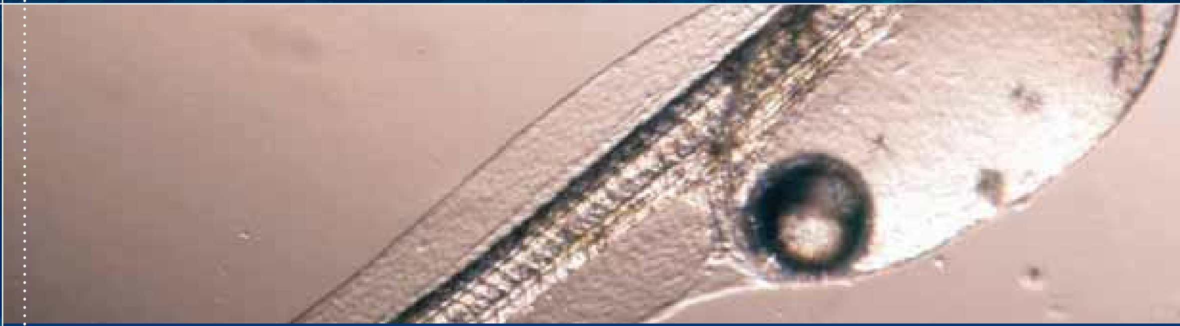
MARINE RESEARCH *TOPICS*

4–2007



PIONEERING RESULTS FROM THE INSTITUTE OF MARINE RESEARCH

Aquaculture research, 1882–2007

INSTITUTE OF MARINE RESEARCH
HAVFORSKINGSINSTITUTTET

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Aquaculture research, 1882–2007

Photo: Norwegian Seafood Export Council

The Institute of Marine Research (IMR) is one of Norway's leading aquaculture research institutes. The Institute can trace its research in this field all the way back to the pioneering work of G.O. Sars (1837–1927), and G. M. Dannevig's (1841–1911) large scale production of yolk sac larvae for release in the sea The first attempts to culture cod fry took place in a seawater basin on land in 1886. Dannevig's cod hatchery in Flødevigen near Arendal (1882) is now part of IMR. To the best of our knowledge, the first trials of rainbow trout farming in sea-cages were carried out by Gunnar Rollefsen, then director of IMR, and Fritjof Wise. Hansen, on Askøy in 1956.

The solid aquaculture research that had been done by IMR was a very important weight on the scales in the political controversy over whether the Fish and Shellfish Aquaculture Act should be administered by the Ministry of Fisheries or the Ministry of Agriculture.

We present here some of the pioneering research in aquaculture carried out by the IMR.

USING LIGHT TO CONTROL SMOLTIFICATION AND SEXUAL MATURATION

Salmon

Research carried out at IMR has shown that light is an important environmental factor throughout the life cycle of salmon, and results from the Aquaculture Station in Matre have been the basis of a number of advances that have made salmon production more efficient.

IMR has shown that long days or continuous light stimulate growth in both the freshwater and seawater phases of the salmon's life cycle, and light control allows the smoltification and production of under-yearling smolt to take place independent of season. Light control can also reduce the incidence of early sexual maturation in the seawater phase and the proportion of dwarf males in fresh water, and can also be used to control the timing of spawning in salmon.

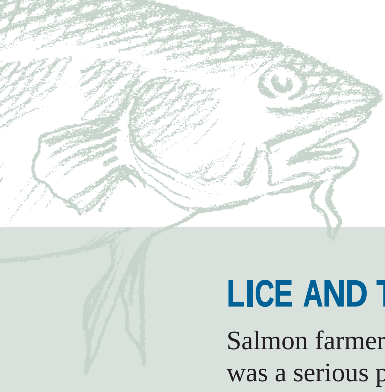
Research at the end of the 1980s laid the foundations for production of under-yearling smolts, or autumn smolts. Traditionally, it takes at least 18 months from the time of fertilization to produce normal spring smolts, but advances in knowledge about the importance of light cycles for growth and smoltification and the importance of threshold length (7–8 cm) for the start of the smoltification laid the foundations for the ability to produce smolt only 10–12 months after fertilization. The production of under-yearling smolt is made even more efficient by the use of light control in combination with temperature control of brood stock for early spawning, so that start-feeding can commence early without the need to use warm water excessively on the eggs.

At the end of the 1980s, experiments were initiated on the effects of using light control in sea-cages as well. The aim was to influence growth and sexual maturation. The results showed that we could both increase growth in weight and postpone sexual maturation by installing lights on the perimeter of the sea-cage. The technique was commercialised at the beginning of the 1990s. More research has since been done on the importance of various light intensities and colours, and we have further documented the physiological effects of light control on salmon.

