The Innovation System of Norwegian Aquacultured Salmonids

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Abstract

This paper is about one of the most important export products in Norway, "Norwegian salmon", focusing especially on the innovation system of aquaculture of salmon and trout in Norway, the aim of the paper is to describe the sector in a national and global context, for thereafter highlight in particular how different aquaculture firms operate and carry out innovation by looking at what kind of external relations and interactive learning processes are involved in innovation, and as such suggesting input to policy makers on how to strengthen the sectoral innovation system, a sector with the potential to become even more knowledge intensive and innovative than today. By differentiating aquaculture according to knowledge base and degree of structured and functionally differentiated organisations, the empirical material presented in this paper shows that aquaculture firms have very different approaches to innovation; from anti-innovation strategies to strategies of being in the fore-front of innovation in the industry. The empirical material has shown that firms with very different innovation systems exists side-by-side and the overall functioning of the sectoral innovation system of aquaculture is influenced by all the different layers of firm types.

Version of 06.08.2007

TIK Working paper on Innovation Studies No. 20070606

*This paper is part of the project "Innovation, Path-dependency and Policy" (IPP) carried out at the Centre for Technology, Innovation Culture (TIK), University of Oslo with the support of the Norwegian Research Council (Contract no. 154877). However, the Centre, University and Research Council are not responsible for the content of the paper, which is the sole responsibility of the author(s).

Introduction[1]

”Norwegian salmon” is probably Norway’s best-known export product. It is the main driving force behind the development within the Norwegian aquaculture industry. The value of exported fish and fish products from Norway was about 32 billion NOK in 2005, representing the third largest export category in Norway that year. The export value of aquacultured salmonids[2] accounts for approximately 50 per cent of this total. As wild capture will decrease slightly in the years to come (FAO 2002) the growing demand for seafood must be produced through aquaculture production. The last 20 years, Norway has increased its market share significantly in relation to the total supply of salmon worldwide. Since the early 1970’s production of farmed fish has doubled every three years (Berge 2000).

Today, the aquaculture industry has reached the size and maturity where business can no longer be run efficiently merely by employing the ways and means that have been successful in the past. Moreover, during the last couple of years the Norwegian world market share have diminished, in large part due to competition from other countries like Chile, which has a strong and expanding aquaculture industry. The industry is confronted with a series of new challenges. The strong demand experienced by the industry since its inception is no longer outpacing supply. The firms are increasingly exposed to price pressures. At the same time, customer demands are becoming more differentiated, and not easily addressed by all aquaculture firms.

This paper focuses on the innovation system of aquaculture for salmon and trout in Norway. The aim of the paper is to describe the sector in a national and global context, and to highlight how different aquaculture firms operate and carry out innovation. The paper discusses the external relations and interactive learning processes that are involved in innovation and describes the sectoral innovation system. The main interest is in how innovation efforts are handled by actors today, in a time where the framework conditions of this global industry are changing significantly. By looking at how various actors use the innovation system differently, the paper provides input to policy makers who seek to strengthen the sectoral innovation system, a sector with the potential to become even more knowledge intensive and innovative than today.

The paper addresses the following main questions:

1. What are the main characteristics of the evolution of aquaculture of salmonids and what characterises the sector in today's global economy?
2. What are the main types of innovation strategies that we currently find among aquaculture firms and what do they tell us about the functioning of the sectoral innovation system?

The outline of the paper is as follows; in section 2 the aquaculture industry is presented, focusing especially on the evolution of the industry and the development of important innovations in the sector. Section 3 gives a short description of important regulations in aquaculture and the interconnections to regional policy. Section 4 presents the aquaculture industry as it is today and places it in a national and global context. Section 5 presents the analysis of the operations of different types of aquaculture firms and how they relate to external actors in their innovation efforts. The final section 6, summarize key findings and discusses innovation barriers in aquaculture.

The evolution of the aquaculture industry

This section presents the evolution of the aquaculture industry by looking at important actors and important innovations that have formed the industry.

The early years of aquaculture

Commercial farming of salmon and trout in Norway is a relatively young sector, dating back to the 1970s. Nevertheless, experimentation and testing related to feeding, breeding and technology for fish farming has been going on for a longer time among entrepreneurs and scientists at different localities in Norway.

Going back to the early 1930s, a researcher named Rollefsen at the Institute for Marine Research in Bergen, carried out experiments to find out how captured salt-water fish could survive. One of the cardinal questions was ensuring that the fish (here cod) survived the critical fish larvae stage (Schwach 2000: 223). He eventually managed to feed the cod larvae with a little crawfish, a breakthrough that set the foundation for *marine* aquaculture (as opposed to farming of anadromous species as salmon and trout). The experimentation on both hatching and feeding carried out in the 1930s were documented by Rollefsen. He also played an important role as knowledge provider when the interest in *salmon* escalated at the institute around the late 1960s.

The growth of fish farming was a bottom-up, decentralized process with a centre of gravity in communities dominated by fisheries. The first impulses to aquaculture in Norway came from Denmark in the 1950s, where farming of trout in dams and lakes where carried out (Schwach 2000:338). At the same time, several pioneers in Norway experimented with fish farming independently of each other. Much of the farming activities were linked to wild-salmon and trout in rivers and lakes in Norway, where voluntary associations worked to support the natural production of wild salmon. Developments took place in coastal regions recognised by people sharing a common culture and knowledge and experience from fisheries. These were communities where untraded exchange of knowledge and other resources was part of the values and norms of everyday life (Ørstavik 2004).

In 1968, certain pioneers within fish farming approached the Institute for Marine Research. They needed help to solve problems related to hatchery-produced fish for stocking and combat of diseases. One of the younger researchers at the institute, Dag Møller, had at that point of time written a masters degree on salmon and had a special interest in population genetic studies. After spending a year in Canada, Møller returned to the institute in 1970. This was the start of a period where activities related to aquaculture of salmon escalated in Norway.

Another important break-through came about in the late 1960s. That was when a salmon farmer conducted successful pilot production with remarkable and far reaching consequences; farming of salmon in sea-water net-pens. This lead to an end to years of trial and error of proper location specifications and technology choices, and to an increased demand for specified costal space (Aarset 1998). The insight that it was possible to farm rainbow trout in seawater spawned the idea that it ought to be possible to do salmon farming in sea water as an alternative to the farming of trout. Big market demands for wild salmon and existing distribution and sales systems could secure very good prices for salmon, in Norway as well as internationally (Ørstavik 2004).

Another scientist to become important for fish farming was professor Skjervold at the University of Life Science at Ås, who was a specialist in animal husbandry. As a geneticist he was at first engaged to do experiments with fish as species. However, the focus of research in agriculture and marine biology changed from studying fish to analyzing fish as a *product* in an industry that could develop further with the support from scientists (Schwach 2000:339).

Even though early experimentations and try-outs among scientists had important consequences for how the industry developed, fish farming of salmon and trout cannot be viewed as “science driven”. Fish farming was rather an entrepreneurial experienced-based activity carried out by fishermen along the coastline having both capital and knowledge of fish farming as a sideline activity. Commercial fish farming drew on technology and experience-based knowledge from the fisheries sector. The significance of this transformation is evident when comparing Norwegian aquaculture with Scottish fish farming, an industry that historically has been dominated by large enterprises and external capital (Jakobsen et al. 2003).

Knowledge of fish farming was accumulated among individuals in distinct communities. The learning process was long. In the 1970s a combination of experience-based knowledge and research based knowledge were used to solve the different biological, physical and chemical problems that arose.

