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Research and development of 'new species' in Norwegian aquaculture

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ABSTRACT

Because of salmon farming, Norwegian aquaculture today is a remarkable economic success. The success is partly explained by aquaculture research of high international quality. However, this salmon farming research overshadows how research and industry interact to create growth. The focus of this article is on the reciprocity of the system that produces fish and shellfish and the system that produces research. The research is organized as a comparison of salmon farming with four other initiatives within Norwegian aquaculture that represent enterprises with various initial problems. While research tend to be oriented towards one-factor explanations, industrial development will include immaterial considerations as trust (do we believe in this), risk acceptance (do we believe sufficiently in this to risk our own money), knowledge (do we have complete understanding about how these things work), path of development (do colleagues that believe in the same as us, exist), values (is this the enterprise we wanted to be part of). The institutional environment, which gives new enterprises content and meaning, existed for salmon farming when the enterprise was new. The (so-called) new initiatives basically lack this institutional context. The imagery of salmon farming still dominates the arena. In order for aquaculture research to contribute to qualitatively new industrial development, the research must take place in relation to real activity where actors with a common goal in sight use the research results. The main conclusion is that the role of research and knowledge production in industrial development is not sufficiently problematised.

Introduction and approach

Norwegian aquaculture has experienced a strong growth over the previous 30 years. Qualitatively good and goal directed research has been an important part of this development. However, the industry has been through a significant institutional transformation. Practical

outcomes of this transformation are that the average firm has become bigger and more professional, the knowledge production has become more effective, and the industry has become more rational and modern. Norwegian aquaculture has been – and still is – dominated by salmon-farmers. Parallel to this industrialisation of salmon aquaculture, a diversification of Norwegian aquaculture is taking place. A range of species is now in production – all of them, however, in small numbers.

In particular during the last 10-15 years an increasing number of socio-political areas are transferred from the political arena to the market (Jakobsen, 1998; Hersoug and Holm, 1992). In defence of the market based solution it is often referred to as a reform that makes the decision systems more cost effective as any decision can be measured in a cost-benefit perspective, that it is value neutral as they eliminate the power base for traditional political (bureaucratic-administrative) governance systems, and that it is perceived as a democratic reform as it delivers what people want to a price people are willing to pay. This angle pinpoints the dilemma of public research, and in particular public support for innovations. If farming of all of these species is so promising, why is nothing happening? Why does the public have a role here?

Industrial innovation is central to the economic politics and development (Skoie, 1996). In Norway industrial innovation is proposed as a strategy to transform the economy from petroleum based economy to an economy based on land-based industries (Aakvaag et al., 1996). Segments of industrial life beside petroleum that do compete internationally, such as the aquaculture industry, are expected to improve processing and are thus an arena for innovations. The focus of this article is on the reciprocity of the system that produces fish and shellfish and the system that produces research. The research is organized as a comparison of salmon farming with four other initiatives within Norwegian aquaculture that represent enterprises with various initial problems. While research tend to be oriented towards one-factor explanations, industrial development will include immaterial considerations as trust (do we believe in this?), risk acceptance (do we believe sufficiently in this to risk our own money?), knowledge (do we have complete understanding about how these things work?), path of development (do colleagues that believe in the same as us, exist), and values (is this the enterprise we wanted to be part of?).

The reorganization of the research sector was supposed to stimulate innovation and increased profits from Norwegian research (Ramberg and Skoie, 1997). In addition to this general process, the government aimed at stimulating innovation within the aquaculture industry (Anon., 1995; Stortingsmelding, 1994). This stimulation was based on the identification of a significant amount of "good" knowledge in the research sector that with some stimuli would be available for industrial development, and, eventually, profit. The researchers had to argue with the utility of the research in order to get funds. When the researchers have to justify why the research activity failed to reach the expected results, a problem of explanation occurred and thus a problem of legitimacy.

