faeroes, Denmark, Sweden, Iceland and Norway.

Objectives

The overall project objective is to create a forum for R&D dissemination to develop the cod farming business in Nordic countries.

Sub objectives

- Define status and need for cod farming in the Nordic countries
- Define important research topics
- Distribute information to cod farmers by the internet

Members of Nordic Cod Farming Network

Hannes Gislason, Aquaculture Research Station of the Faeroes
Jana Pickova, Swedish University of Agricultural Sciences Uppsala, Sweden
Josianne G. Støttrup, Danish Institute for Fisheries Research, Denmark
Jørgen Borthen, Project Leader "Go for Cod", Norwegian Seafood Centre, Norway
Valdimar Ingi Gunnarsson, AVS Aquaculture group, Iceland

AVS Aquaculture group

Aquaculture group is a part of the AVS group, established by the Minister of Fisheries to look at possible ways to increase the value of Icelandic fisheries products. The main objectives are:

- Be a liaison to the ministry of fisheries and agriculture and to the AVS Project management group
- Be leading for the work of special-topic groups to ensure further strategic work within the industry
- Acquire more information regarding competitive competence
- To take initiative in regular assessment of the progress of research and development

Website: www.fiskeldi.is and www.thorskeldi.is

Conference Committee

Björn Björnsson, Marine Research Institute
Valdimar Ingi Gunnarsson, AVS Aquaculture group

Conference website: www.fiskeldi.is/codconference.html

Meeting program

Day 1: Tuesday, 30 September

08:00 **Registration**

09:00 **Welcome, Minister of Fisheries and Agriculture in Iceland**

Session 1: Stock enhancement and sea-ranching

Chairman: Jóhann Sigurjónsson, Marine Research Institute

09:15 Rationale for restocking the eastern Baltic cod and results achieved so far, Josianne Støttrup, Danish Institute for Fisheries Research

09:35 Cod ranching in Iceland, Björn Björnsson, Marine Research Institute

09:55 Discussion

10:05 **Coffee break**

Session 2: Capture-based farming of cod

Chairman: Rannveig Björnsdóttir, Matís Ltd./ University of Akureyri

10:30 Capture based aquaculture of cod - state of the art in Norway, Bent Dreyer, Norwegian Institute of Fisheries and Aquaculture Research

10:50 Capture and on-growing of cod juveniles in NW Iceland, Thórarinn Ólafsson, Háafell Ltd.

11:05 Cod farming quota project in Iceland, Valdimar Ingi Gunnarsson, Marine Research Institute

11:20 Discussion

Session 3: Juvenile production

Chairman: Josianne Støttrup, Danish Institute for Fisheries Research

11:35 Production and challenges of juvenile cod production – on overview, Albert K. Imsland, Akvaplan-niva Ltd.

11:55 Hatchery production of cod in Iceland, Agnar Steinarsson, Marine Research Institute

12:10 The effect of carbon dioxide on cod growth in recirculating aquaculture systems, Damian Moran, Danish Institute for Fisheries Research

Workshop: New Organic Aquaculture Standards and the Farming of Organic Cod

Tuesday, 30 September in Múli, Grand Hotel

Chairman: Karl Gunnarsson, Marine Research Institute

10.30 New Icelandic standard for organic aquaculture and the farming of cod,
Helgi Thorarensen, Hólar University College

10.50 Organic cod farming in the context of international development of organic aquaculture: Standard setting, certification and production,
Stefan Bergleiter, Naturland, Germany

11.35 Discussion

12.25 Cod larviculture - Preparing for a tough life, Rannveig Björnsdóttir, Matís Ltd./ University of Akureyri

12:40 Discussion

13:00 **Lunch**

Session 4: Cod diseases and vaccination

Chairman: Sigríður Guðmundsdóttir, Institute for Experimental Pathology, Keldur, University of Iceland

14:00 Cod diseases – an overview, Hege Hellberg, National Veterinary Institute, Norway

14:20 Cod diseases in Iceland – an overview, Árni Kristmundsson, Institute for Experimental Pathology, Keldur, University of Iceland

14:35 The immune system of cod, Bergljót Magnadóttir, Institute for Experimental Pathology, Keldur, University of Iceland

14:50 Vaccination of farmed cod, Bjarnheiður K. Guðmundsdóttir, Institute for Experimental Pathology, Keldur, University of Iceland

15:05 Discussion

15:25 **Coffee break**

Session 5: Atlantic Cod Genomics and Broodstock Development

Chairman: Jónas Jónasson, Stofnfiskur Ltd.

15:50 Atlantic Cod Genomics and Broodstock Development in Canada, Edward Trippel, Fisheries and Oceans, Canada

16:10 Molecular biology in cod breeding, Sigríður Hjörleifsdóttir, Matis Ltd.

16:25 The Icelandic cod breeding programme, Theodór Kristjánsson, IceCod Ltd.

16:40 Comparison of Atlantic cod from the Faroe Bank and the Faroe Plateau by genetic analyses – initial studies, Petra Hansen, Aquaculture Research Station of the Faroes

16:55 Discussion

17:15 End of the first day

Day 2: Wednesday, 1 October

Session 6: Feed for cod

Chairman: Helgi Thorarensen, Hólar University College

09:00 Feed and nutrition in cod farming – an overview, Jón Árnason, Matis Ltd.

09:20 Latest developments and way forward regarding feed for cod, Torbjörn Åsgaard, Akvaforsk

09:40 Possible effects of feed containing plant oils on farmed cod, Jana Pickova, Swedish University of Agricultural Sciences

09:55 Discussion

10:15 **Coffee break**

Session 7: On-growing of cod

Chairman: Hannes Gislason, Aquaculture Research Station of the Faroes

10:40 On-growing of farmed cod in Norway - an overview, Per Gunnar Kvenseth, Villa Organic

11:00 Cod farming in the Faroe Islands, Arne Kolbeinshavn, Aquaculture Research Station of the Faroes

11:20 Can photoperiod affect onset of puberty of farmed cod? Thorleifur Ágústsson, Matis Ltd.

11:35 Discussion

Session 8: Marketing of farmed cod

Chairman: Jana Pickova, Swedish University of Agricultural Sciences

11:50 Marketing of fresh cod, Karin Olsen, marketing manager of white fish/codfishes, Norwegian Seafood Export Council

12:10 Eco-labelling - status and challenges, Per Gunnar Kvenseth, Villa Organic

12:25 Marketing of farmed cod from Iceland, Ágúst Torfi Hauksson, Brim hf.