When salmon aquaculture emerged it entered the supply chain of wild-caught fish, and as a consequence utilized many of the prevailing market institutions, product requirements and traditions of the fisheries sector. However, the technological innovations in aquaculture led to a greater degree of control of the production process, which over time moved away from the fisheries (Tveterås and Kvaløy 2004). From the late 1970s the Norwegian government's objective for salmon farming was small-scale vertical and horizontal integration, mandating also a producer sales cartel similar to those present and protected by law in fisheries and agriculture in many countries (op. cit.). The regulations and institutions only survived until the beginning of the 1990s, where the government removed the laws that protected the sales cartel and prohibited horizontal integration (op. cit.).

Important innovations combining knowledge bases

Innovation is often a result of interactive learning processes between actors, and for aquaculture firms, breed-, feed- vaccination- and technology suppliers are important sources of new knowledge. The supply industry has developed new and better feed, advanced feeding systems, surveillance equipment, health- and veterinary services etc.

In the following sections important innovations in the history of aquaculture will be presented due to their important role within today's innovation system of aquaculture. They all illustrate how the fish farmers at the beginning had a practical and commercial approach to important inputs to fish farming, but, after a while became more dependent on the involvement of scientific research as well as on adequate policy action. The last paragraph has a short description on related R&D activity today.

Breeding and genetics

With regard to breeding, the problem in the early years was posed as one concerning selection among natural species that were suited for farming. Later efforts were concentrated on scientific breeding programs that focused on the development of different breeds from those found naturally (Aslesen et al. 2002). One of the most important breakthroughs in breeding of salmon and trout for fish farming was the work of Professor Skjervold at the University of Life Science in the 1970s, who started a breeding scheme for salmon that drew on principles developed for cattle breeding, known as Norsk Rødt Fe (NRF). This was the starting point of a global breeding scheme for salmon, based on relatively advanced knowledge of breeding in other animals.

Today, much of the same knowledge is also used on other/new fish and shellfish species. Norwegian institutions and companies have developed and established the most advanced breeding systems for fish and shellfish world wide, and Norwegian breeding companies are established in the most important salmon farming countries (Olafsen et al. 2006). The Norwegian research institution AKVAFORSK, has also developed a breeding systems for tilapia (the Philippines) and shrimps (Thailand).

Feed

In the initial stages of fish farming, knowledge from fur-bearing animals (mink) was used and created what is called wet-feed. During the 1980s dry feed was developed that was much easier to handle and of higher quality. Since the 1980s, Norway has been a centre for research on feed for salmon breeding. Important factors to consider when making fish feed include how to make feed economical, but still nutritious for growth and health, while preventing the remains from polluting the environment, etc. (Aslesen et al. 2002). The fish feed industry has carried out intense research efforts in different institutions and venues in order to improve the feed. Today, Norwegian research institutes and universities doing research on feed have a high international standing. From 1996, salmon production was regulated by means of feed quotas, in order to control the growth of the industry. The amount of feed that each fish farmer could purchase annually was set by the Ministry of Fisheries. The aim of the feed quotas was to limit the growth in export to EU, and to maintain a floor on prices.. As a means to reduce production, the feed quotas have been effective, since fish feed is not easily substituted. The feed quotas led to innovations in Norwegian fish feed such that the type of feed used in Norway contains more fat than in other fish producing countries. The feed quotas were abolished in 2005 and the effects of this both on total production and the type of feed used are still to be seen.

During 2005 the fish farming industry consumed 906 271 metric tons of feed. The Norwegian fish feed industry has become a global actor. In recent years, a comprehensive structural change has made the Norwegian fish feed industry consisting of three large companies: Skretting AS, Ewos AS, and Biomar AS, all of which have research staff in Norway. Salmon feed is the main product for the fish feed industry and their products and services are based on Norwegian expertise. The feed companies are present in all salmon producing countries and other aquaculture countries worldwide, and they are all working hard to develop dry feed for new species (Olafsen et al. 2006). During the last few years Nutreco, which is a supplier of feed for animals as well as fish feed, has made major acquisitions in Scotland and Norway. Through the acquisition of Hydro Seafood, Nutreco also have become Norway's largest fish farmer, thereby making the link between the feed suppliers' R&D activity and fish farming even more interconnected.

Nearly 90 % of the global production of fish oil and more than 50 % of the fishmeal produced is consumed by the aqua-feed industry: It is expected that a reduced availability of fish oil caused by over exploitation of species of fish, will be the first limiting factor for the growth of the global aquaculture industry (Olafsen et al. 2006). The Norwegian research community and feed companies have considerable expertise within the development of fish feed, in where working with developing high energy diets for salmon and increased feed utilization have been central (op. cit.).

Health

Sickness and diseases soon emerged as a key problem for the fish farmers. Among the first concerns of scientific research was to find effective remedies against parasites, bacterial and viral infections, deformities etc. (Aslesen et al. 2002).

During the 80's fish farmers were continuously challenged by diseases and their use of antibiotics rose. It was evident that action was required. In the early years of fish farming the existing research institutes had no or few resources to do research on the mortality in the net cages. There was also limited contact between the research institutions with regard to these problems. Besides, the situation was rather tense between the research institutes and universities representing agriculture and fisheries as to where such research should take place. But as the mortality in the fish farms continuously rose during the 1980s the industry seized the initiative to combat the diseases, while emphasising the need for the different research communities to collaborate in order to find solutions to these severe problems. Through the research programme “Frisk Fisk” (Healthy Fish) constituted in 1983, industry engagements lead to collaboration between the industry and between the different research institutes.

In an evaluation of aquaculture research in 1990-91 for the Research Council of Norway, a Peer Review report concluded that: “In the past, aquaculture diseases studies in Norway have been notorious for the lack of agreement and cooperation between different groups. It was a pleasure to see that this was now a thing of the past and collaborations between the individual scientists and between institutes was so positive and mutually rewarding” (Møller 1996). After a relatively short period of time, efficient vaccination procedures were developed. The disease initiative also paved the way for collaboration between important actors in the innovation system of aquaculture. Today, vaccination programmes and other fish health systems are well established in Norway. Important institutions within this branch are the National Veterinary Institute and the Norwegian College of Fishery Science.

Technology

Process development and equipment-relevant problems for the fish farmers concerned the selection of specific species most suitable for farming, finding locations, deciding what density of population that ought to be maintained, when and how to feed, etc. With regard to equipment, closing nets had to be constructed and anchored adequately, to make them resist strong winds, to keep salmon from escaping, etc. (Aslesen et al. 2002).

The first net cages used in aquaculture were based on homemade technology using wood as material, and fish farming was carried out near to the coastline. In order to carry out farming in deeper seawater, stronger net cages were needed, along with automatic feeding, feed control etc.

Traditionally, the technology[3] suppliers to the aquaculture industry consisted of largely small and medium sized companies, many of them family-owned. Alongside consolidation of aquaculture firms (on the demand side), consolidation has occurred among suppliers. In 2005, the Norwegian Equipment Producers Association (NLTH) counted 29 firms as important equipment producers to the aquaculture industry, of which 9 have sales up to 15 million NOK, and 20 have sales more than 15 million NOK. An overview from the Norwegian Equipment Producers Association (NLTH) shows that the industry had 1197 man-labour year in 2005, and a total sale of ca 800 million NOK domestically and ca 250 million for export (24% of total). The technology suppliers are becoming global actors. The greatest part of technology development is carried out in Norway. Foreign equipment suppliers have often copied Norwegian equipment; however, suppliers from other countries are also themselves involved in development project related to equipment and often such projects are carried out in collaboration between Norwegian aquaculture firms with facilities abroad.