Cod

By the end of the 1990s farming of cod was again considered to be economically viable. Better prices from consumers and smaller catch of wild cod gave the margins necessary. Maturation will generally give reduced growth because the cod stop eating in the spawning season that can last for months. Experiments initiated by knowledge from salmon studies, using continuous light in the rearing tanks show that maturation can be postponed for more than a year. This method is already being tested under commercial rearing conditions in a cod farm with cages in the sea. Another promising method will shorten the spawning period considerably. Turning on the light in the tanks in November or December will induce "shock maturation" and the spawning period will last only a short time.

From the IMR research station in Matre. Light is an important factor throughout the life cycle of salmon. Lights in the sea-cage increase the growth in weight and postpone sexual maturation.



LICE AND THEIR TREATMENT

Salmon farmers soon found that the salmon louse was a serious problem, not only for farmed fish themselves but also for wild fish. In the 1970s, the salmon louse threatened to cut down what was a still fragile industry, and IMR, with Emmy Egidius playing a leading role, realised that treating salmon for lice was essential. The Institute was the first to produce an effective treatment for salmon, with the the use of *Neguvon® (trichlorfon)*. The method was long the only treatment available, and it is quite legitimate to ask where the industry would be today if it had not been for this work.

IMR and what was then the Fisheries Technology Research Institute were also responsible for the use of labrids (wrasse) as a means of dealing with salmon lice, and these institutes ensured that the method was adopted on a large scale in Norwegian fish farms. Since then, more knowledge is gained of the biology of the salmon louse, and of the fact that its larvae are capable of dispersing over large distances. For this reason, IMR took the initiative in establishing national programmes for monitoring and controlling salmon lice. Models capable of simulating the dispersal of salmon louse larvae along the Norwegian coast have also been developed.

The concept of vaccinating against salmon lice was launched by Scottish scientists in the early 1990s, but their initial studies did not produce results. At the end of the 1990s, new technology, based on experience from vaccines targeted on fish viruses produced from genetically modified bacteria and on developments in genome biology, provided the basis for the Institute's studies of interactions between the salmon's immune defence system and the salmon louse. So far, we have demonstrated that it should be possible to produce a salmon louse vaccine, and it is likely that this work will be the basis of future vaccines, not merely against the salmon louse, but also against other parasites of the same type.

In the 1970s, salmon lice threatened to cut down a still fragile industry. Today, IMR has demonstrated that it should be possible to produce a salmon louse vaccine.

VACCINES

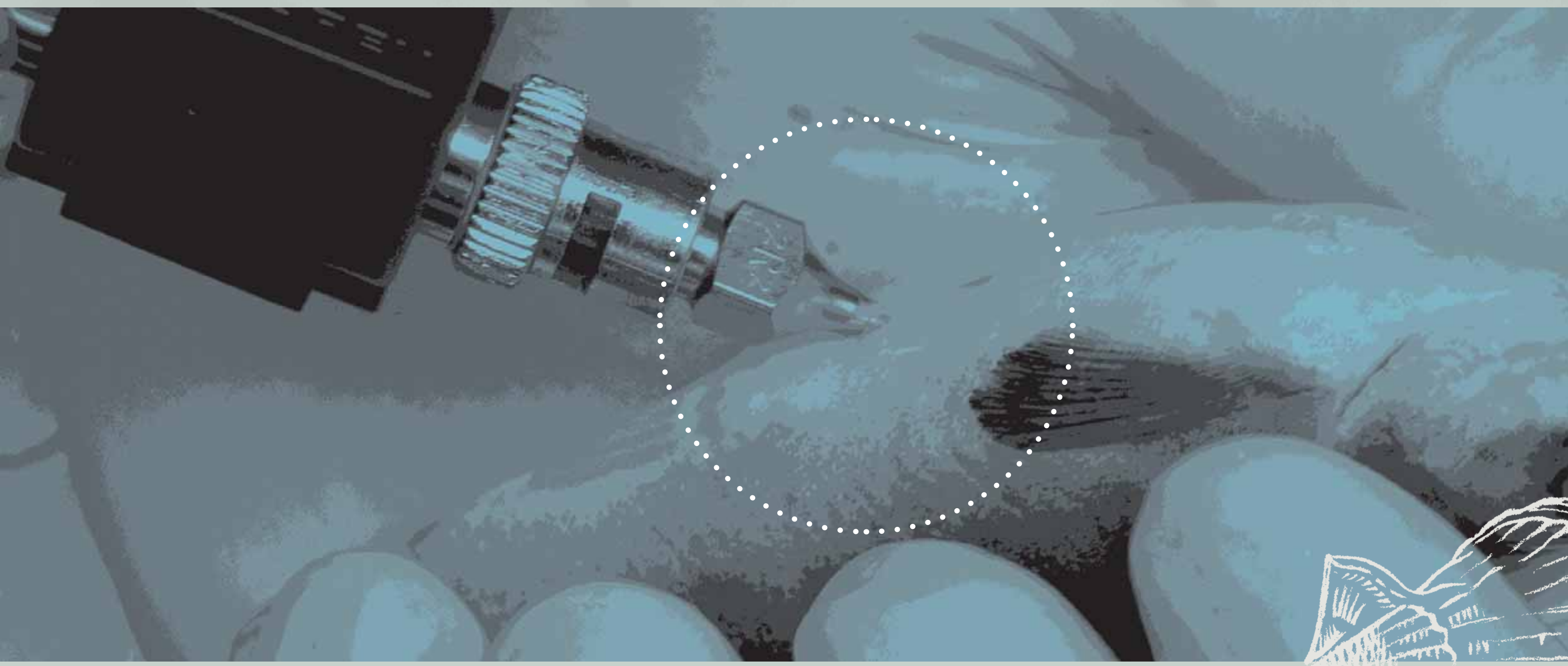
The research strategy of IMR has been to focus on preventive health measures rather than the treatment of disease. Research on fish vaccines has thus been a core aspect of the work of the Institute since the early 1970s. During the first years of this work, focus was on the development of good vaccines and strategies for vaccinating against vibriosis in rainbow trout and salmon.