12:40 Discussion

13:00 **Lunch**

Session 9: Industrial view

Chairman: Jørgen Borthen, Project Leader "Go for Cod", Norwegian Seafood Centre

14:00 Strategy for Codfarming, Sturle Skeidvoll, Board member in Codfarmers ASA

14:20 Cod farming at Cooke Aquaculture, Frank Powell, Cooke Aquaculture

14:40 Integration of cod fisheries and cod farming at Hradfrystihusid-Gunnvör Ltd., Kristján G. Jóakimsson,

15:00 Discussion

15:15 **Coffee break**

Session 10: Production cost and competitiveness of cod farming

Chairman: Sigurður Stefánsson, Glitnir bank

15:40 Competitiveness of cod farming, Lars Liabø, Kontali Analyse

16:00 Production cost in cod farming in Norway, Jørgen Borthen, Project Leader "Go for Cod", Norwegian Seafood Centre

16:20 Fishing for financing, Kjartan Ólafsson, Glitnir bank

16:40 Discussion

17:00 **Reception hosted by the Icelandic Minister of Fisheries and Agriculture**

Day 3: Thursday, 2 October

Icelandic Fisheries Exhibition 2008

Following the last day of the conference the 9th Icelandic Fisheries Exhibition will open its doors on the 2nd of October. The Icelandic Fisheries Exhibition will be open from 2-4 October in Smárinn, Kópavogur about 5 km from the conference hotel. Further information is to be found on the exhibition web site: www.icefish.is

Posters

Kettunen, A., Fjalestad, K. & Mortensen, A. Selection for increased disease resistance in cod.

Maier, V.H. et. al. Healthy cod - endogenous antibiotics in cod.

Lauzon, H.L. Gudmundsdóttir S., Steinarsson , A., Oddgeirsson, M., Magnadottir, B., Árnason, Í.Ö. & Gudmundsdóttir, B.K. Effects of autochthonous probionts at larval and juvenile stages of Atlantic cod (*Gadus morhua* L.) rearing.

Gísladóttir, B., Gudmundsdóttir, S., Brown, L., Jónsson, Z.O. & Magnadóttir, B. Isolation and characterisation of two C-reactive protein homologoues from cod (*Gadus morhua* L.).

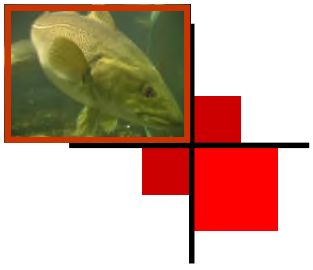
Gísladóttir, B., Gudmundsdóttir, S., Jónsson, Z.O., Audunsdóttir, S.S., Bragason, B.Þ. & Magnadóttir, B. Acute phase response of cod (*Gadus morhua* L.).

Björnsson, B., Steinarsson, A. & Arnason, T.. Growth model for Atlantic cod (*Gadus morhua*): effects of temperature and body weight on growth rate.

Johannsdottir, J.T., Hakonardottir, K., Hrolfsdottir, L. Hermannsdottir, R., Steinarsson, A. & Bjornsdottir, R. Detection and stimulation of IgM production in first feeding cod (*Gadus morhua*) larvae.

Bjornsdottir, R. Johannsdottir, J.T. Thorarinsdottir, E.E., Petursdottir, M., Steinarsson, A. & Sigurgisladóttir. S. Mapping of bacteria associated with first feeding cod (*Gadus morhua*) larvae.

Adalbjarnardóttir, A., Frye, S.A., Andrésdóttir, V., Tønjum, T. & Guðmundsdóttir, B.K. Study of the *Aeromonas* ExeD secretin.



An overview of cod farming

Björn Björnsson, Marine Research Institute (MRI), P.O. Box 1390, Skúlagata 4, 121 Reykjavík, Iceland
bjornb@hafro.is

Introduction

During the last four decades the total catch of Atlantic cod has declined from 3.9 to 0.8 million tonnes due to overfishing and environmental changes. Other species of whitefish both from wild stocks (e.g. walleye pollock) and fish farming (e.g. pangasius) have only partially filled the gap and thus there is believed to be a large market for farmed cod. During the last two decades the total world catches of fish have been stable around 90 million tonnes whereas the production from aquaculture has increased from about 10 to 50 million tonnes.

For thirty years there has been interest in developing farming of cod. In 1983 there was a milestone conference in Norway called: "The Propagation of Cod *Gadus morhua* L." At that conference results of the first successful mass production of juvenile cod in a Norwegian lagoon were presented as well as the first intensive production of juveniles in an English laboratory.

Sea ranching

In the late 19th century, large cod hatcheries were built in USA and Norway to produce yolk sac larvae for stock enhancement purposes. In the period 1924-50 the American hatcheries released between 1.5-2.5 billion larvae and the Norwegian hatchery between 20-400 million larvae per year. In Danmark there is renewed interest in using yolk sac larvae for restocking the eastern Baltic cod stock, which has been severely depleted in recent years. In the period 1976-96 several studies were carried out in Norway to explore the possibilities of enhancing the local cod stocks by releasing farmed juveniles in Norwegian fjords. The conclusion of those studies was that sea ranching of cod in Norway was not economically feasible.

Capture-based farming

For more than 20 years capture-based farming of cod has been carried out on a relatively small scale in Norway, Iceland and Canada, mainly based on capturing 1-3 kg cod and rearing in sea cages for several months. In 2007 the total production by Norway and Iceland amounted to about 3000 tonnes (Canada has dropped out).

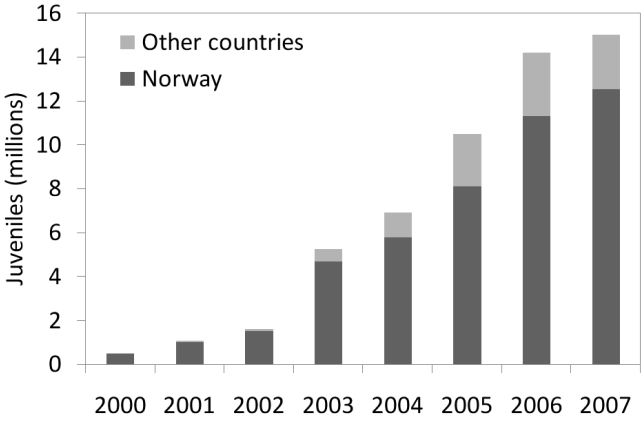


Fig. 1. Production of cod juveniles in Norway and other countries in the years 2000-2007.

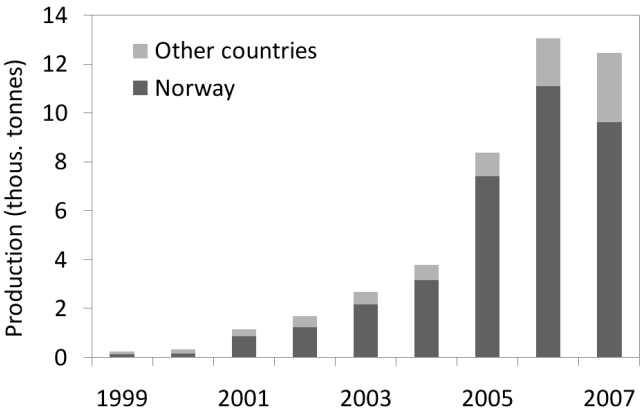


Fig. 2. Production of farmed cod in Norway and other countries in the years 1999-2007 (including capture-based farming).