There are two perspectives on industrial innovations: the value chain model and the cooperation model (Skoie, 1996). In the value chain model, research, innovation, and development are described as "mechanistic" or "static", where a given situation demands a particular solution, which per definition will be developed and supplied. The value chain model is based on the idea that there is a simple chain of innovations from the basic research to the final product. The process is incremental as value is added to the initial idea, from one link of the chain to the next (Godø, 1996) and where idea is the first link and marketable product the last. In the cooperative (or dynamic) model, on the other hand, the research agenda is designed by mutual and reciprocal influence between "sender" and "receiver" and negotiation between these parties. The relative political strength between the parties determines the result (Busch, 1980). The cooperation model launches a view with more nuances on how innovations take place (Skoie, 1996). In this perspective the significance of the genuine research is reduced, as everything takes place in reciprocity between researchers and research consumers. Applied agricultural research develops under constant supply and demand, and the consumers are included as an active part in the design of the agenda, in the conduct of the research, and in the interpretation of the research results (Busch et al., 1983; Busch, 1980). As the research is applied, the researchers are also motivated to demonstrate the use of their findings.

In this work, the relationship between research and industry is studied as a process affected by a variety of factors, but where patterns are identifiable and where knowledge about the future can be won by understanding how research questions are posed, agenda formed, resources channelled, ideas and interests marginalized or articulated. The process is dynamic in the sense that "the right answer" today might be "the wrong answer" tomorrow (Weir, 1992). Politics is about managing differences and allocating resources. In a longer perspective, politics is about

marginalisation of some interests and legitimatisation of other. Also the transition to marked based systems is a political problem as such transitions affect cases of equity and allocation.

This paper is an explorative study of an industrial field in transformation. Norwegian aquaculture may – or may not – transform from a rather monolithic salmon-based and expanding industry and to a diversified, multi-species, and multi-entrepreneurial industry where one or more of the followers of salmon farming (that is "new species") are included. Such institutional process-analyses have a longitudinal component.

This article is organized as follows. First some analytical concepts are established in order to study the relationship between industry and research. In the second section, the production system of aquaculture research is presented, followed by a presentation of the production systems for farming of the four (so called) "new species". In the third section differences in how the aquaculture enterprises organize the interaction between industry and research are discussed. In the fourth section the article is concluded.

Relation between the system of "industry" and "research"

Two models for the relationship between the aquaculture industry and the research sector are described here: the market based R&D system and the corporate R&D system (Table 1). The R&D system itself can be divided into an industrial sector and a research sector. The focus here is how these systems choose to interact. Each sector is embedded in its own institutions, and within an institutional perspective there are two possible solutions to this interaction. In the market based R&D system, representatives of the two systems will relate to each other as professional partners where objectives for and conduct of the research are negotiated, where institutions delimit the negotiations. These institutions determine the ownership of the results and how the research is published. In the corporate R&D system the institutions themselves are subject to negotiations. Representatives from the research- and industry sectors will have the opportunity to influence the institutional apparatus, and thus guide the direction of the research, how the research is conducted, what type of research that is prioritised, and finally how the results are utilized.

Table 1: Comparison of R&D systems.

	Market based R&D systems	Corporate R&D systems
Motivation	Creating values	Building knowledge
Interests	Local, private	Common, sectorial
Perspectives	Industrial development	Social development
Rights	Private	Collective
Target group	Company level	Industrial level

The formation of research and industry policy used to be based on delimited sectors and powerful organisations, but a shift has taken place and now market-based models are most prominent. The firms' ability to compete has thus been changed. A possible strategic choice within the market based model is to protect the firms' core by closing the production process – for instance by a quality security program – which provide exclusive access in a market.

The institutional processes that embrace all participants in a specific sector determine industrial organization. These processes can be cognitive, where appropriate behaviour is maintained by various social sanctions; and regulative, where access to the field and action within the field are regulated by formal rules. Public policy is to prioritise, and policies with effect for the salmon aquaculture are industry are such as rural policy, industrial policy, economic policy, environmental policy, fisheries policy, and research policy.