Scientists at the Institute led the development of the vaccine for the so called “Hitra disease”, or cold-water vibriosis. While other scientists believed that this disease was due to environmental or nutritional conditions, Emmy Egidius and her colleagues drew on the principles of marine microbiology to demonstrate and culture *Vibrio salmonicida*, then an unknown bacterial species. They described it as a new species and gave it its name.

The vaccination studies soon demonstrated that the fish could be protected from this disease. The vaccine that was developed as a result was the first to be utilised on an industrial scale in fish farming. Together with the development of the vaccine against furunculosis, this was what made it possible to bring the consumption of antibiotics in Norwegian aquaculture under control. It is unlikely that the Norwegian aquaculture industry would have survived very long without these vaccines.

Scientists at the Institute have since played an important role in the development of vaccines against fish viruses. The vaccine against the infectious pancreatic necrosis (IPN) virus was the first with well-documented disease-prevention effects to be adopted on a large scale in fish farming. This was also the first time that a vaccine based on recombinant DNA technology was employed in aquaculture.

Today, IMR is developing DNA vaccines for nodavirus and other viruses. This is a completely new vaccine concept, in which the gene that produces the antigen we wish to vaccinate against is injected into the fish. The results so far are promising, and they have put us on the trail of hitherto unknown mechanisms in the fish immune defence system. There is every reason to believe that our ability to reinforce the defence system of the fish against disease can be improved even more.



INTENSIVE AND EXTENSIVE SYSTEMS FOR CULTIVATING MARINE SPECIES

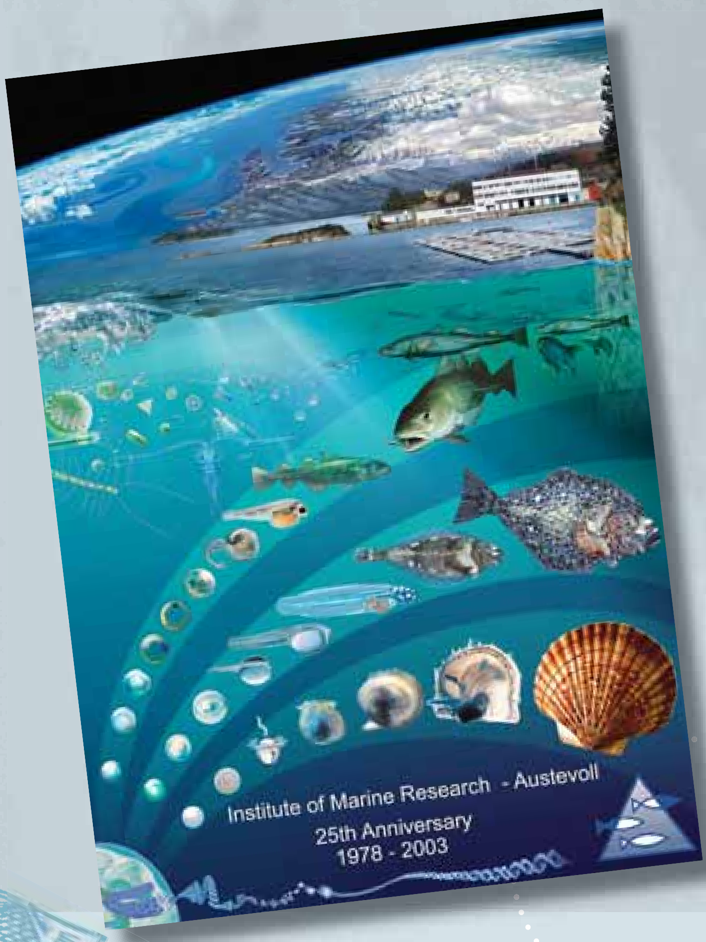
Success in farming salmon led to a search for new aquaculture species. The experience of the Flødevigen research station led to the development of a large-scale spawning system for cod by the Institute's research station in Austevoll, where the first farmed cod were harvested in 1977. However, the breakthrough came in 1983, when 60,000 cod juveniles were produced for the first time at Hyltropollen in Austevoll. Use of extensive rearing systems was further developed by IMR on the basis of these results in a larger sea water enclosure Parisvatnet in Øygarden, where the first large-scale production of cod juvenile in the world started up. With its annual production of 300,000–400,000 cod juveniles, this became an important, indeed essential, starting aid for the establishment of commercial production of cod for the table. Juvenile production at Parisvatnet was also an important part of the large-scale cod sea-ranching trials in the 1990s.