Experimental ranching trials of free-ranging cod have been carried out in Iceland 1995-96 and 2005-06 based on forming herds by regular feeding at certain locations and subsequent harvesting.

Production of juveniles

Full-cycle farming with juveniles produced in hatcheries only started about eight years ago in Norway, UK, Canada, USA and Iceland. In the year 2007 about 15 million juveniles were produced in the world, most of it in Norway (Fig. 1). Initially, the quality of hatchery produced juveniles was not as good compared to wild juveniles or juveniles produced in lagoons on natural zooplankton. The incidence of deformities was higher and the growth

rate less for hatchery reared juveniles. With improved enrichment of rotifers, better formulated feeds and improved physical conditions the quality of hatchery produced juveniles has gradually improved.

On-growing

There was a rapid increase in total production of farmed cod until 2006 when it reached 13 thousand tonnes, most of it in Norway. There was a slight reduction in the production in the following year (Fig. 2). In the foreseeable future the largest production of farmed cod will be in Norway. The rate of increase in cod farming will depend on the profit margin. At the moment there are few companies making money from cod farming but with increased experience, better quality of juveniles, selective breeding, development of vaccines, prevention of sexual maturation and better feeds it is hoped that cod farming will be profitable.

Research and development

Presently, selective breeding of cod is being carried out in Norway and Iceland but in Canada and the Faroe Islands selective breeding is about to start. The main emphasis will be to select for faster growing fish. Initial results indicate that for each generation the growth rate can increase by at least 15%, i.e. 5% per year. Usually the feed conversion also improves with increased growth rate. Many of the farmed cod (especially the males) become sexually mature in their first year in sea cages before they attain a weight of 1 kg and virtually all of the fish become sexually mature in their second year before they attain 3 kg. The growth rate is affected much more by the second than first maturation. It is not considered feasible to get rid of the first maturation with selective breeding. However, selecting for increased growth will in time produce market size fish before it attains the second maturation. In laboratory experiments it is possible to prevent sexual maturation in cod with photoperiod manipulation but it has proven more difficult in outdoor sea cages. Whether this method is feasible on a commercial scale has yet to be established.

There have been large mortalities of cod juveniles in sea cages, up to 20-30% per year, mainly due to bacterial diseases. It has proven difficult to develop efficient vaccines for cod but research and development in this field is under way. Cod is capable of escaping through small holes in the net which can result in serious losses. Cod have been seen tearing the net with their teeth and thus it is necessary to use stronger and more expensive nets.

Grower feeds constitute the largest expenditure in cod farming. They must be nutritious and well balanced to ensure fast growth and high growth efficiency, yet they must be inexpensive. There are ongoing studies to determine how much of the protein and fat from marine origin can be replaced by raw material from terrestrial plants to reduce feed cost. Finally, feeding systems developed for salmon farming are being tested and adapted to cod farming to reduce labor cost and minimize feed wastage.

Future prospects

There is some uncertainty about how fast the cod farming industy is going to grow. The production capacity of juveniles is not a limiting factor anymore. However, large capital is required to build up biomass in cod farming and the banks hesitate to grant loans while the world markets are down. Therefore it is likely that the cod farming industry will grow slowly for the next few years. However, during this phase the farmers and researchers will gain much more knowlegde about cod farming and find ways to make it more profitable, e.g. with selective breeding. Now the price of farmed cod is at a peak level but the price could drop substantially if the wild cod stocks came back to their normal levels. Perhaps, the most serious threat to the cod farming industry may thus be the restoration of the cod stocks, especially during the next 20 years.

Cod farming in Norway

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Vision

”One way or another, fish will be farmed. China, India and the countries of Southeast Asia are surging ahead, producing more aquacultured animals than the rest of the world combined, with very little attention paid to environmental concerns. Private investment in cod farming in Norway is building, and entrepreneurs are predicting that the harvest of farmed cod, like salmon before it, will begin to grow exponentially in the next few years and surpass the country's wild cod catch by 2020. As acquaculture surges, the central question is starting to change. It is no longer "should" the oceans be farmed. Rather, it is "how." No matter what Norway or the Shetlands do with cod, at least they will have thought about it. At least they have the beginning of a philosophy and the semblance of a plan. ” (New York Times, June 18, 2006, Paul Greenberg)

Production

- The total sales from Norwegian cod farming in 2007 was around 10,000 tons (2006: 11,000 tons, 2005: 8,000 tons. These figures include around 1,500 tons from capture-based farming.
- This volume will increase in the nearest years, and the plan is to annually produce 15,000-30,000 tons in the coming 3 - year period.
- Today almost 100 companies of all sizes are in this business, of them around 10 produces 500 tons and more yearly.

R&D

Aquaculture is one of the seven large-scale programmes established by the Research Council of Norway, and financed by The Ministry of Fisheries and Coastal affairs. Large-scale programmes are an important new initiative towards realising central research–policy priorities. The programme is developed through extensive dialogue within and between research communities, users and public authorities. Norwegian Research Institutions and industry have for the past 25 years developed knowledge used in cod farming. The first small cod was produced in 1983 by Norwegian scientists. There have been hundreds of private financed projects ongoing the last years in Norway. Only a part of these projects are financed by the Research Council in Norway or EU/Nordic Funds.

Codlight - tech an EU CRAFT financed project is ongoing with leading partner from Iceland, with Norwegian partnership from IMR, Intravision Group AS and Fjord Marin AS. Website address: http://www.codlight-tech.com

Strategic Plan COD 2001-2010

Key findings in R&D outlined in the plan are:

- Production methods for good quality fry and broodstock
- Sexual development in relation to economic and environment friendly production
- Genetic and ecological interactions between wild and farmed cod
- Production methods and technology to ensure fish welfare and prevent escapement
- Disease and parasite control, with focus on vaccine development
- Selective breeding to increase production yield
- Feed and nutrition
- Product development, utilization of raw material, product quality
- Development of gentle, cost-effective and approved systems for weighing, counting and measuring individual fish.
- Marked knowledge and consumer behaviour
- Safe seafood will require knowledge about xenobiotics and metals (iodine, selenium and heavy metals)

Research Council of Norway

Cod projects 2008 (in millions NOK):
Juveniles 7.375, Ongrowing NOK 20.052, Live caught raised NOK 0.756, Technology NOK 0.985, Genetics 12.256, Health 17.465, Environment, welfare etc 10.050, Markets and products 5.586. Total 74.525.