Education and the knowledge infrastructure

Compared to other salmon producing countries, Norway was quick to build educational establishments supporting the industry. In 1994, reforms were carried out (Reform94) establishing specialised education in aquaculture and fisheries at secondary level. There is also specialised education at the university level (i.e. at Norwegian University of Agriculture, Norwegian College of Fisheries Science, University of Bergen, and Norwegian University for Science and Technology (NTNU). Most of these educational institutions have close relationships with research institutes supporting the industry with R&D services. For example, the Norwegian College of Fisheries Science collaborates with the Norwegian Institute of Fisheries and Aquaculture Research and the Norwegian University of Agriculture works with AKVAFORSK. Many of the lecturers at these higher educational institutions are also employed as researchers in the institute sector. In the ten year period from 1992-2002 the industry had a general increase in the education level of its workforce. Both the number of employees with secondary education and employees with 1-4 years of education from university grew (especially Natural Sciences).

Although formal training and educational attainment for the aquaculture industry's workforce are fairly high, the industry itself invests only modestly in training. *Attitudes* towards qualified labour in the seafood industry were studied by Reve and Jakobsen (2001) in their book ”Et verdiskapende Norge”. Compared to other industries, only trading companies put less weight on skills upgrading than firms working in the seafood industry. In aquaculture 30% of the firms do not have a strategy for skills upgrading.

It is said that research was a net-receiver of knowledge from the fisheries sector up until 1985 (Berge 2002). Nevertheless, research has made important contributions to fish farming, as the section above noted. The knowledge structure surrounding the aquaculture industry has been important for the development of the industry, especially in relation to developing fish health systems, breeding schemes and fish feed. The enormous growth in the sector in the 90's would probably not been possible without the research efforts from the 20 public, semi-public, and private research institutes in Norway that carry out research in relation to the aquaculture industry. These are clustered in four main areas of Norway, namely Northern Norway (Tromsø and Bodø), Mid Norway (Trondheim), Western Norway (Bergen and Stavanger) and Eastern Norway (Ås and Oslo). The bulk of their research activity is focused on the salmon species.

According to Sundnes et al. (2005) the marine Research and Development institutions (including Universities and University Colleges) in Norway had a total R&D spending of 1,7 billion in 2003. In 2003, 1 600 researchers, scientific personnel and specialist employees were engaged in marine R&D in Norway working either within the institute sector, at universities and colleges or within the industry (Sundnes et al. 2005). R&D expenditure in aquaculture was 684 million in 2003, to which the industry contributed 29%, the institute sector 53% and university and higher educational institutions 18%.

Governance and integration in aquaculture

Governance

Historically the regulation of aquaculture has played an important role in the development of Norwegian aquaculture (Jakobsen et al. 2003). As the industry has grown in importance so has the governance of the industry. The aquaculture industry has benefited from an active Norwegian regional policy, a policy that has sought to sustain communities in sparsely populated areas in Norway and an infrastructure along the coastline that is unique compared to the competing countries (Jakobsen et al. 2003). These circumstances have been made possible due to the strong position peripheral areas have had in Norwegian Society Formation (op. cit.).

The governance process related to aquaculture during the 1970s is described as an ”Regional policy hegemony” (Berge 2002), and the development of fish farming policy can be said to be path dependent with relation to the foundations laid in the 1970s. The influence of these foundations, however, has not prevented considerable changes in governance and the regional effects of policy (Jakobsen et al. 2003). As political attention towards the industry has grown during the last years, the development of the framework conditions of the industry has been affected.

Norwegian public administration of aquaculture is built on the Aquaculture Act established in 1973 and administered by the Ministry of Fisheries. Central in this law is the obligation to acquire a license for operating a fish farm. The system required the registration of new entries and most applicants were granted permits at first, but in 1977, the authority banned new permits in the expectation of a permanent act. The

Aquaculture Act mirrored the core principles of the Fisheries Participation Act, but fish-farming differed significantly from the existing fishing industry. In addition the emerging aquaculture industry wished to promote aquaculture as an interesting investment opportunity and thus sought to downplay any association between aquaculture and the then heavily over-subsidised fisheries sector (Jakobsen and Aarseth 2007). The second Aquaculture Act (1981) sought to maintain an industrial structure based on small enterprises, an ownership structure based on local ownership, and a geographically dispersed industry. The law had a strong regional political superstructure in supporting small-scale operations in order to disperse fish farming activities and to support employment in sparsely populated areas.

Towards the end of the 1980s, the Norwegian aquaculture industry was facing increasing problems as prices fell due to increased international competition. Due to effective vaccines, production growth increased dramatically, profitability fell and softened the ideological resistance of small-scale operators to “distant” investors, leading to liberalization of industry ownership regulations in 1991.

Until 1991 it was only permitted to have one license pr. company, and it was also required that the owner should be local. In 1991, the Aquaculture Act was amended and the rules for ownership liberalized, resulting in a sweeping restructuring of the industry. How did this development affect the regional and local control of the industry? Acquisitions and the concentration of ownership of licenses in the form of mergers resulted in increases in the value of licenses as well as bankruptcies. In 2001 Paragraph § 6 of the Act was changed to include provisions allowing the Ministry to require payment for permits for the breeding of salmon and trout.

The new regulations mandate payment by operators of compensation to the Government for new concession assignments, 4 million NOK for assignments in Nord-Troms and Finnmark and 5 million NOK for the rest of the country. It is hard to imagine that the industry's modest profitability, combined with these prices for concessions, will make it possible for young people to be able to finance new concessions. An important reason for establishing the requirement for a license for fish farming was the wish to have local control with the industry.

The geography and horizontal and vertical integration in the sector

The aquaculture sector has become an important industry for the coastal areas of Norway. Production of trout and salmon has traditionally been concentrated to Western Norway and Trøndelag (mid-Norway). These areas were assigned a large number of concessions before the concession stop in 1997. The later concession rounds have favoured the sparsely populated Northern parts of Norway. The regional distribution of employment shows that in 2005 Nordland was the county employing the most people in aquaculture, followed by Hordaland and Møre and Romsdal.

The Norwegian salmon industry was originally an owner-operated industry with hundreds of small single-farm firms. The changes in the Aquaculture Act of 1991, however, triggered considerable sales of existing licenses and a growing number of licenses for salmon and trout are today owned by limited companies. In 2001 97,3% of fish food licenses were held by such entities, a substantial increase from the 86,3%

in 1992. The share of salmon and trout licenses owned by sole proprietorships has seen the opposite trend. In 2001 only 1,2% of the licenses were held by such entities, a drop from the 1992 share of 6,7%. The 10 largest production companies' share of total production of farmed salmon in Norway also has increased since 1989 (Figure 1).

[FIGURE 1 ABOUT HERE]

As can be seen from the figure above, while the 10 largest companies in 1990 accounted for 8% of total production, the share in 2001 was 46%. The curve is especially steep from 1991 to 1992, a period with many bankruptcies in fish farming (Jakobsen et al. 2003).

This increased horizontal integration in the salmon farming industry can also be linked to the considerable production and price risk that is characteristic of the industry. The production period from release of salmon fingerlings to harvest is typically 12-18 months, a period in which the fish are exposed to diseases, temperature changes and extreme weather conditions (Tveterås and Kvaløy 2004:12). The prices of salmon also can change significantly in the same period.