In the wake of the success at Hyltropollen, the mesocosm method of producing marine fish juveniles (a semi-intensive system) was developed in Svartatjern at IMR's research station in Austevoll. Several different species, including plaice, turbot, sole, herring, cod, saithe and wrasse have been produced in these systems. The mesocosm method is based on floating plastic bag enclosures for the fish larvae and culturing the plankton food of the larvae in the enclosed bay followed by filter collection. The first halibut larvae were start-fed in bags in Flødevigen in the 1970s, and Hallstein and Viggo Jan, the first two farmed halibut in the world making it through metamorphosis to juveniles, were produced in Austevoll in 1985. Virtually all of our knowledge of the early life stages of the halibut is derived from aquaculture research, and at the end of the 1990s more than 40% of the world's scientific literature on the halibut had its origins in IMR.

IMR has also played a leading role in the development of intensive production lines for cod and halibut. Season-independent spawning in these species took place for the first time anywhere in the world at Austevoll Research Station. The technology for keeping halibut yolk-sac larvae alive until start-feeding (the silo phase) was also developed in Austevoll, as well as the actual concept of intensive start-feeding of halibut larvae, including ways of estimating food requirements and efficient methods of cleaning the tank bottom. In 2000, about 20,000 cod juveniles were produced independent of season for the first time, laying the basis for the Norwegian production of cod juveniles that we can see developing today.

IMR was the first in Norway to start haddock farming trials in 2000. The aim was to find out whether the same juvenile production techniques could be used as are used with cod. The results show that it is possible to raise this species under similar rearing conditions as for cod. At the Austevoll station, we have also hatched out and start-fed hake.

The Institute has created the basis of flow-through systems for scallop larvae based on technology developed for halibut larvae. The first trials of water flow-through for scallop larvae were carried out at the Austevoll aquaculture station in 1997, since when the system has been further developed, with the result that the system is now in operation at Scalpro AS, Norway's commercial shellfish hatchery. The system eliminates the need for using antibiotics in scallop spat production.



The IMR research station in Austevoll has played an important part in the development of intensive production lines for cod and halibut.

GENETIC RESOURCES AND METHODS

Natural genetic variation is a resource we want to preserve for the future. The development of DNA technology over the last two decades has given us a much better understanding of how this variability is distributed in nature. It has also provided us with better means to monitor human impact on wild populations and their genetic resources.

Salmon

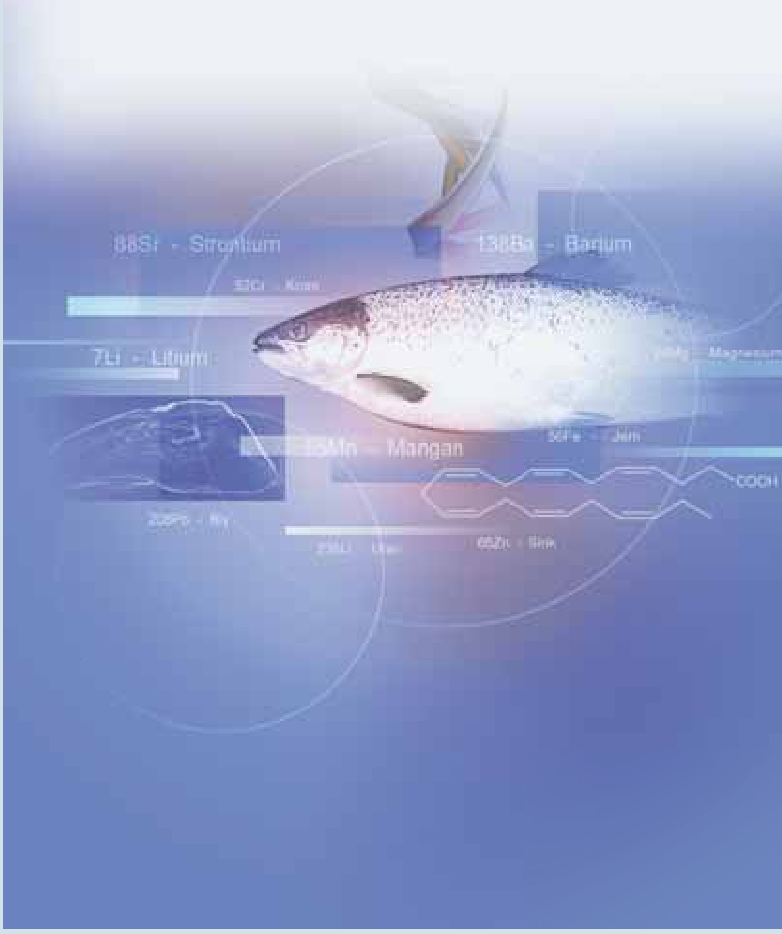
The debate over the potential genetic effects of escaped farmed salmon on wild stocks goes back for some 20 years. As early as 1980, large numbers of escaped salmon were being registered in the sea and in many wild salmon stocks, for example in the Vosso, Opo, Etne, and Namsen rivers. Are these and other important stocks lost to us, or do we still have stocks of wild salmon that have not been affected by escaped farmed salmon?