Long term goals

- Norway’s marine environment is ideal for cod farming with cold, clear water and an environment that is natural for cod. The goal is to establish a production, based on sustainability, food safety and high quality

products.

- A combination of wild cod, capture-based and farmed cod gives us a possibility to deliver cod to the market 365 days a year.
- In the future – it is our hope that farmed cod can become as important for Norway as the salmon and trout farming industries are.
- But it is a long way to go. The production in 2008 is expected to be 14,000 tons.
- Even if the industry is up-and-coming, they are also up against challenges related to up-scaling; both biological and economical related knowledge are needed for further growth on a sound basis, biologically and financially.
- Always been a close cooperation between Nordic Countries, also in this field. Many Nordic researchers have their degrees from one of your universities.
- As a follow up on the Ministers initiatives, Norwegian North American strategy, USA, Canada and Norway have established several joint aquaculture research projects. Main areas are fish health, genomics, feeds for tomorrow's fish farming and farming technology. Cod research is included in several research projects proposed by scientists from the three countries.

The annual Go for Cod- network conference (open) includes English language sessions on:

1. Cod farming in Norway
2. Farmed species in competition with cod
3. Cod health and other important R&D
4. International cod networking
5. Excursions to cod farms
6. Cooking competition on cod and best farmed cod awards

Next meeting will be in Bergen, Norway 11- 13. February 2009. Info: borthen@sjomat.no

Cod farming in Iceland

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valdimar@sjavarutvegur.is

The first on-growing trials with wild cod started in Iceland in 1992. For the first years the amount of cod farmed in sea cages was limited but increased greatly in 2002 when the Ministry of Fisheries decided to allocate 500 tonnes quota annually to promote cod farming in Iceland. The production of cod juveniles was carried out on a research basis since 1994 and scaled up in the year 2004. A selective breeding program for cod farming was started by the company IceCod Ltd. in 2003. This is recognized as an important step for future development of cod farming in Iceland.

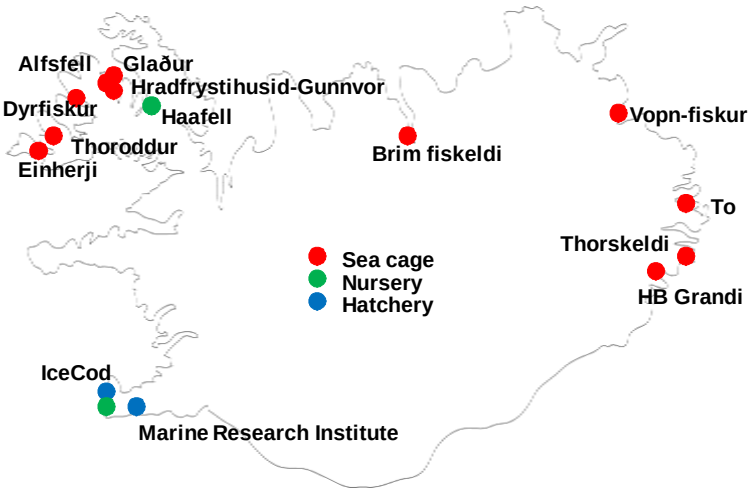

Fig. 1. Location of cod farms in Iceland.

Juvenile production

The hatchery production has been carried out at the Mariculture Laboratory of the Marine Research Institute which is located on the southwest coast of Iceland (Fig. 1). In the years 2004-2007 the hatchery produced 100,000-200,000 cod juveniles per year which have been delivered to cod farms in Iceland and the Shetlands (Fig. 2). The company IceCod Ltd. has recently started production of cod juveniles and the production is expected to increase next year. Each autumn since 2003 about 1 million cod juveniles have been collected in an inshore area in Northwest Iceland and reared in Haafell´s nursery over the winter months; in the following spring 300,000-700,000 juveniles have been stocked in sea cages. With selective breeding and better culture technology it is expected that the quality of the hatchery produced juveniles will be superior to the wild juveniles.

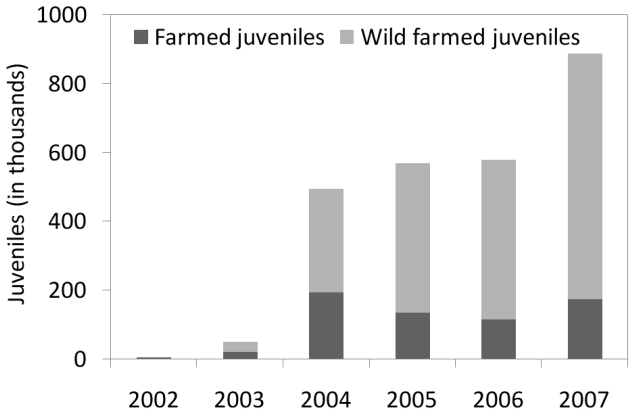

Fig. 2. The production of wild farmed and farmed juveniles stocked in sea cages in the years 2002-2007.

On-growing

Today 11 farms are on-growing wild or hatchery produced cod (Fig. 1). The slaughtered volume of farmed and wild farmed cod has increased from 10 tonnes in year 2000 up to 1450 tonnes in 2007 (Fig. 3). Hradfrystihusid-Gunnvor and Brim, the two largest producers of farmed cod in Iceland, are vertically integrated seafood companies, controlling the juvenile production, on-growing, harvesting, packaging and marketing of the products. Today it seems that on-growing of wild cod is more economically efficient than using farmed juveniles. For the next few years the production of cod will

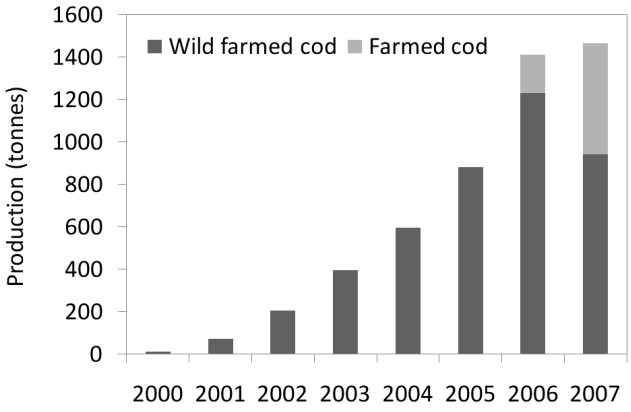

Fig. 3. The production of wild farmed and farmed cod in the years 2000-2007.

still be based mainly on on-growing of wild cod. There is going to be slow growth in the production of farmed cod in Iceland and the expected volume is less than 4000 tonnes in 2010. If cod farming in Iceland becomes profitable a large increase in production is to be expected after 2010, especially when the breeding program can deliver cod juveniles with faster growth and delayed maturity.