The two R&D systems have strong as well as weak sides (Table 2). The corporate system may function well in early stages of the innovation process as it has a longer time perspective; the system allows other types of evaluations, and allows other resources access to the development projects. In the more mature stages of industrial innovation it is reasonable to assume that this system will be rigid and not particularly creative. The market based system, on the other hand, will often be too focused on details in the early stages, while in a more mature phase, when the resources are more easily accessible from the industrial actors, this system will be able to channel the resources to the most appropriate tasks.

Table 2: Difference between corporate and market based R&D systems.

	Corporate R&D systems	Market based R&D systems
Industry in initiation phase	Good system	Bad system
Industry in mature phase	Bad system	Good system

Organization of "industry" and "research" in the aquaculture sector

Organization of aquaculture research

Aquaculture Act amendments in 1989 marked the end of ownership regulation. These changes were followed by the bankruptcy of the Fish-Farmers' Sales Organization (FOS, in Norwegian: Fiskeoppdretternes Salgslag), which also discontinued the authority of the Raw Fish Act (Aarset, 1998). Within the aquaculture research system the focus shifted more towards applied goals (NOU, 1988). In 1993, the Research Council of Norway (NFR; in Norwegian: Norges Forskningsråd) was established and user-governed applied research was decided to be the ruling principle for the council's policy. New strategies for aquaculture research was launched in 1995 when a white-paper on aquaculture suggested a change of direction of the research away from "salmon research" and in stead prioritised research projects focused at "scallop" and "halibut" (Stortingsmelding, 1994).

In the 1980s the salmon segment of the aquaculture industry increased significantly measured by production volume and value. Four reasons in particular are highlighted as explanations for this growth (Arntsen et al., 1996). First, the industrial growth took place by the expansion of the simple net-pen based technology, a situation that opened a series of growth problems such as local pollution, capsizing, and uncontrolled pandemics. Secondly, a general liberation in the access to capital in the Norwegian market combined with significant growth in the aquaculture industry motivated private investors to become more interested in the industry. Thirdly, the industrial growth also encouraged suppliers of technical equipment to be interested in the industry. And fourthly, aquaculture was selected by the government as one of four areas for special focus in the governments' state budget proposal for 1985 (Stortingsmelding, 1984).

The assumption is that there is a connection between "the trade of salmon" and "the trade of research products". Regardless of the level of the salmon production, the government may still want to prioritise the production of research – as with the research on marine species in aquaculture. Other areas – such as fish feed – occupies a stable level of public funding since this research is directly involved in the aquaculture production. The fish health research does of similar reasons receive an increasing part of the research funds. In addition, there is an increasing attention on the preventive aspects of the fish health issue in the aquaculture industry. The environmental and political – and ultimately economic – costs of loosing the control will be significant.

System for production of "new species"

In the shadow of salmon farming there has been conducted experiments with several other new species' in Norwegian aquaculture. The list over so-called "new species" is long, and the experiments have been ongoing for several years. However, these experiments have still one property in common – the research activity has been significant, but the production curve – to the extent there has been any production at all – has levelled out by a few hundred tons. Eel, bass and bream, turbot, wolf fish, hake, wrasse, oysters, kamchatca crab, and sea urchins are among the exotic species. Down below four of the – in this picture – significant initiatives will be presented. A common feature for several of these species is that they have a history back to research activities in the 1970s, or even earlier.

<u>The cod initiative</u>

The dream of increasing the output from the cod stock in Norwegian waters by releasing hatched fry goes more than 100 years back, and grand restocking programs were conducted more or less continually in the previous century (Aarset, 1995). In the 1970s, a research-based breakthrough took place, as researchers were able to bring the cod larvae past the larvae stage under controlled conditions. This opened new opportunities, among them intensive cod farming. The first larger project was funded by the "oil-fish" fund. The aim of the program was to generate knowledge to be able to restock wild cod in case of uncontrolled environmental disasters in relation to the increasing oil related activity in the North Sea. Later other funding sources took over, and a significant research activity was established. In 1986, a review article on cod research concluded that the knowledge base was sufficient, and that industrial activity now could start (Kvenseth, 1986). However, it has proven to be difficult.