DNA markers make it possible to identify from which family and which stock any given individual comes. This means that we can study salmon stocks and changes in these that are caused by escaped salmon, and obtain accurate data on the extent and consequences of such changes. We can also make genetic profiles of a given salmon stock on the basis of the DNA from old salmon scales, and compare these profiles with profiles of the same stock today.

In 2004, DNA profiles of the five most important cultured brood lines in Norway were published, together with profiles of a number of wild salmon stocks. This is the most extensive DNA study of Norwegian salmon published to date. With the aid of the DNA profiles we were able to distinguish between the five aquaculture lines with an accuracy of about 95%.

The results have shown that the salmon stocks in the Namsen and Etne rivers have been stable, while changes in the genetic profiles were demonstrated in the Vosso and Opo.

In the autumn 2006, sudden increases in catches of escaped salmon were reported in the Romsdalsfjord, western Norway, although no escapement in the area had been reported to the Directorate of Fisheries. In collaboration with IMR's TRACES project, the Directorate of Fisheries collected samples from all sea cages within the region. 69% of the escapees matched with the genotypes of the salmon in one specific sea cage. The police authorities concluded that the results were sufficiently strong to initiate a full police investigation on the owner of this specific sea cage.



Under the TRACES project, a stand-by method for DNA tracing of escaped salmon has been developed.

The method for tracing escapees that has been developed under the TRACES project is a "stand by" method which use only naturally occurring characteristics of the fish, such as DNA profiles, and therefore any artificial marking can be avoided. Also, there is no need to develop storage of material or data, as each escapement is treated as a separate case. The method has proven successful under certain conditions and can therefore be implemented in the management of the aquaculture industry, although it will be developed further to increase the precision of the results.

Cod

Cod is developing fast as an aquaculture species, and the same problems relating to escapes and genetic impact found in salmon farming also apply to cod.

IMR was quick to start genetic studies of the cod populations along the Norwegian coast. In the mid-sixties, the Institute based its studies on genetic variations in bood proteins and varying antibodies. The results documented that the populations along the coast could be divided into the “skrei” (North-East Arctic Cod) and coastal cod, leading to a separate quota for the coastal cod. The study was followed up by the PUSH programme (Programme for Development and Motivation for Sea Ranching, 1990–1997).

Based on the newly developed methods in DNA analysis, a rigorous genetic mapping of the coastal population of cod has been undertaken along the entire coast. Samples have been collected from more than 10,000 individual fish from a total of 105 geographical areas, from Varanger in the north to Hvaler in the south. The results confirm the earlier conclusions on two separate populations. Additionally, a considerable genetic variance between coastal cod in different geographical areas has been documented. The established genetic profiles constitute important and necessary reference material for evaluating the potential genetic effects of escapes from a growing cod farming industry.

IMR has also collected cod brood stock from different geographical areas. Spawning trials have been conducted in the field station, Parisvatnet, and the offspring is tested under fish farming conditions at IMR’s research station in Austevoll and at the Norwegian Institute of Fisheries and Aquaculture Research in Tromsø. The brood stock in Parisvatnet consists of several different coastal cod populations gathered from the Porsanger Fjord in the north to Lillesand in the south. It also includes several fish farm stocks and a population with a specific genetic marker. The material constitutes a living gene bank and is important as genetically defined experimental material and as a biological resource for the marine genome research.

Studies show that farmed cod can be equipped with a genetic marker that explicitly will identify

them as of farmed origin. This genetic marker was developed by IMR in the late 1980s, and the development of a new group of brood stock was started in Austevoll in 2002. This offers unique possibilities to follow the effects on wild cod both from escapes and spawning in sea-cages.

Fish with the genetic marker has already been used to study the effects of released farmed fish within the PUSH programme. The results from both Masfjorden and Austevoll revealed no effect of these single point releases, while a small effect was found in Øygarden.

Contrary to salmon, cod will spawn in the sea-cages and eggs and larvae may be dispersed with currents. The effects are difficult to ascertain, but by using genetically marked fish, studies of the effects can be carried out directly in the ecosystem. In 2006 and 2007, spawning cod were placed in a net pen within the virtually enclosed area of Heimarkspollen in Austevoll. By April 2007, more than 30% of the cod larvae recaptured within Heimarkspollen was of farmed origin. Surprisingly, as much as 10% of the larvae caught in the furthermost sampling location 8 km away were also of farmed origin.