Research and Development (R&D)

In the year 2008 about 15 R&D projects are financed with grants from Icelandic funds. The following R&D projects are now in progress:

Cod breeding and juvenile production
- Cod breeding program and juvenile production
- Bioactive compounds for cod larvae

Sexual maturation and growth
- Control of growth and sexual maturation of cod by use of cold cathode light technology
- Genetics of photoperiod effects and maturation in cod
- The effects of salinity on growth rate, feed conversion and biology of cod
- Induction of triploidy by pressure shock in cod and investigation of its effects on newly fertilized eggs, larval quality and maturity status in adult fish

Disease and immune system of cod
- Research projects on *Aeromonas salmonicida*
- Isolation of a psychrophilic enzyme and vaccine development against winter ulcers caused by the bacterium *Moritella viscosa*.
- Characterisation of endogenous antibiotics in cod
- Research on cod immune system

On-growing of wild cod
- Cod farming quota project
- Cod ranching in Arnarfjördur

Other projects
- Processing and quality of farmed cod
- Sea cage for farming in Icelandic fjords

Icelandic scientists are also participants in a few international R&D programs with grants from Nordic and EU funds.

The strategic plan for R&D work

In the year 2007 strategic plan for R&D work 2008-2010 was published for cod farming by AVS aquaculture group (AVS stands for Added Value in Seafood). The main objectives in the strategic plan are as follows:

Selective breeding of cod
- IceCod´s selective breeding program

Juvenile production
- Increasing productivity in cod larvae culture
- Improvement of growth and quality of cod juveniles
- Enrichment of live food for cod larvae

Cod diseases and vaccination
- The immune system of cod
- Development of vaccine (especially against *Aeromonas salmonicida*)

Environmental condition and farming technology
- Improve knowledge of ice, algal blooms and jellyfish (*Cyanea capillata*) in Icelandic fjords
- Development of submerged cages
- Preventing sexual maturation of cod
- Production of large juveniles in land based farms for stocking in sea cages
- Cannibalism

Today only a few Icelandic R&D projects for cod farming are carried out in cooperation with scientists in other countries. It is desirable to increase the cooperation between scientists in countries in the North Atlantic.

Cod farming in Denmark

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Commercial activities

No strategic plan for developing cod farming in Denmark has been drawn up. There is no commercial activity with this species at present.

R & D activities

Two projects concerning cod farming are presently in operation in Denmark; RESTOCK and CODFARM.

RESTOCK is a project concerned with restocking the eastern Baltic cod stock, which has been severely depleted in recent years. A rationale for restocking was described in a report in 2005 and published in 2008 (Støttrup et al. 2005; Støttrup et al. 2008a). The RESTOCK project was therefore initiated in 2005 to demonstrate the practicality of restocking. A broodstock was established which, through photoperiod manipulation, can produce eggs from April to September. Egg incubation techniques and larval production techniques were established, as well as techniques for marking fish larvae and their release at different depths depending on ambient temperature conditions. All the work is conducted on land in closed recirculation systems and on artificial seawater. The results so far are collated in a project report (Støttrup et al., 2008b). It is expected that the project will continue for a further three years if the necessary funding is available.

CODFARM is a project concerning on-growing cod in land-based recirculation systems (RAS). Information on cod rearing was collated in a report 2002 (Støttrup, 2002), which provided the background for a feasibility study conducted by Cimbria Aquatec A/S and KPMG to establish whether or not it would be economically feasible to rear cod in recirculation systems in Denmark (Cimbria Aquate A/S 2002; Sørensen, 2002). The findings of that study was that although it was biologically and economically feasible to rear juvenile cod to 5 g in land-based RAS, it was not economically viable to rear cod beyond 5 g. Subsequent to this study a commercial enterprise was interested in examining in more detail the costs for rearing cod, as no actual data existed at that time on cod growth or actual costs for rearing cod in RAS. The project CODFARM was therefore launched in 2006. The CODFARM project was just recently completed, and the results will be published in a DTU Aqua report (Jarlbæk & Støttrup, 2008), and in separate scientific publications. The results of some of the experiments show a potential for rearing cod in closed recirculation systems, providing good growth and food conversion rates higher than those documented in the literature so far, also at high densities of up to 90 kg fish per m^3. However, several disease issues were highlighted during the project and a well-functioning disease management program would be an essential prerequisite for a commercial RAS. Concurrent with the absence for a strategic plan incorporating the development of cod farming, no plans for further research projects on cod have been made.

References

Cimbria Aquatec A/S. 2002. Projekt Danish Cod. Hovedrapport. 35pp.

Jarlbæk, H., Støttrup, J.G. In press. Torskeopdræt i landbaserede recirkulerende anlæg. Fase II. "Pre-production trials". 185pp.

Støttrup, J.G., Overton, J.L., Möllmann, C., Paulsen, H.E., Pedersen, P.B., Lauesen, P. 2005. Opdræt af torskeyngel til udsætning i Østersøen. DFU-report 143-05.

Støttrup, J.G., Overton, J.L., Paulsen, H., Möllmann, C., Tomkiewicz, J., Pedersen, P.B., Lauesen, P. 2008. Rationale for restocking the eastern Baltic. Reviews in Fisheries Science 16, 58-64.

Støttrup, J.G., Overton, J.L., Sørensen, S.R. (Eds.). The production of Baltic cod larvae for restocking in the eastern Baltic. RESTOCK I. 2005-2007. DTU Aqua report nr. 189-08. 81 pp.

Sørensen, M.S. 2002. Danish Cod. Torskeopdrætsprojekt. Evaluering af torskeopdrætsprojekt. BD gruppen, KPMG. 53pp.

Cod farming in Sweden

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Ongoing activities

A project on cage keeping of spawning fish on the west coast of Sweden has been initiated. This project aim is to reproduce and thereby re-introduce fjord cod in fjords where no catch has been obtained during some years. It is coordinated by Lysekils kommun. Also the Board of Fisheries is involved in this project.

No commercial activities are presently ongoing in Sweden.

R & D

Codlight - tech an EU CRAFT financed project is ongoing with Swedish partnership from Swedish University of Agricultural sciences.
Website address: http://www.codlight-tech.com

A previous project has shown that plant oils might inhibit gonad maturation. Results from this project are presented in three scientific publications.

Mørkøre,T., Netteberg, C., Johnsson, L. Pickova, J. 2007. Impact of dietary oil source on product quality of farmed Atlantic cod, *Gadus morhua*, Aquaculture 267; 1 -4: 236-247.

Pickova, J., Mørkøre,T. 2007. Alternate oils in fish feeds. European Journal of Lipid Science and Technology 109: 256-263.