Many defined the problem of cod farming as the cost of producing cod fry. Those who managed experimental stations for production of cod fry asserted that they would be able to reduce the costs significantly the moment they received a demand from food fish producers. In comparison to salmon farming, the production of cod fingerlings is technology and competence intensive. It is thus not possible to establish a viable farm environment without having identified the buyers. On the other hand, the day buyers exist; it is too late to up-scale the fingerling production.

At the end of the 1980s an important divide emerged in the farmed cod segment (Aarset and Foss, 1996). First, the (wild) cod stock decreased with the implication that the price-per-kilo

increased, which changed the profitability for the cod farming projects significantly. Secondly, the salmon farming industry reached new highs, and the total volume was for the first time larger than the volume of landed cod. This proved that the fish farming knowledge worked, and that farming of fish in large quantities was possible. Thirdly, the salmon farming industry experienced turbulent times, and some actors looked for other projects. In addition, there were cheap second hand pens in the market from bankrupt salmon farms.

All together, this motivated the government to initiate a rather peculiar aquaculture reform. Fishermen were granted the opportunity to apply for a limited license to farm cod. This farming was supposed to take place as feeding of the fishermen's own live capture. No limit was put on the allotment, and within a couple of years between 300 and 400 new licenses for cod farming was allocated. However, there were two problems with this model. First, it was obvious that if this model was going to have any significant impact, the framework for the technical production as well as the economic transactions had to open up. The core of the problem was the sales organizations, basically the Raw Fish Association (RFA)[1], which had the responsibility for the trade of cod in the area. The RFA practiced the rules for trade of live fish so rigid that other actors where stopped from entering the sector and receive the necessary buyer licenses. Secondly, the wild stock increased in size. This led to decreasing prices and less interest in cod farming. The fact that the framework for the trade of live fish was deregulated was less significant as cod farming now was seen as less interesting. In the more research-based model cod is farmed all the way from hatching to the grow-out stage. In practical farming there are problems connected to sexual maturation. On the other hand, there are several institutional opportunities for a cod farming operation. Since cod is a significant species in the common fisheries, there are also production-related overlaps with the wild fish fisheries at areas such as the use of live fish technology and market effort. The cod fingerling is expensive because it requires a costly technology and competence. However, the product's "farmed cost" is priced relatively low because of the market price of "wild cod". Hatched cod can be phased into the production when prices and costs at large are acceptable. The price is (relatively) low, but after all robust against fluctuations even by large quantities.

[1] In Norwegian: Norges Råfisklaget.

The arctic char initiative

The arctic char has traditionally been a speciality for North-Norwegian farmers and researchers. This is due partly to the natural distribution of sea-going strains of the arctic char, to Bindalen south in Nordland County. The focus at arctic char as a farmed organism started in the 1970s. A group of salmon farmers with experience from either grow-out or fingerling production experimented with arctic char farming. Similarly, researchers in Tromsø experimented with arctic char farming. Several of those that became arctic char farmers had background as students and researchers in Tromsø.

In retrospect, it seems like a paradox that this species that have so many preconditions as a farmed species, has not been the subject for more significant industrial enterprise. Among such preconditions are qualitatively good ratings as a product with high scores on organoleptic studies, seemingly robustness under farmed conditions, acceptance of high fish densities, and thriving at low temperatures (Aarset, 1997). Arctic char has some flaws as a farmed organism, though. First, the seawater tolerance varies significantly over the year, independent of sexual maturation. The species grows well in seawater in the summer months, but the fish suffer increased mortality in the fall if it is not given the opportunity to seek back to fresh water. Secondly, sexual maturation takes place at a relatively low body size, starting at a few hundred grams. As a farmed product as well, Arctic char has a couple of flaws. Judged by items in the trade magazine "Norsk Fiskeoppdrett" there is no agreement on what kind of product the Arctic char is. Some argued that the Arctic char was useful as a portion fish product between 0,8 and 1 kilo (Anon., 1986). Others argued for farming a food fish in the size 3-5 kilo (Reinsnes, 1985), while still others for a portion fish market in the size 300-400 grams (Anon., 1995), while others again argued for a portion fish category on 400-600 grams and another category on 1-1,5 kilo (Kingswick, 1988).