A comprehensive sampling programme will be undertaken to establish whether the genetic marked cod will survive to maturation and crossbreed with the wild population of cod in the area.

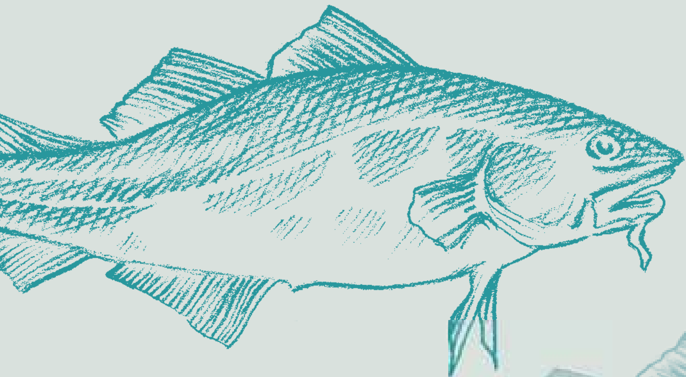
One of the aims for creating the genetically marked cod has always been to do trials on a commercial scale in close cooperation with the industry. In 2007, 600,000 cod juveniles were produced in Parisvatnet, and of these, 500,000 were transferred to a cod fish farm in Florø where they will be raised in commercial conditions. Reference sampling of the wild cod population in the area has been carried out, and a surveillance programme will be established where escapes of all sizes of fish as well as the effect of spawning in sea-cages may be studied directly.

Thanks to this genetic marker system we have a much better knowledge basis than we had for salmon farming, where the long-term effects of farmed escapees have been difficult to determine. This cod population represents a unique tool to study the ecological effects of cod farming.

Photo: Norwegian Seafood Export Council

SEA RANCHING

Sea ranching has been a field of research at IMR for the past 17 years, with studies of species that were involved in the former PUSH sea-ranching programme and development studies on the great scallop (*Pecten maximus*). Important topics studied have included fry production, interactions with wild stocks, health status, predators and other benthic fauna in the release area.



Cod

Norway has being carrying out cod cultivation trials since the 1880s, at first using newly hatched cod larvae. In the 1980s, this activity was taken up again, this time using the more viable cod larvae, and fjord studies and tagging/recapture studies were carried out with the aim of mapping the potential of cod sea ranching. The Institute played a key role in these studies, and the final report came in 1997 as part of the PUSH programme. In spite of wide variations in environmental conditions, natural production and fish mortality on different parts of the Norwegian coast, the results showed that, under the natural conditions that existed during the 1980s and 1990s, cod production could not be increased through a release programme. However, the report pointed forward to the potential for cod farming, and to the possibility of releasing cod for tourist fishing. Cod ranching research has resulted in a number of doctorates and publications by the Institute, and these studies are one of the best documented studies of marine fish sea ranching in the world.

A cod egg before hatching is less than 1,5 mm.

Break-through in the production of cod juveniles (5–10 cm) at IMR in 1983.



Lobsters

IMR started lobster sea ranching towards the end of the 1980s based on knowledge produced at Tiedemann's lobster station. Between 1990 and 1994, 128,000 young lobsters were produced and released near Kvitsøy in Rogaland. An important condition of these trials was that the egg-bearing lobsters used as broodstock should have come from the areas in which the young animals were to be released. The aim was to evaluate whether releasing young lobsters could help to increase local stocks. The sea-ranching phase is defined from the time the young lobsters were released into the sea until they were recaptured.

The first ranched lobsters were registered in the commercial lobster fishery in autumn 1992, and in the course of the two years since they had been released, they had grown from a length of 4–6 cm to 24 cm overall length. Since then, the proportion of sea-ranched lobsters has risen, and in 1998, more than half the catch consisted of released lobsters. A total of more than 1,300 egg-bearing lobsters have been registered, all of which have spawned at least once, and these have undoubtedly made an important contribution to the overall rate of reproduction in the release area. An important question regarding these releases is whether the released animals have had a negative impact on wild stocks. The focus has been possible effect on growth, reproduction, migrations and genetics.

The main conclusion, which was drawn as early as 1981, was that is possible to strengthen a local population by releasing young lobsters. This has formed the basis for a large-scale redevelopment of lobster stocks, but it remains to be seen whether this will be commercially viable

Scallops

IMR scientists have played an important role in the development of great scallop (*Pecten maximus*) sea ranching. As part of the effort to improve survival rates in scallops, IMR launched the use of fences to stop crabs from getting at scallops that had been released on the seabed for sea ranching. The necessary equipment has since been developed in collaboration with industry, and the method is currently in use in most sea-ranching facilities. Fences are regarded as essential for scallop ranching in Norway.