Pickova, J., Mørkøre, T. 2007. Plant Oils as Fish Oil Replacements in Fish Feeds. Feedinfo News Service Scientific Reviews. March 2007. Available from : URL: http://www.feedinfo.com."

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Cod farming in the Faroe Islands

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Cod farming in the Faroe Islands is in its infancy with one public research institution and two private companies actively involved. The interest in cod farming in the Faroe Islands is mainly due to the near-ideal environmental conditions around the islands and most importantly the sea-water temperature of about 6-10 ^{o}C. This temperature window is close to optimal for on-growth of cod with weights larger than 100 g, as seen by model calculations of specific growth rate of cod for various weights as a function of temperature (B. Björnsson et al. / Aquaculture 271 (2007) 2 16-226). The availability of high quality brood fish captured from two distinct populations stocks of cod, the costal cod and the Faroe Bank cod, is also an important asset for cod farming in the Faroe Islands.

From the point of fisheries management, these cod stocks are now seriously depleted, and the fisheries of cod around the islands have dropped to about 12,800 tons in 2007 as compared to a mean value of 23,700 tons for the period of 1993-07. The standard deviation of 10,400 tons for the same period indicates unsustainable high variations in the cod fisheries. This large variation may in part be caused by unsuccessful fisheries management. With proper management of the fish stocks in place, the situation may improve with time.

Future cod farming in the Faroe Islands may, however, prove to be an important sustainable supplement, or even a sustainable alternative to the variable cod fisheries, now also seriously troubled by the high oil prices. Cod farming close to land, or on land, is less affected by the high oil prices, and as an extra benefit, cod farming may lead to a better utilization of the cod liver. In the cod fisheries around the Faroe Islands, the cod liver is usually discarded.

Diversification of the aquaculture industry may also have significant future interest. Although salmon aquaculture in the Faroe Islands is very successful at the moment, this situation may change because of competition from other countries, e.g. Chile, or from disease problems in salmon aquaculture.

Juveniles for cod farming 2006-08

The research institution Fiskaaling has been working on juvenile production in Nesvik since 2005. The juveniles are mainly produced from brood fish captured at the Faroe Bank (FB), but also from costal cod (CC), and the cod fry is produced with a semi-intensive method known from Norway.

Fig. 1. Juvenile production in Nesvik, P/F Fiskaaling.

Fig. 2. On-growing in sea cages in Árnafjørður, P/F Faroe Salmon.

In 2006, the juvenile production was 140,000. Then, on-growing of 100,000 FB-juveniles from Fiskaaling was started in sea cages by P/F Faroe Salmon, Árnafjørður, in December 2006. Also, in January 2007, 32,000 FB-juveniles and 8,000 CC-juveniles were put into a recycling plant built by P/F Faroe Cod Farming, Hvalba.

Unfortunately, since 2006, the juvenile production at Fiskaaling has been declining due to various production problems with the semi-intensive method. The whole production of 41,000 FB-juveniles in 2007 was put into the recycling plant in

March 2008. In 2008, the juvenile production is only about 20,000, and no decision has been made regarding the on-growth of this year's production.

Good growth results in 2008 from on-growing in sea cages

However, 2008 is an exiting year for cod farming in the Faroe Islands, because successful growth results have been obtained from the on-growing in sea cages since 2006. The mean weight obtained from 20 months growth at sea in 24 h light is 4100 g. The total growth period is 28 months from egg: 2 months start feeding, 6 months to 6o g, and 20 months on-growing at sea to 4100 g. The corresponding growth in sea cages in Árnafjørður without light is 3000 g. These results regarding growth rate, both with and without light, are milestone results for cod farming in the Faroe Islands.

In comparison, according to B. Björnsson et al., fast growing juveniles, year-class 2002, produced in sea lagoons on natural zooplankton (Parisvatnet, 7 months to 70 g) reach 4000 g in about 25 months on-growing at sea under constant illumination (Villa Cod farm, Norway). Slower growing intensively produced 30 g cod juveniles stocked in sea cages 15 May 2003, and reared under constant illumination, were predicted by the growth model to reach 1600 g and 2100 g by the end of the second year and 4600 and 6300 by the end of the third year, in Northwest Iceland and West Norway, respectively.

Main research and development projects today

The main current research and development projects are: the cod juvenile production, the on-growing in sea-cages and in the recycling plant on land, and a PhD-project at Fiskaaling investigating the possible growth- and genetic differences between the costal cod and the Faroe Bank cod.

The strategic plan for R&D

Depending on future national funding, Fiskaaling intends to improve the cod juvenile production, and invest in much better facilities for this activity and for research projects investigating various aspects of cod farming. Also, the possibilities for a large EU/ Nordic research project within cod farming should be considered.

Expected development in cod farming

The developments in cod farming are hard to predict. However, we expect an increased interest from the industry from the good growth results in sea cages. This will, however, also depend on the escape and mortality rates, which are not known at the moment.

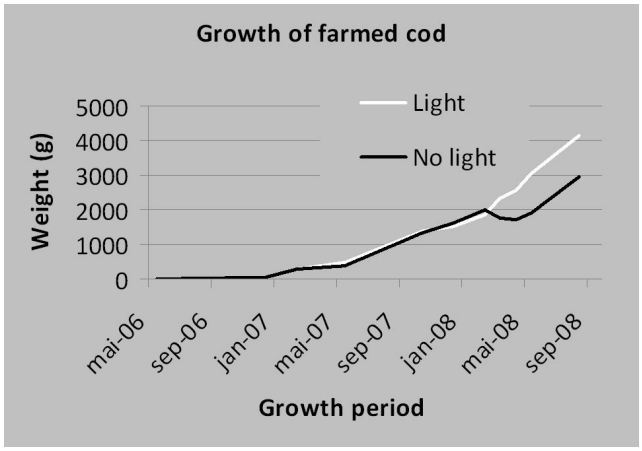


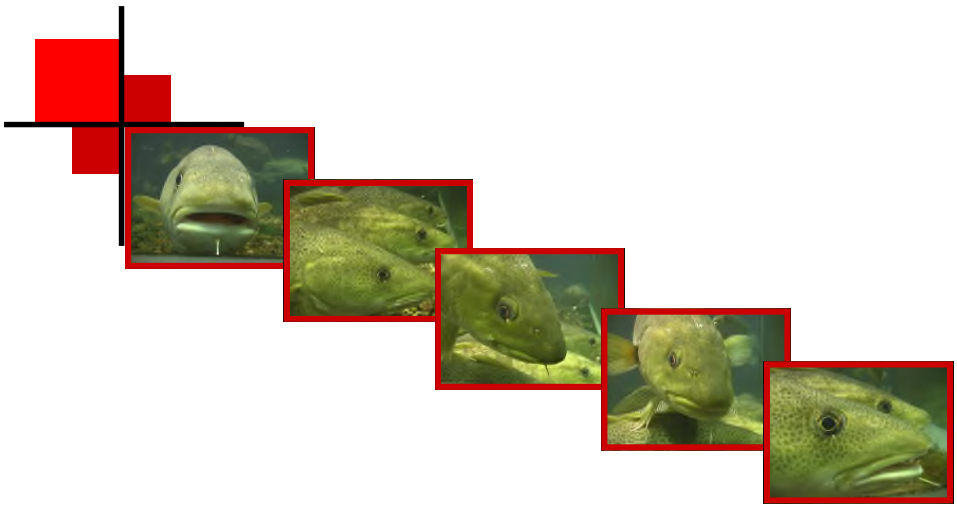
Fig. 3. Growth curves of farmed cod for 8 months at sea in Nesvik and 20 months at sea in Árnafjørður.