Recent years also have seen increased *vertical* coordination in the supply chain for salmon to Europe, reflecting growth of large horizontally and vertically integrated companies with direct ownership of production hatcheries, fish processing and export operations (op. cit.:4). This industrial structure resembles the most industrialized value chain in agriculture; nevertheless, the salmon supply chain has some idiosyncrasies that distinguish it from the typical manufacturing supply chain. Fish are more perishable and unpredictable, which means that larger investments and higher degree of coordination in the supply chain is necessary to preserve product quality and increase shelf life. It also is more costly to monitor external inputs in the production process and the supply chain is between countries (op. cit.:8). The figure below gives an overview of the core activities linked to fish farming, including estimates on the contribution to total value added of each step of the value chain.

[FIGURE 2 ABOUT HERE]

Today, there are between 15-20 roe producers and approximately 250 fry plants in operation in Norway, contributing to 1.200 million NOK in value creation. However, the largest value creation is found in ongrowing fish (6.100 million NOK 2002). 150 companies work in this segment of the value chain which involved that the fish is fed until it is slaughtered, usually at a size of 3-6 kg. Well-boats are used to transport both smolt from the hatchery to the ongrowing farms, and fully-grown live salmon from farms to the slaughterhouse. All the salmon are slaughtered in specialised fish processing plants. In Norway, there are 120 exporters involved in the export of salmon and trout. The exporters can either be part of a vertically integrated company that is involved in fish farming, such as Pan Fish Sales AS, or the company can act as exporter for several companies, such as NRS (Norwegian Royal Salmon), or they can be independent. The exporters represent the link in the value chain that has frequent contact with the market. They have close relationships to several foreign companies that import salmon and trout from Norway. At the same time they have relations to a broad set of actors in Norwegian aquaculture.

The product palette in the export business has changed over the last few years. Due to the large-scale horizontal integration among the salmon producers, the firms have taken over sales and distribution functions that were previously provided by intermediaries (Tveterås and Kvaløy 2004:19). As such a diminishing share of the primary products goes through traditional distribution channels and wholesales dealers. Simultaneously, the downstream end of the value chain consists of larger actors that optimise distribution of seafood through strategic value chain collaboration. This means that the actors, especially those in retail, reduce costs by building long-term relations with one or a few suppliers of fish – suppliers that can meet stringent demands with concern to volume and timing, raw material attributes, product range and differentiation, production process and transactions costs. According to Tveterås and Kvaløy (2004), this vertical coordination of the supply chain – from salmon aquaculture production to the supermarkets – is a relatively recent phenomenon in Norway.

There has been a tremendous growth among many of the largest fish farmers in Norway by the end of 1990 and the start of 2000, especially among companies like Pan Fish and Fjord Seafood. The earlier expansion in Hydro Seafood/Marine Harvest Norway, has stagnated. According to Tveterås and Kvaløy (2004:23) one cannot say that the larger firms are more cost efficient than smaller firms and it has been argued that a biological production such as salmon farming requires motivated workers and managers with an economic stake in the production outcome (Tveterås 1999). The economic results of the consolidation processes in the industry are still to be seen.

Employment and production in aquaculture

Employment in *salmon and trout* aquaculture has decreased steadily the last decade from 3503 people employed in 1995 to 2208 persons employed in 2005. On the other hand the sales of salmon and trout have increased steadily, to 645 387 tons in 2005, threefold the sales in 1994.

[FIGURE 3 ABOUT HERE]

The adoption of new technologies and learning within the aquaculture industry has contributed to this productivity growth. Cost of production declined steadily up until the year 2000, where reduction in production costs slowed because the most obvious sources of farm-level cost reduction had been exhausted (Tveterås and Kvaløy 2004:11). Today, there has been a shift within the industry to cut costs further downstream in the value chain, particularly processing and distribution to customers.

Even though the number of employees working with salmon and trout in Norway is relatively low, the aquaculture industry's contribution to gross national product (GNP) was 2,6 billion NOK in 2004. Overall, the marine sector (fishing, catch and aquaculture) contributed to 1,05 per cent of total GNP in 2004 and represents the only primary industry that keep up with the general growth in Norway's GNP (Sandberg et al. 2005). In comparison the oil and gas extraction contributed to 20 per cent of GNP in 2004.

Apart from the direct effect of the industry on Norwegian employment and growth, the sector has affects other industries since the aquaculture industry is dependent on several input factors such as feed, vaccination, technical equipment etc. from other sectors in order to operate. These linkages with other industries mean that the aquaculture industry contributed to an overall employment of 13 200 man years in 2003 (Sandberg et al. 2005) and a contribution to GNP from other sectors of ca 6,6 billion NOK in 2004.

In 2005 the value of the exported fish and fish products from Norway was 32 billion NOK of which 17 billion came from wild catches and 15 billion from aquaculture of salmonids (Olafsen et al. 2006). Norway is mainly an exporter of “primary” fish products; which is fresh round or filleted fish. In 2002, 78 per cent of Norwegian exports were head-on gutted fish whereas 80 per cent of Chilean exports were fillets (Tveterås 2004). This is due to several factors among which relate to traditions, trade barriers (high tariffs) for processed products, and high labour costs.

The industry is very export-oriented and very cyclical, the export ratios varying within the year and between years. It is only oil and gas and “other means of transport” that has more variation in export (Sandberg et al. 2005). In comparison the export value of the Norwegian petroleum sector was 346 billion NOK in 2005 (crude oil, natural gas, suppliers etc.) or 10 times more than the export value of fish and fish products (Olafsen et al. 2006).

Olafsen et al. (2006) have estimated that the export value of *marine expertise* such as deliverables from “Suppliers”, “Research, Development and Educational institutions” and “Other knowledge-intensive services” amounted to 3,8 billion NOK in 2005, representing 10% of total marine export value. According to Olafsen et al. (2006) this segment could increase its share of marine exports to 25% by 2025.

Norwegian salmon production in a global context

The main producers of aquacultured Atlantic salmon in the world, besides Norway, are Chile, UK, USA/Canada, Faeroe Islands, Ireland and Iceland. Aquaculture of salmonids in other countries has in varying degrees relied on Norwegian expertise and technology (Olafsen et al. 2006). The total production of farmed salmon from these countries was 1,130,700 ton wfe[4] in 2003 (Winther et al. 2005) (see table below). Of this volume 587,000 ton were supplied to the EU, either as import or as domestic production in Scotland and Ireland.

[FIGURE 4 ABOUT HERE]

The Norwegian world market share decreased from 49 percent in 2000 to 46 percent in 2004, while Chile had a growth in market shares from 19 percent in 2000 to 29 percent in 2004 (Winther et al. 2005). The most important market for Norwegian exports of farmed salmon is the European Union. The Norwegian market share in the European Union increased slightly in the period (being around 65% in 2004 while the Chilean market share had the largest relative growth (from 4 percent in 2000 to 7 percent in 2004) (Myrland 2003; Nielsen 2003; referred in Winther et al. 2005). The main explanations for Chile's increasing market share have been adoption of best practice technologies, exploitation of economies of scale, and lower labour and feed input costs (Bjørndal et al. 2004 referred in Winther et al. 2005).

Norwegian fish farmers have become more internationalised over the past few years, investing in fish farms in other countries, especially Scotland, The Faeroe Islands, USA, and also in Chile. Norwegian farmers are now operating within important, external markets, often with Norwegian nationals placed in key positions in the new company. Thus, some of the diminishing share of Norway's world production reflects the growing "offshore" operations of Norwegian firms.