Research done at IMR has been an important factor in the passing of the Sea Ranching Act, and not least it's accompanying regulations. The new Act, which was passed in December 2000, covers releases of crustaceans, molluscs and echinoderms, and it has the aim of encouraging the development of a new coastal industry in the framework of well-balanced, sustainable development. The first licences were issued at the end of 2004. The Sea Ranching Act means that we will need more knowledge of the effects of sea-ranching activities on the environment and sustainability, genetic interactions with wild stocks, risks of disease and ecological effects. Our knowledge will have to be improved in these fields if we are to be able to answer the questions and satisfy the demands for advice that will come from the authorities.

In 2005, the Institute began research aimed at identifying the long-term effects of lobster sea-ranching on the composition of local fauna and the lobsters' own genetic structure. Genetic analyses of scallops will be developed for studies in the future. Ongoing research on transmission of disease between fish and shellfish is highly relevant for the development of models of disease control in sea ranching. Other studies have begun to look at how fenced sea ranching of scallops might affect other benthic species.


ENVIRONMENTAL EFFECTS OF AQUACULTURE

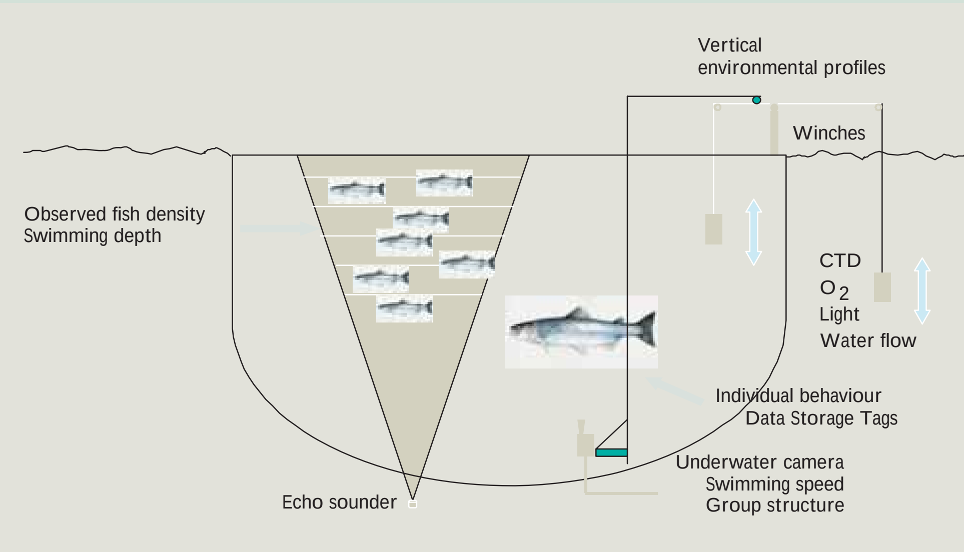
Overloading of fish-farm sites has been a serious problem for the Norwegian aquaculture industry. The result has been pollution, poor growth rates and high levels of disease. IMR has put long-term efforts into solving these problems, and has developed a system that can be used to modify the load from the fish farm to match the carrying capacity of the site. This system is known as MOM (Monitoring, Ongrowing site and Modelling). MOM is an example of how research results can be utilised to develop user tools, in this case for the fisheries and environmental authorities as well as the aquaculture industry itself. MOM comprises a monitoring program for effects on the seabed, upper limits for permitted effects and a simulation model that can calculate how much we can produce at a given site without exceeding the maximum limits (i.e. the site's carrying capacity). MOM is based on the idea that a site will be utilised for a long period of time, and that the loads must not be so great that the benthic community under the sea-cages disappears. The intensity of monitoring is adapted to the severity of the load, so that the greater the impact of an aquaculture facility, the more monitoring will be required. The system consists of a number of independent modules that can be replaced as required if and when conditions change or new knowledge becomes available.

WELFARE OF AQUATIC ORGANISMS

Animal welfare is a relatively new cross-disciplinary area which requires an integrated perspective. IMR's wide range of knowledge of aquatic biology – from genome to natural ecology – thus provides a good basis for the development of this discipline. In the course of the past few years the Institute has established several laboratories and methods aimed at answering questions about the welfare of farmed fish.

Topics such as indicators of wellbeing, behavioural development, environmental preferences, learning ability and memory in fish, stress and growth physiology (including deformities) as well as markers of stress related to the immune defence system, pain and anaesthesia all fall within the Institute's range of research on fish welfare. These are important topics that focus on basic aspects of understanding aimed at solving concrete problems by providing results that may be of importance for fish welfare.

For example, at its sea-cage environment laboratory in Matre, the Institute has carried out a unique series of studies on environmental preferences and behaviour in both individuals and groups of fish under realistic production conditions. This research has revealed that the fish respond very actively to changes in temperature, oxygen and light. Such behaviour leads to wide variations in depth of swimming and schooling density. Among other things, the results have demonstrated that the body temperature of the salmon is capable of changing by several degrees in a short time, and that different salmon in the same sea-cage have different body temperatures. This could have important consequences for physiology and growth in fish.