Source: P/F Fiskaaling.

Fig. 4. Recycling plant. P/F Faroe Cod Farming, Hvalba.

The results from the growth trials in the recycling plant on land have until now been less successful. Although, the rate of sexual maturation has been low, so has the growth, and the cod in this plant has not reached much beyond 2000 g. The recycling plant with marine biofilters and 24 h light illumination on land is however a very exciting industrial experiment, which may reach better results, when the production processes are fully optimized.

In conclusion, the biological results from the on-growing in sea cages are encouraging. This growth has been obtained without selection improvement. The growth at sea may be further optimized by selection and by stocking the sea cages with larger juveniles at higher spring or summer temperatures. The juveniles in Nesvik are reared at sea temperatures of 6-11 ^{o}C, but juveniles of e.g. 2-100 g could be reared at higher temperatures of 12-15 ^{o}C. Then, ideally, in the sea temperatures around the Faroe Islands, the juveniles should be larger than about 100 g and put to sea at peak temperatures of 10-11 ^{o}C.



Presentations of institutes and research firms

Institute for Experimental Pathology, University of Iceland, Keldur

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tel. 354-585-5100, fax 354-567-3979, keldur@hi.is, www.keldur.hi.is, www.hi.is/gadus/

General information about the institute:

The institute for Experimental Pathology, at Keldur, was established in 1948. It is under the administration of the Ministry of Education and affiliated to the administration of the Medical Faculty of the University of Iceland. The institute employs around 60 people and 10 employees of the Chief Veterinary Officer are also located at Keldur. Principal roles of the Institute are:

- Basic medical and veterinary research
- Applied research, diagnostic services, animal disease control and expert advice in collaboration with the Chief Veterinary Officer of Iceland
- Development, production and distribution of vaccines against animal diseases
- Provision of research facilities for University instructors and other experts

  Further education and communication of new information to veterinarians

  Rearing of laboratory animals for research

  Research and development in biotechnology

The Institute is divided into four sections; i.e. Administration, Fish Disease Laboratory, Department of Virology and Molecular Biology and Division of Bacteriology and Parasitology. The main role of the Fish Disease Laboratory is:

- Diagnosis of fish and shellfish diseases and disease surveillance
- Research on various aspects related to fish diseases, immunology and vaccinology

Among research activities within the Department of Virology and Molecular Biology are studies on fish immunology. The Institute has access to facilities outside Reykjavík for experiments with live fish, i.e. at the Marine Research Institute Mariculture Laboratory near Grindavík and at The Research Centre in Sandgerdi.

Scientists at the Institute, including students, involved in research on cod farming

- Árni Kristmundsson, biologist, M.Sc. fish diseases (esp. parasitology), epidemiology
- Berglind Gísladóttir, biologist, B.Sc. fish immunology
- Bergljót Magnadóttir, zoologist, Ph.D. fish immunology
- Bjarnheidur K. Gudmundsdóttir, microbiol., Ph.D. bacterial virulence, immunology, vaccinology
- Bryndís Björnsdóttir, biologist, M.Sc. bacterial virulence, vaccinology
- Ívar Örn Árnason, biologist, B.Sc. bacteriology; detection methods
- Johanna Hentschke, biochemist, M.Sc. bacteriology; bacterial virulence
- Matthías Eydal, biologist, B.Sc. parasitology, epidemiology
- Sigrídur Steinunn Auðunsdóttir, biologist, B.Sc. immunology
- Sigrídur Gudmundsdóttir, immunologist, M.Sc. fish immunology, vaccinology, probiotics
- Sigurdur Helgason, bacteriologist/fish pathologist, Ph.D. fish diseases, epidemiology

Main research activities related to cod farming

- Monitoring of and the epidemiology of diseases in farmed cod
- Susceptibility of cod to various bacterial fish pathogens. Research on experimental and commercial vaccines against bacterial diseases
- Research on virulence factors of relevant fish pathogens
- Research on the effects of immunostimulants and probiotics during the first months post hatch on the immune system and susceptibility to pathogenic bacteria
- Studies of the effects of age, environmental conditions, immunostimulants and disease on the immune system of adult cod
- Studies of the acute phase response in cod

Marine Research Institute

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The Marine Research Institute (MRI) is a governmental institute with headquarters in Reykjavík and five branch laboratories all around Iceland. It has one Mariculture laboratory near Grindavík on the south west coast and two main research vessels, Árni Fridriksson (70 m) and Bjarni Saemundsson (50 m). The three main areas of activities of the MRI are the following:

- to conduct research on the marine environment around Iceland
- to provide advice to the government on allowable catch levels
- to inform the government, the fishery sector and the public about the sea and its living resources

The MRI has a staff of about 60 scientists, 70 research assistants and 40 crew members.

The Marine Research Institute Mariculture Laboratory near Grindavík.

Scientists involved in research on cod farming:

- Agnar Steinarsson, C.Sc. Aquaculture (agnar@hafro.is): production of cod fry
- Björn Björnsson, Ph.D. Aquaculture (bjornb@hafro.is): growth rate and temperature; ranching; behavioral control
- Tómas Árnason, M.Sc. Aquaculture (tommi@hafro.is): growth rate and salinity
- Amid Derayat, Ph.D. Aquaculture (amid@hafro.is): triploidy
- Hjalti Karlsson, B.Sc. Marine biology (hjalti@hafro.is): ongrowing of cod in seacages
- Valdimar I. Gunnarsson, M.Sc. Fisheries (valdimar@sjavarutvegur.is): cod farming statistics

Main research activities related to cod farming:

- MRI produces annually about 200 thousand cod fry which are sold to cod farms all around Iceland. The aim is to develop a protocol to improve survival and quality of cod fry.
- MRI is a large shareholder in Icecod Ltd. which is a company with the aim to develop a breeding program for cod. Cod roe and milt have been collected all around Iceland since 2003 to establish a base-population for the breeding program. Selective breeding started in 2006 when the first generation became sexually mature.
- MRI has been carrying out various growth rate studies with the aim to establish the growth potential and optimal rearing conditions for cod. It has e.g. been established how optimal temperature for growth decreases with weight of cod and how growth rate can be estimated from temperature and body weight.
- MRI has been supervising data collection by the cod farmers which have been assigned cod quota for on-growing and making an annual report based on the results. In some cases the MRI has been directly involved in research projects in cooperation with the cod farmers.
- MRI has carried out experimental ranching of cod in two fjords: Stödvarfjördur 1995-96 and Arnarfjördur 2005-2006. Large herds of free-ranging cod have been formed with regular feeding with capelin and herring. Cod showed high fidelity to their herds and displayed enormous growth rate.