The sum of all these flaws and disagreements was an unclear product identity and undefined production technology, and thus also an unclear organization structure. A comparison with the early phase of the salmon farming industry illustrates that the Arctic char farmers did not find the technology that provided the appropriate solutions at the same time as they farmed a product that met the competition in a fresh-fish market. Seawater tolerance, winter death, and sexual maturation are problems that have initiated a series of research projects. The point here is that a lot of that activity could have been reduced if the industry had made strategic choices. If, for example, there had been an agreement among the producers that farmed Arctic char was

a product for the portion fish market, the winter death problem would have been less important simply because the fish would have been ready for processing after one season in sea water. Further, the technological issue would have been easier to solve; portion fish is a product with so strict demands on size that production in tanks on land probably would have been the only way to accomplish this. American fish farmers that produced Coho salmon for the portion fish market in fresh water tanks tried to raise them in pens in seawater. They moved the production back to tanks on land because they were not able to control the size on the processed fish sufficiently. In this market even a slightly too large fish is a non-optimal fish.

The institutional anchoring of the Arctic char farmers is weak, which means that there is little guidance on how to cope with different matters in order to achieve industrial development. The development so far has evolved around technology, without any kind of consensus among the producers on what type of production they want to establish. Arctic char as a farmed organism has a series of qualitatively and production related advantages. Further, it is paid relatively well. The core challenge for the industrial actors is to organize so they can communicate consistently with the research environments on relevant problems.

The halibut initiative

A great optimism was attached to the halibut initiative. Successful hatching was first conducted at the experimental station of the Institute of marine research in 1985 (Engelsen, 1995). In the 1980s the research effort was increased. While the development of salmon farming was based on an agreement on technological solutions institutionalised by laws and regulations, plurality ruled in the halibut industry. The halibut initiative is presently characterized by a diverse farm technology and diverse organization structure (Foss et al., 1998). Breeding, hatching, and start feeding of halibut fry are still difficult processes. The corresponding process within salmon farming was never regarded as difficult, and the methods have been known for several decades. Further, the salmon fry is a relatively large and robust organism, while the halibut fry is about 1/140 the size of a newly hatched salmon (Øiestad, 1986).

Three start feeding methods for halibut are developed: extensive, semi-intensive, and intensive method. The production of large fingerlings proceeds through the stages in the hatchery, with hatching, start feeding, and weaning. The fingerlings are reared in land-based tanks, and the grow-out phase takes place in pens in the sea and/or land based tanks.

Halibut farming takes place in an institutional vacuum. In an attempt to fill this void, the fisheries authorities initiated a limited aquaculture reform in 1995, as selected salmon farmers were offered an opportunity to transform parts of their pen volume to halibut farming[2]. The motivation for this initiative was that the intense research activity had released a strong increase in the supply of halibut fingerlings, and the authorities wanted to encourage increased demand for the fry. In the following two years the problem was the opposite. The fry production met difficulties, and the grow-out farms only received a fraction of what they wanted. In 1995 halibut was selected as one of two species of priority for further research (Stortingsmelding, 1994).

Most halibut farmers today are organized in two separate networks (In Northern Norway: Kveitesatsingen til Landsdelsutvalget, in Western Norway: Kveitesatsingen på Vestlandet), but there are larger private groups in the market as well. The halibut farmers are relatively weak as there is no common platform for product or process technology among them. It is possible to live with this situation as long as the authority keeps the projects alive and "subsidies" parts of the R&D activity. Still, it will be of significance for the communication with the research sector, and for the results, that the farmers focus on fewer solutions and refine the production technology. They have, all things considered, a good product (and project), but the prices are unstable, and the costs seem to be too high. So focused development is conclusive. However, the weakness described above may also be turned into advantage – plurality means that several technological applications are tested. As a development strategy this is expensive and demands a certain organisation.