The table below shows the ten largest global companies for farming of salmon and rainbow trout in 2003. Nutreco, with headquarter in the Netherlands, is the largest single producer of salmon and rainbow trout globally in 2003. Nutreco also was the largest single producer in Norway in 2003, and has large operations in Chile, UK and "other countries". Pan Fish, Fjord Seafood, Stolt Seafarm and Cermaq, all with headquarters in Norway, are among the five largest producers, all having large productions in Norway and in several other countries. According to Tveterås and Kvaløy (2004), Pan Fish produced almost the same amount of farmed salmon in the UK as the UK-based company Scottish Seafarmers, and Stolt Sea Farm had a higher production of farmed salmon and rainbow trout in Canada than the largest Canadian producer George Weston/ Connors. Chile is also an important actor. Among the ten largest actors, five have headquarters in Chile. These companies have no farming facilities in other countries.

[TABLE 1 ABOUT HERE]

The responses to interviews with Norwegian aquaculture firms with activities abroad (Aslesen et al. 2002) suggest that Norwegian companies find that operating globally is important for their activity. During a certain period in time it was expensive to expand and to buy up activity in the Norwegian market compared to buying up facilities in other countries. Being established in other salmon producing countries has given the firms proximity and flexibility in the most important markets for salmon. The companies are of the opinion that operating in leading foreign markets (in i.e. Scotland – EU, Canada – North America) reduces the risk in case of trade barriers. Establishment abroad comes therefore in as a strategy for risk reduction (i.e. if outbreak of diseases among the fish in certain localities). Facilities abroad also lower logistics costs and increase flexibility in production, improving Norwegian firms' delivery performance in these markets.

Innovation strategies and the organisation of aquaculture firms

In studies of innovation systems one point of departure is to investigate how learning is achieved through interaction with others – so-called interactive learning. As such the knowledge base of the firm is one of the most important background variables to understand innovation strategies. By understanding the structure of the knowledge base, we may also gain insight into the types of interactive learning processes that may be observed empirically, for instance through a mapping of innovations made – and not least – if there are recognizable patterns in the sense that there are specific types of innovations that actually do not happen.

The analysis is based on 25 in-depth interviews with actors in the aquaculture industry (Aslesen et al. 2002; Aslesen 2004). The interviews were based on semi-structured guides developed in the two projects, focusing especially on innovation activities, innovation collaboration, networks and innovation strategies. The main aim of the interviews were to understand how new knowledge is created, used and spread in the innovation system. Based on these interviews we found it reasonable to distinguish between two different strategic approaches among aquaculture firms:

1) A large number of firms base their activities, and the development and gradual improvement of these activities, almost exclusively on practical knowledge. Learning happens by experimenting, and the knowledge base underlying innovation activities is to a large degree tacit. Knowledge is gained through experience generated by effective operations through practical solutions based on accessible practical and tacit knowledge in the field of aquaculture. We here denote such a knowledge base a *practical knowledge base.*

2) Another significant number of firms base their innovation efforts by interacting with and contributing to a system of scientific knowledge. The learning in these firms is based on interactive development and the use of new scientific or technological knowledge and can as such be denoted as formal knowledge involving both scientific and technological knowledge.

In our extensive empirical research, we have seen that firms are not placed in a continuum between the two alternative approaches to innovation, but that there is a tendency to choose either one or the other. Innovation and knowledge strategy varies with firm size, but not in a simple way. Our interviews have indicated a more complex relationship. The aquaculture industry consists of a large number of small firms, and a much smaller number of big firms. However, also the smaller firms are quite different in their approach to organisation of innovation-related activities. We have found that there are a surprising number of firms that have organisations marked by ad-hoc solutions to structural problems. A number of other firms, usually older firms, have a more structured management structure and more elaborated, functionally differentiated organisations.

This line of argument provides us with the following table, as a classification of aquaculture firms (and their different innovation systems):

[TABLE 2 ABOUT HERE]

The model outlined above offers a suitable framework for the presentation of results from our empirical research on what firms are like in Norwegian aquaculture, and how they operate with respect to innovation:

1) ”The family firm”

”The family firm” is usually a small aquaculture company. It is run by the owners themselves, often a single family, and with second generation family members involved in the running of the company. The different functions within the firm often overlap and rely on knowledge obtained from practical experiences. The implication of this is that the aquaculture technicians, the management and the operational personnel are often one and the same person (“a Jack of all trades”) – or if there are more people involved, they are in face-to-face contact and dialogue. This facilitates operational improvements as well as other innovations. The “family firm is rarely in control over more than its own little piece of the whole value chain. Management focuses on costs and is financially conservative, because of the unpredictability (in relation to biology, market and regulations) characterizing production. Decisions are taken swiftly and the “written word” is of little value. Management philosophy is often that “*money not made today will never be made*”.

Problems do arise that the firms cannot solve by themselves. These actors primarily draw on competence from the knowledge intensive-service activities available from the vertical networks of suppliers of feed, equipment (also ICT), and medication, as well as their competitors (similar firms). The firm will take part in development projects with actors in their vertical network and receive valuable knowledge of practical- and experience-based nature (as opposed to scientific). Knowledge related to adjustments and incremental development activities (especially technologically related) is a very important source of innovation in the “family firm”.

[BOX 1 ABOUT HERE]

Another important innovation driver of relevance to the family firm is the open and accessible knowledge that exists in the Norwegian aquaculture cluster as a result of fish farmers meeting informally and sharing their knowledge on “best practices”. “Everybody knows everyone”, and as such the channels for the free flow of knowledge are in operation. However, knowledge nodes are not very heterogeneous, and channels to the scientific community are both rare and inefficient.

Together with their suppliers, some aquacultures firms have joined user-oriented projects managed by the Research Council of Norway (RCN) and in that way the firms have received input from Regional Technology Offices. In this way, thus, the supplier serves as an important bridge builder between the aquaculture firms and the knowledge infrastructure.

2) “The coastal enterprise”

“The coastal enterprise” has developed beyond the ad-hoc organisation of the family firm to a more mature, permanent operational phase. The firm has developed a more professional and functionally differentiated organisation, with permanent management. The “coastal enterprise” seeks to exploit advantages of both horizontal integration (mergers with other fish farms) and vertical coordination down the value chain. The “coastal enterprise” represents a shift from the organisation adopted from traditional fisheries (found among ”the family firm”), towards a model of a more industrialized value chain found in manufacturing, although these organizations still have a long way to go.

Several of the “coastal enterprises” pursue a strikingly “anti-innovation” strategy. We are told explicitly that they do not, and do not plan to, carry out any research and development, and they systematically avoid being in front with regards to new technologies and solutions. Most innovation thus takes place in the same manner as among the family firms, basically through copying and through trial and error. The “anti-intellectual” characteristic of this culture seems to have been only reinforced by the increasing pressures towards increased efficiency and adjustment to lower prices, during which administrative capacity has been regarded as a luxury that is a lower priority.

[BOX 2 ABOUT HERE]

In spite of these anti-intellectual and anti-innovative strategies, the coastal enterprises must engage in innovation to some extent. Pressures towards innovation in the "coastal enterprise" stem from the operational side, and, as in the family firm, often result from interaction with the suppliers of equipment. Innovations take place by employing new equipment, new feeds, etc., and at times, the risks associated with possible failure are shared with the suppliers. The interviews indicated that these firms' innovation activity also relied on finance from RCN's user driven projects. Innovation Norway was used by several of the interviewed firms as an important contributor to innovation in the firms, both for direct investment support and for "softer" inputs of importance to innovation, such as different types of business courses and training. One of the interviewed firms had also received public money for the marketing of their products abroad.

Important parts of the knowledge infrastructure are still not integrated in the "coastal enterprises" innovation efforts, raising challenges to these organizations' long-run viability. A strategy of vertical coordination puts pressure on these firms that increases the need for long-term, strategic innovation projects (i.e. buyers demand for high quality attributes, raw material in feeds).