Matís - Food Research, Innovation and Safety

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General information about the company:

Matís is a dynamic R&D company which offers various services to the food industry in Iceland and abroad in close collaboration with research institutions and universities in Iceland and abroad. Matís employs many of Iceland's most competent scientists in the field of food technology and food research: food scientists, chemists, biologists, engineers and fisheries scientists. Furthermore, many M.Sc. and Ph.D students are doing research at Matís and working on their theses. Employees at Matís are around 100. The research at Matís emphases on biotechnology, new processing technology, aquaculture, the processing and improved quality of chilled seafood products and the safety and wholesomeness of marine seafood.

Scientists involved in research on cod farming:

- Rannveig Björnsdóttir (rannveig.bjornsdottir@matis.is). PhDs, Cand.Sc. in Fish immunology & Pathology. Preventive measures during the first stages of marine aquaculture.
- Þorleifur Ágústsson (thorleifur.agustsson@matis.is). Ph.D. Fish Physiology. Physiology of fish in culture. Effects on growth and quality. Aquacultural technology
- Jón Árnason (jon.arnason@matis.is). Dr Scient. Animal Nutrition. Feed. Aquacultural technology.
- Helene L. Lauzon (helene.l.lauzon@matis.is). M.Sc. Food Science (Microbiology). Development of preventive measures during the first stages of cod aquaculture.
- Jónína Jóhannsdóttir (jonina.johannsdottir@matis.is). M.Sc in Molecular Biology. Preventive measures during the first stages of marine aquaculture.
- Jón Gunnar Schram (jon.g.schram@matis.is). M.Sc. Aquaculture. Aquaculture technology.
- Bjarni Jónasson (bjarni.jonasson@matis.is) . M.Sc. Fish Nutrition. Feed.
- Sigurjón Arason (sigurjon.arason@matis.is). B.Sc. Chemistry and M.Sc. Chemical and processing Engineering. Handling and processing of farmed fish, feed and feeding studies.
- Ragnar Jóhannsson (ragnar.johannsson@matis.is) B.Sc. Chemistry and Ph.D. in Chemical Engineering; Designing of aquaculture facilities. Developing production and business plans for aquaculture operations and environmental studies.

Main research activities at Matís related to marine aquaculture:

Marine aquaculture, especially cod farming, is progressing rapidly in many countries. This development could have a considerable impact on the markets for both wild as well as aquaculture fish in the future. Matís's goals in aquaculture are therefore to reinforce and strengthen marine aquaculture with emphasis on the whole production chain from hatch through the growth period.

- Survival of larvae during the first stages, with special emphasis on prebiotics and probiotics, is an important research area.
- Research projects also focus on reducing the cost of feed without negative impact on growth, health and quality of the final product.
- Matís runs projects on farming technology, use of light in cod farming as well as optimization of farming technology.
- Product quality, filleting yield, process ability and the safety of farmed products are furthermore important aspects of Matís's research projects.
- All research is carried out in collaboration with the farming industry as well as other R&D bodies and universities in Iceland and abroad.

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Holar University College is located in northern Iceland. The Department of Aquaculture and Fish biology offers undergraduate programmes in aquaculture and fish biology and an M.Sc. programme in aquatic biology. The Department also runs courses for the United Nations Fisheries Training Programme. Furthermore, a number of graduate students from other universities are affiliated with the department, working on their projects under the supervision of departmental staff. The department has good facilities for research and teaching in laboratories and two fish farms with access to both freshwater and seawater. Through a special contract with the Ministry of Fisheries and Agriculture the Department runs the Icelandic breeding program for Arctic charr. In total, 18 staff and graduate students are involved in research in the Department.

Verid, Holar University College Facility for Research and Teaching located at Saudarkrokur.

The principal roles of the Institute are:

- Providing education in aquaculture and fish biology
- Research in aquaculture and fish biology
- Breeding of Arctic charr for aquaculture

Scientists involved in research on aquaculture and fish biology

- Bjarni Kristófer Kristjánsson M.Sc. (bjakk@holar.is), fish evolution and ecology
- Einar Svavarsson M.Sc. (einsi@holar.is), breeding programmes
- Helgi Thorarensen Ph.D. head of department (helgi@holar.is), aquaculture and fish physiology
- Ólafur Sigurgeirsson M.Sc. (olisig@holar.is), aquaculture
- Ragnar Jóhannsson Ph.D. (ragnar@holar.is), aquaculture and water chemistry
- Stefán Óli Steingrímsson Ph.D. (stefan@holar.is) fish behaviour and ecology

Main research activities related to cod farming

- Developing and testing feed for cod, primarily aimed at defining the minimum protein requirements of cod, testing protein from different sources in feed and lipid content of feed.
- Behaviour of cod fry with special reference to cannibalism.
- The function of digestive enzymes during early development.
- Research on immunostimulants and probiotics during the first months post hatch.

IceCod Ltd.

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IceCod's aim is to do selective breeding of Atlantic Cod. The major shareholders are Stofnfiskur hf, HBGrandi hf, Hraðfrystihúsið Gunnvör, the Marine Research Institute, Fiskey and Þorskur á þurru landi. The manager is Jónas Jónasson.

The company has from 2003 been working in selective breeding of cod. During the first 3 years a wild broodstock was caught and stripped around the Icelandic coast. This formed the base population for future selective breeding. The first round of selection was performed in 2006 where 20% improvement in growth was achieved.

Theodor Kristjansson M.Sc. is the coordinator of the project. (theodor@stofnfiskur.is).

IceCod runs it's own fish farm at Hafnir on the Reykjanes Peninsula. Two cohorts of broodstock are kept there where one is light manipulated to produce eggs off season. A family tank facility was built in 2008 where 106 families can be kept separate until tagging.

The company aim is to improve the Icelandic cod stock for farming around Iceland in the coming years.

Pictures from the cod farming conference in 2005

Pictures from the cod farming conference in 2005

Pictures from cod farming activity in Iceland

Pictures from cod farming activity in Iceland

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