The scallop/shellfish initiative

Examples of commercial scallop activity occurred in the 1970s as well as in the 1980s. An updated modern facility for production of scallop fry/larvae was left when one of the initiatives of the 1980s went bankrupt. The farm was assigned to the home municipality, Øygarden outside Bergen. This facility was part of a network that included scallop-farming competence represented by the university of Bergen and the Institute of Marine Research. There was a growing national as well as international market for scallop and shellfish, and in addition,

[2] Letter from the Directorate of Fisheries to all regional Fishery Managers about directions on how to process applications for co.location of salmon/trout and halibut (Oversendelse av retningslinjer for behandling av søknader om samloklaiseirng laks/ørret og kveite), May 28th, 1995.

important producer nations had increasing problems with bad environmental conditions – all this were preconditions for a new push for commercial scallop production. Øygarden wanted new activity at the facility and contacted Hordaland County, which then initiated and organized the Scallop Project. This project organization is central to explain how the scallop initiative restarted (Aarset, 1996).

The "scallop initiative" is interesting for two reasons. First, the initiative takes its own aim of industrial development seriously, and secondly, the initiative develops its own model for cooperation between industry and research. The link between "industry" and "research" is complicated. Often, research does not engage the relevant industrial segment sufficiently, no matter how applied the research is. The scallop project represents an interesting model in order to accomplish this, because here industrial actors, public employees, researchers and funding institutions join forces in a group where scallop farming is the over-arching goal. The direction and momentum of the process release new problems of applied, scientific, or administrative origin. The problems are defined and solved and the new knowledge is spread among the involved interests.

This initiative as well started in an institutional vacuum. No model for how to organise the industry existed. The scallop initiative has, as the halibut initiative, experienced a series of (technical and political, and ultimately economic) problems that have led to a turn from "scallop" farming to "shellfish" farming as the prime objective of the project. Scallop was selected as on of two prioritised species for further aquaculture R&D (Stortingsmelding, 1994), but blue mussel has now raised as the most important species within the project.

Interaction between "industry" and "research"

The aquaculture research sector has changed from being a political instrument in the establishment of the salmon farming industry in the 1970s to becoming an innovative force in the 1990s (Aarset, 1998). This transformation is a part of the changes that have taken place in the institutional environment of the industry. The Strategy plan for the program Bio-production and processing (1996-2000) of the Norwegian research council state:

> The task of the research is to strengthen the knowledge basis that is necessary to ensure vigorous communities and coastal societies, and shall contribute to developing competence and technology that makes Norwegian industries more adaptable to transformations and innovations [my translation].

Isolated, this is a valuable goal. However, more interesting is it to find out how priorities channel resources to certain development processes and away from other within this framework, and what interests that are systematically marginalized.

From industry to research

The four cases indicate variations in how the interaction between industry and research is organised. In the following the difference between the two perspectives on R&D – cooperation or value chain – will be analysed by cases from the industry. Within salmon farming the farmers have determined the needs, effort, and direction of the research. The expansion (and significance) of the aquaculture industry promoted the researchers to take the farmers into account when research projects were designed. The paradox was illustrated by a comparison between research and industry within salmon and arctic char farming. Despite long and intense research on problems related to arctic char farming, a group of qualified and committed researchers, and a qualitatively "good" farmed product (as a farmed species and as a market product), the arctic char industry has not managed to raise the production above a level of a few hundred tons total production. The source of these problems was the sectors lack of institutional framework and thus the actors' lack of political platform (Aarset, 1997). The arctic char farmers were less fortunate than their salmon farming colleagues a few years earlier. Political break-through for new ideas is not only based on good political craftsmanship and good connections, but also on properties by the political climate at the critical moment (Aarset, 1997). The arctic char farmers express little unity about what product to produce, so there is no common ground for interpretation of the research. As a result, the arctic char farmers did not communicate sufficiently consistent when the industry negotiated with the research system about what were actual research themes. The researchers can justify just about any project as relevant for the industry as there is no "industry" corrective.