3) “Research based entrepreneurs” – profiting from being in front

The focus of this class of aquaculture firm has moved away from operational aspects to scientific and technological knowledge development. These firms’ rely on knowledge generation, coupling diverse forms of knowledge and including knowledge development developments in the frontiers of scientific research. Operational aspects of aquaculture may actually be irrelevant to such firms, and are often outsourced to others. Despite their highly technological orientation, these firms pursue an open strategy vis-à-vis technological developments (based on shared and generally accessible knowledge), and pursue joint projects with people in research institutes and universities.

[BOX 3 ABOUT HERE]

The research-based firm often depends on access to scientific knowledge that is open and accessible. “Research based entrepreneurs” are often tightly connected to the publicly financed “knowledge infrastructure” in Norway and close relationships to other research activities bearing on innovations. Surprisingly, these firms do not try to shield new solutions internally within the enterprise. Instead, many of them prefer an open and accessible knowledge base for the whole cluster. There are a number of reasons for this. An important factor is that no one company possesses the resources needed to privatise and control both new knowledge generation and the practical application of new knowledge in the company. As a matter of fact they depend on the collective knowledge base of the cluster, and as such have every reason to keep the commons open. Of course, there are exceptions to this characterization. Some very competent research-based firms depend on open sources of knowledge, while simultaneously protecting their own knowledge and technology through secrecy and formal IPR protection.

“Research-based entrepreneurs” pursue innovations of a more radical nature (products or processes that are new or have been significantly improved, and/or also novelties in the market) since “new” knowledge is the driving force of the firms investments/business activities. The projects are often long lasting, and interviews suggested that many research based entrepreneurs utilized public or semi-public Regional Technology Offices for the purpose of obtaining co-financing of projects.

4) “Science based process industry”

Increased demand for quality, reliability, and safety in fish and shellfish raised through has become an important source of pressure on innovation in recent years. Demands concerning food safety and traceability are growing stronger, and together with regulatory changes have directed innovation activity in specific directions. Important challenge for aquaculture firms include the establishment of high-quality and stable channels of access to the market, in order to be able to understand, “translate”, and use market signals in innovative behaviour in the firm. The fourth organisational model, “the science based process industry” (which is not yet represented in Norwegian aquaculture), has the knowledge base to exploit the potential of horizontal integration and vertical coordination as it encompasses both scientific and practical knowledge, in its efforts to innovate and to develop its business.

This organisation model resembles the most industrialized value chains in agriculture, relying on their control of unique scientific knowledge, and using this control to expand activities. Such control may come in the form of secrecy or patents, i.e. privatisation of the control of knowledge. These types of firms have the resources available to privatise and control both knowledge generation and its practical application (as opposed to "research based entrepreneurs"). The objective of knowledge development in such a company is to develop a competitive advantage that needs to be protected from competitors. Firms with research activity will thus have incentives to hold on to their knowledge. They may not be as dependent on the collective knowledge base of the cluster, and may to a lesser extent participate in the informal networks that, for many actors, seem to be the most important channel for knowledge.

There are signs, however, that the large "science-savvy" firms that we call science based process firms may believe that a functioning public knowledge infrastructure with open access to scientific results has significant advantages for them. Aquaculture firms moving towards this organisational model have established relations with the knowledge infrastructure through mobility of personnel and through project cooperation. This part of the aquaculture industry has extended its network to include parts of the knowledge infrastructure, and in this way has made communication and networking between the heterogeneous actors easier. The development of this segment of the aquaculture industry is only in its infancy but the "science-based firm" seems to be the organisational model with the most operative and functioning sectoral innovation system.

Summary

Knowledge on fish farming has accumulated in different communities in Norway through time. The learning process was long and drew on both experience-based and scientific knowledge. From the 1970s a combination of knowledge and actors were able to solve specific problems and initiated commercial fish farming. Innovations and change have occurred in all parts of the value chain in aquaculture over the years, making the industry continuously more productive. Employing approximately half the people that it did 10 years ago, the sector in 2005 had tripled sales over the 1994 level. The value of exported aquacultured salmonids is approximately half the value of the total export of fish and fish products from Norway. The last years there has been a tendency of horizontal integration and a growing numbers of licences are owned by a limited number of companies. In 2001 the 10 largest companies accounted for 46% of total production, a significant increase from their 1989 share of 9.5%. There are also several examples of vertical integration in the supply chain of fish farming the last years. Norway is the largest producer of aquacultured salmonids with a world market share of 46% in 2004. Chile's share is growing, accounting to 29% in 2004. Norwegian fish farmers have become more internationalised and have bought up whole or shares of aquaculture firms in other countries.

Research activity in the public and semi-public institutions in Norway has been of great importance to the development of the aquaculture industry in Norway. The enormous growth and productivity gains experienced in the sector during the 90's would not have happened without this effort. Public funding provides more than half of the funding for aquaculture R&D conducted in Norway. Other important innovation drivers in aquaculture are the technology suppliers and the feed suppliers.

Much of the innovation activities going on in aquaculture firms can be traced back to the supply industry.

By differentiating aquaculture according to knowledge base and degree of structured and functionally differentiated organisations, we found that aquaculture firms have very different approaches to innovation; from “anti-innovation” strategies to strategies that seek to be in the forefront of innovation in the industry. Firms with very different approaches to innovation and very different linkages to the sectoral innovation system exist side-by-side and the overall functioning of the sectoral innovation system of aquaculture is influenced by all the different firm types.

The 4 different types of firms have similarities with Wicken’s analysis (2007) of the different developmental paths that have relied on different innovation systems (including different knowledge base, social groups and institutional structures). As Wicken notes, even though these different paths have emerged in different times, new paths are added to existing paths – as the “family firm” exists at the same time as “the science based process industry”. Wicken’s path 1 represents an innovation system characterised by localised learning and weak connections to the knowledge infrastructure, exemplified by the “family firm”. Wicken’s paths 2 and 3 represent innovation systems characterised by larger integrated firms with internal R&D activity and non-local ownership, similar to the innovation systems that are developing in the “science based process industry” and possibly in the “coastal enterprise”.

The discussion above reveals that the sectoral innovation system of aquaculture firms is heterogeneous. The degree to which firms are able to move beyond interactive learning in practical day-to-day operations depends on, among other things, the composition of their key knowledge base, their organisational structures, their size, and their maturity. That is to say, companies in the aquaculture industry relate in different ways to sources of knowledge in their surroundings. We have seen how firms can be described as ideal types, and we have seen how different firm types vary systematically with respect to their approach to innovation. In the table below, we point out the key barriers to innovation in aquaculture firms.

[TABLE 3 ABOUT HERE]

The firms in type 1 (the family firm) have not developed a clear strategy in relation to their development activity in Norway or in the other countries in which they are operating. The individual companies are left to their own devices, and this category of aquaculture firms will face the greatest challenges in the coming years.

The main strategy of a number of the firms in the coastal enterprise (type 2) is to make use of existing knowledge, so-called best practices, and disseminate such knowledge as soon as possible among the different production units in order to improve process innovation. There is no strategy to pursue independent research through establishing research and development units or institutions in this type of firms. However, the companies are continuously evaluating new knowledge and promptly implement relevant - proven - technology.

The research based entrepreneurial companies (type 3) are characterised by having control over parts of the value chain that require continuous R&D activity. They are closely connected to the scientific research infrastructure, and an interesting question for these firms concerns their ability to develop into larger organisations with sustainable value creation activities.