In the sea-cage environment laboratory we can measure how densely and how deep the fish is swimming and compare this with natural environmental variations.

PIGMENTATION AND QUALITY

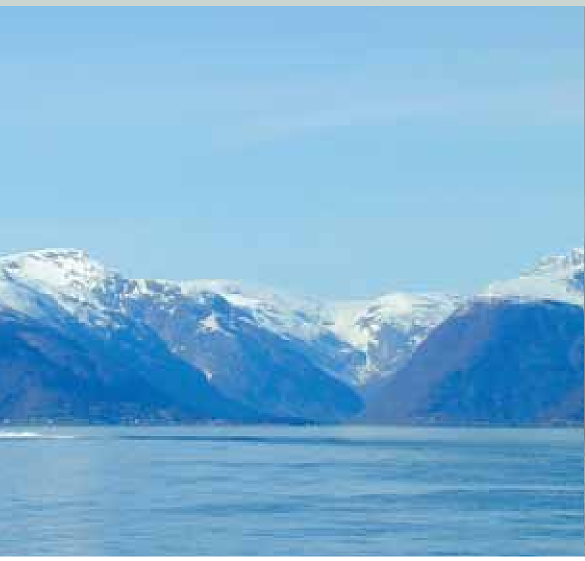
IMR has carried out research on the quality of farmed fish since the 1970s. The main focus has been on flesh pigmentation in salmonids. A great deal of work has been done on the relationship between season and fat content in salmon, and between muscle-fibre thickness and the texture of the flesh.

The Institute has mapped the relationship between pigment dose in the feed and the amount of pigment in the flesh of the fish. These results provide a basis for the pigmentation regimes recommended by the feed industry. The Institute was the first to show that pigments are essential for the survival, growth and disease resistance of these fish. This suggests that the pigments astaxanthin and castaxanthin should be regarded as nutrients or vitamins rather than as feed additives.

UPWELLING OF NUTRIENT-RICH DEEPWATER FOR CULTIVATION OF TOXIN-FREE MUSSELS

Since the late 1990s, IMR has been working towards the establishment of a full-scale facility for creating an artificial upwelling of nutrient-rich deepwater in fjords. A collaborative project with Norwegian Shellfish Production AS of Lysefjorden in the County of Rogaland resulted in the first plant for brackish water-driven upflow being established there.

In Lysefjorden, scientists from IMR have demonstrated for the first time that upflows of deep brackish water can increase algal production in a fjord. The upwelling of nutrient salts from deeper water strata approximately tripled algal production and levels within an area of about nine square kilometres near the head of the fjord. There were clear differences in the species composition of the algae in the area of influence, with a greater dominance of diatoms. High, stable production of algae, dominated by non-toxic species, could form the basis of more predictable mussel cultivation in our fjords.



NEW MARINE FEED RESOURCES

For several years, the IMR has been looking into the possibilities of exploiting organisms further down the food chain as raw materials for fish feed. The protein and fat content of many species of krill and other types of plankton are extremely variable. There are also geographical and seasonal variations. The copepod *Calanus finmarchicus* and the tiny krill species *Thysanoessa inermis*, both of which occur in Norwegian waters, are among the species with the high percentages of fat; up to 70% of their dry weight. However, much of this fat is of a type that fish find difficult to digest. We can say that large krill tend to be good sources of protein, which makes up about 60% of their dry weight, while their fat content is moderate to low. Feeding trials using salmon, cod and halibut have shown that a significant proportion of krill (either from the Antarctic or northern regions) can be added to the feed without negative effects on growth, feed utilisation or quality. In salmon feeding trials, copepod oil has been shown to produce similar growth rates and feed utilisation as fish oil, without influencing the content of the fatty acids EPA and DHA, that are beficial to human health. We can conclude on the basis of these experiments, that krill is a good substitute for fishmeal in most farmed fish species, and that copepod oil could be a good substitute for fish oil in the salmon diet.

Cod larva. Genome research can provide new knowledge on fish reproduction and development.

CODGEN - THE COD GENOME

IMR has recently launched a project which will identify tools and methods for functional genome research on cod. Important aims of the project include building up a collection of gene sequences as a point of departure for a cod micromatrix that will enable us to study how this fish expresses a large number of genes. The initial goal will be to create a micromatrix based on at least 10,000 gene sequences. This technique will be used in studies of various biological processes such a reproduction, development and immune functions in cod. The ambition of IMR, in collaboration with its Norwegian partners, the University of Tromsø, the Norwegian Institute of Fisheries and Aquaculture Research, NIFES and the University of Bergen, is to sequence the cod genome. We have taken the first step towards this goal by creating what is known as a BAC library from cod. This library consists of large bits of DNA (an average of 125,000 bases per clone) and it will form an essential part of our studies of the structure of the cod genome. Knowledge of this sort is important if we wish to study the functions of individual genes, as well as enabling us to compare cod with other species. Comparative studies of this sort are useful as a means of letting us know how relevant it is to transfer knowledge about one species to another.

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