Industrialization of "new species" and "new production forms" has accomplished next to nothing measured in production volume, despite years of research and attempts to motivate the industry to engage in research. The experience of the salmon farming industry illustrates the significance of political power and collective support from the actors. The institutional apparatus exist, but has to be copied from other activities and adapted to the new activity. Planned farming of species that are subject to a commercial fishery provide the opportunity to expand or change solutions that already exists within the fisheries. Institutional systems allocate rights and the actors have the choice to cooperate to act politically and change the

rights, or comply with them. Cod farmers were provided with a window of opportunity within an institutional apparatus that coupled the new enterprise with the coastal cod fishery.

The arctic char case illustrate how "good research" is not enough to bring the industry forward, if there is no common ground for a desired direction of development. In an industrial initiation phase a cooperative model ensures that research can be conducted without a cost-benefit evaluation of what project will immediately be profitable. In a marked-based model the research projects tend to be focused on details, but it is taken for granted that the industry will have a positive trend based on the implementation of inputs of these sub-projects. The industrial development must include "wholeness" in order to get the right effect of the research activity. In other words, the significance of having committed industrial actors in the initiation phase in order to keep the research activity "on track" cannot be over-stated. But research can also have the opposite effect, where research projects can be used as tools for political actors in an attempt to transform the industry. This was the case in the salmon aquaculture industry in the 1980s, and is the theme below.

From research to industry

The Lysø commission defined relevant research as the sum of all relevant marine and fresh water biological research (NOU, 1977). In the 1980s the research acquired a more goal-directed character, where the research was supposed to solve a production related crisis. At this time the new strategy was to utilise research as an agent for new ideas in order to affect the further development the industry (Aarset, 1988). In the 1980s, the aquaculture industry was marked by strong expansion, large problems, and significant conflicts. The conflicts had internal – the organization of the fingerling production and the export organization – and external – external interests' engagement in the industries production units – sources. The structure of the research field was a possible entrance for interests that represented other norms and values, and other interests, and had a different agenda for the industry.

A technical industry-oriented model was launched, based on rational production management. The model had implications for the owner-regulation and the industrial structure of the existing industry. The model was proposed by alliances between the technical-industrial research institutes and significant actors in Norwegian industrial life. In the early 1980s, this industrial alliance ("network") of the research council for technical-industrial research and larger industrial firms launched a series of perspective analyses, resource analyses, and research

projects. The study presented a formidable growth potential for Norwegian aquaculture, preconditioned by significant changes and organizational innovations. However, these first attempts were thematically beyond the institutional framework of the industry at that time. The first initiative from the industry alliance was rejected because the industrial structure remained a structure based on relatively small farmer-owned units (Aarset, 1988). However, in the 1980s the global paradigm shift of economic policy from keynesianism to market liberalism affected the aquaculture industry as well. In Norway this development has been followed by a series of changes in the industrial policy, in particular promoted by the desire to adapt the national industrial policy to the rules of EU. The adjusted policy aims are more vague, but the industry is still supposed to remain competitive and to offer safe and sound employment opportunities in rural coastal areas.

The technical-industrial research council presented its own strategy for research within the field of aquaculture research. Part of this strategy was a description of desired participants, products, and aim of the research. This strategy represented the introduction of an innovation perspective in the aquaculture research and industry, where future goals were articulated and an Action Plan to reach these goals was decided. This perspective competed with an ad hoc perspective where the problems of the aquaculture industry were treated and possibly solved by researchers and others as they occurred (Arntsen et al., 1996). In the innovation perspective, research, industry and industrial development are treated as units where there are compliance between the participants about the goals of the activity; while in the ad hoc perspective, the research system has character of a supplier of services that has to solve the problems released by the development process (Arntsen et al., 1996).

The establishment of the Norwegian research council was an attempt to remove the traditional influence of the corporate interests from the research. This aim has only been partly successful. The funding structure is still "sectorised" where the departments still finance "their" research (Kallerud, 1996), and the corporate element in the research commission are still present (Søgnen, 1995). The changes of the research sector in the 1990s can be described as a transition from "openness" to "closure". The products of the research sectors were presented openly so everybody that found it relevant could put it into good use. Now the production of research is more closed by various contract specifications. Major private funding agencies also limit open access even if research council has contributed. Smaller firms are automatically marginalized, as they cannot compete.