Firms of type 4 are uncommon in Norwegian aquaculture today. This is not only because the number of large firms is limited, but also because some of the large companies actually are structures where a "holding company" controls the operations of many small operations that continue to operate much in the same way as they have done before. It appears that the main impetus to create integrated operations in which heterogeneous knowledge and scientific knowledge are relevant at all stages in the value chain, from microbiology to marketing, comes from international firms establishing themselves in the aquaculture industry by way of acquisitions.

In general, many aquaculture firms do not possess the ability to establish, on their own, a basis for scientific competence to underpin their own activities. The causes of this are linked to falling prices and other crises, which have driven the firms into a efficiency trap in which the focus of the firms activities have been on operational effectiveness and learning by trial and error, rather than long-term science-based knowledge development. Aquaculture firms nowadays tend to use suppliers to gain access to knowledge. Suppliers of feeds, medicines, roe and fry are important sources of new products and processes coming into the industry. The knowledge of these suppliers is to a greater extent embedded in the products they deliver. Aquaculture firms seldom participate in cooperative projects in which the core knowledge of the product is in focus.

Knowledge acquisition thus is peripheral to the firms' main line of activity and depends on suppliers and in the research community. In this way, suppliers function as "translators" of knowledge between the suppliers of analytical knowledge (R&D institutions, universities) and aquaculture industry; thus they are a compulsory "check point" on which the aquaculture companies depend in order to gain access to knowledge.

Measures to improve the Norwegian aquaculture industry's innovative ability should be directed at stimulating firms to expand their strategic and analytic knowledge base, in order to enable them to gain a better understanding of the uses of research as a tool for product- and process development to meet future market demands. This entails an effort among firms to develop their own "innovation systems" and their own knowledge bases.

Notes

[1] The empirical work underlying the paper was undertaken within the framework of two different projects focussing on innovation practices and the business system in Norwegian aquaculture. A project focussing on the innovation system in aquaculture was particularly important. This project was financed by the Ministry of Fisheries in 2002. Åge Mariussen, Heidi Wiig Aslesen and Finn Ørstavik (all from the STEP group in Oslo) formed the core research team for the project together with Ulf Winther and Trude Olafsen from KPMG in Trondheim. The project was reported in Aslesen et al. 2002. Another important project was the OECD project focusing on knowledge intensive service activities on the aquaculture industry, reported in Aslesen (2004).

[2] Salmonidae is a family of ray-finned fish, the only living family of the order Salmoniformes. It includes the well-known **salmons and trouts**; the Atlantic salmons and trouts of genus Salmo give the family and order their names (WIKIPEDIA).

[3] Based on Olafsen et al (2006), technology in this context is defined as technological solutions for land-based brood stock, fry and smolt production, and sea-based food fish production. The transport of living organisms in well-boats and tank lorries is also included. Examples of land-based technologies are the construction of buildings, energy installations, tank constructions, control- systems, IT systems, feeding systems etc

[4] WFE = Whole Fish Equivalent, i.e. whole fish that is starved and bled (Winther et al., 2005 p. 8).

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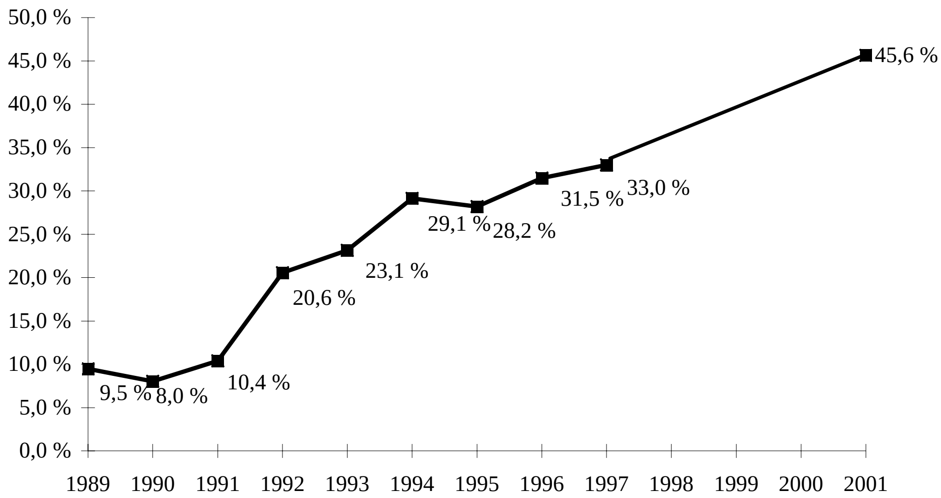
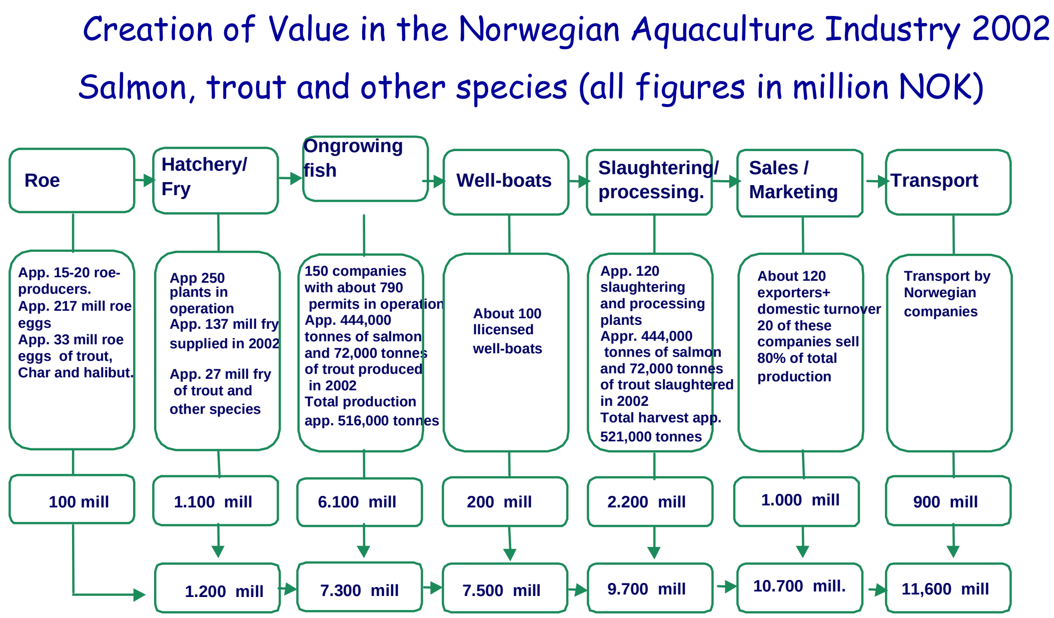
Figure 1. The 10 largest aquaculture companies' share of total production 1989 – 2001. Percentage.



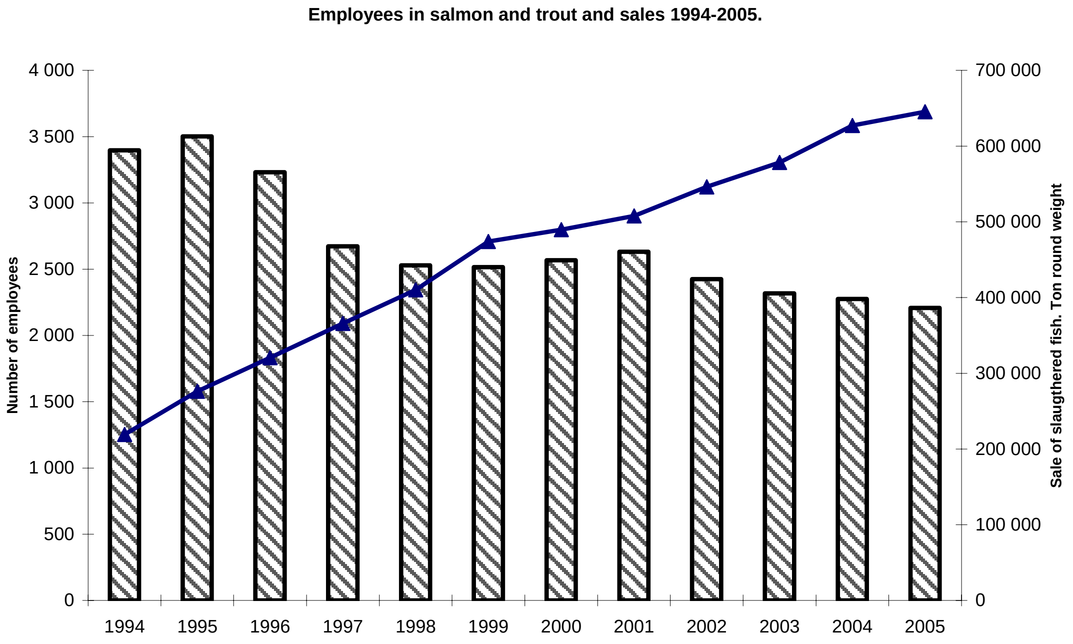
Source: Jakobsen et al. 2003

Figure 2. Estimated creation of Value in Norwegian Aquaculture Industry 2002



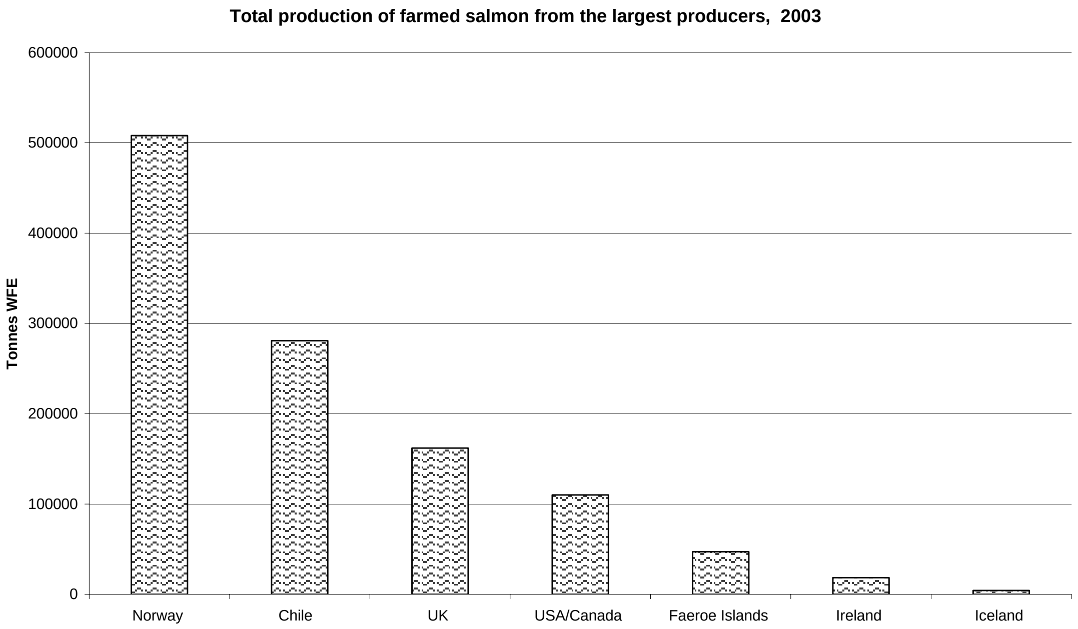
Source: Kontali Analyse AS

Figure 3. Employment of persons working with salmon and trout in Norway from 1994-2005, and sales of salmon and trout in the same period.



Source: Directorate of Fisheries /NFF. Pr 30.11.2006.

Figure 4. Total production of farmed salmon from the largest producers, 2003



Adopted from Winther et al. 2005 based on statistics from Kontali Analyse A/S.

*Table 1. Companies ranked by global production of salmon and rainbow trout 2003 (in metric tonnes)**

Company	Headquarter	Total production 2003	Norway	UK	Chile	Canada	USA	Other countries
Nutreco	Netherlands	178500	70000	32000	59000	12500		5000
Pan Fish	Norway	86100	31100	20500		9800	12000	12700
Fjord Seafood	Norway	72500	35000	7000	28000		2500	
Stolt Sea Farm	Norway	70500	15000	6000	24000	25000	500	
Cermaq	Norway	48500		8000	32500	8000		
Aquachile	Chile	48000			48000			
Pesquera Camanchaca	Chile	37000			37000			
Cultivos Marinos Chiloe	Chile	34500			34500			
Salmones Multiexport	Chile	34000			34000			
Pesquera Los Fiordos	Chile	33000			33000			

Source: Tveterås and Kvaløy (2004)

*The total production of farmed Atlantic salmon was, according to Kontali, 1130700 tonnes wfe in 2003 (Winther et al. 2005). Although trout is included in the table, comparing these figures gives an indication that the ten largest companies produced nearly half of the supplied Atlantic salmon in 2003.

Table 2. Stylized variants of aquaculture firms

Knowledge base Organsation	Practical	Technological/scientific
Entrepreneurial, ad-hoc	1)"The family firm"	3) "Research based entrepreneurs"
Structured management system	2)"The coastal enterprise"	4) "Science based process industry"

Table 3. Perceived impediments to innovation

Knowledgebase Organisation	Practical	Technological/scientific
Entrepreneurial, ad-hoc	*1)"The family firm"* - Linearity and technology transfer characteristic of innovation - Limited interactive learning beyond the practical experience based	*3) "Research based entrepreneurs"* - Difficult to 'move researchers out' - Capital intensive and time consuming projects, need for long-term and knowledge intensive capital
Structured management system	*2)"The Coastal enterprise"* - "Anti-innovation strategies" - Limited participation in interactive learning providing 'higher ranked competitive advantages' - Dependant on suppliers' knowledge base	*4) "Science based process industry"* - Difficult to integrate and have full control over relevant types of scientific knowledge - Cost intensive strategy, which also contributes to shut off other actors' access to information/knowledge

Box: 1. Example of an innovation in the "family firm"

Incremental innovation and adjustments rely on regular interactions between the firm and especially the technology suppliers. For example the use of new steel constructions at different localities and new anchorage systems has been an important source of improvement in fish farming. The firm has also acted as a test site for equipment developed by a local entrepreneur that gathers dead fish and feed spillovers and provides information that supports optimal feeding of the fish. As such the firm has engaged in an innovation project without bearing the financial burden or the entirety of the risk.

Box: 2. Example of an innovation in a "coastal enterprise"

A firm had taken part in a development project with a local supplier of technology. The collaboration ended in an innovation that makes it easier to change the fishing net in the net cages and as such gives a better environment in the net cages. The use of the so-called "Environment drum" means that fish farmers do not need to impregnate the fishing net as frequent as before. This has both an economic and environmental benefit. Firms interviewed indicated that one of the aims of the project was to make the drum fully automated. This product is today commercialized, suggesting a successful innovation.

Box: 3. Example of an innovation in a "research based entrepreneur"

This firm has close collaboration with both fish farmer and the most important national and international aquaculture related research institutes and universities. Innovations in this firm include developing breeding schemes to create fish that are the most resistant to diseases. The firm also has innovation projects taking into use DNA technology in order to use paternity tests on fish. Simultaneously the firm had started a breeding scheme for cod.