In the last decade, the innovative pressure has been most visible in the field of "new species". The situation for the salmon farming industry is so far unclear. The government has signalled that they will reduce allocation of resources for research to the salmon aquaculture segment (Stortingsmelding, 1994). The transformations of the salmon farmers' relations to the research sector reflect the general transformations in the framework for the salmon farming industry (policy, regulations, and institutions). Due to industry size, the salmon farming industry is politically powerful (and self-conscious), problems are dealt with continuously, and the industry can invest more resources in adjusting their framework. For the actors that farm "other species" the situation is different. The fund of knowledge is more fragmented. In addition, as mentioned earlier, the initiative lacks to some extent a common conception about what to do and where to go.

Perspectives on "industry" and "research"

The themes that are discussed are research situations where the development is not just a product of research based knowledge and capital, but also institutionalised production systems based on fisheries, processing, and export activities. The discussions also illustrate social sciences' significant contribution to the understanding of the possibilities of the aquaculture industries, because many of the challenges that are connected to this industry are social and institutional rather than technical in character (Bailey et al., 1996).

Innovation and economic development in Norwegian aquaculture generated by research

The perspective on research as a controlled chain of industrial development is problematic. A researcher that is loyal to hers/his scientific methodical and theoretical ideals is objective and "neutral" to the result of the research project. The rejection of the hypotheses that was the basis for the project is a good result, scientifically. A precondition for industrial development is that someone has a positive demand of knowledge, and pose a question, and that the question is answered. A negative answer is consequently a bad answer. These two qualitatively different processes are also organized very differently. The simple model for connection between research and economic development, the value chain model, builds on an agreement that even basic research is founded on "useful" applications and a source for innovative ideas that will push the economy forward by "leaps", in the line with the ideas of Schumpeter.

All projects within the aquaculture research are defined by the existing industry. The only innovation of significant structural character was the break-through of the pen technology at the end of the 1960s. All other knowledge production has been explained by this innovation. As an innovation, the introduction of pen technology had far-reaching consequences. The technology became the basis for the industrial structure and was institutionalised by the aquaculture regulations. Following intense development, the industry is at present more conform, the actors more occupied by margins, and new ideas less interesting because they represent higher costs. The industry may thus be less dependent on publicly funded applied research than earlier. The transition to larger units and an intense price competition lowers the interest for radical research questions. The research projects are more focused on cutting costs as the margins are reduced. But if small actors with a conviction that they have a good product at hand first and foremost generate innovations, then the increasing "closure" of aquaculture research is a significant challenge to today's R&D organization.

Large companies seek market dominance and power, not an open market. The concept of a "liberal market" is a political campaign label to remove institutional barriers against larger companies' entrance on regulated arenas such as salmon farming. Continuing rationalization of existing production processes is the strength of the industry, and the aquaculture research is a significant factor force in this rationalisation. The salmon segment of the aquaculture industry has matured, and now a market based research organization based on large units may be appropriate. One problem now is seemingly that new initiatives within the aquaculture industry do not have the opportunity to go through the same maturation phase by a cooperation model.

From openness to closure in the production of research

Companies' attitudes towards research have changed. Research is a value in its own right, but the production of research is now more "closed" than it was before. The importance of protecting research results for one owns use, is no less than restraining others from using the results. Research becomes a comparative advantage, and research products become commodities. This closure of the research and knowledge production marks a transition from the supportive or ad hoc perspective to the innovative perspective above. Corporate organizations ensured user participation in the previous research organization. Today users are obliged to partially pay the costs in order to have them funded. In the first case the research was available to the public in open reports and thus available to everybody. In the other case the research production is closed. Whatever is produced will be exclusive for the participants.

The research will be available for all when time has deteriorated the value of the results. Participation in such coalitions is costly, which makes this form of organization exclusive and centralizing. In other words, being small is most costly. This transition is thus an institutional transition that disfavours small firms. However, a moral dimension is the shift from an inclusive research policy that was established to develop an industry for a set of actors or a defined type of actors, to a policy oriented in the direction of optimisation of an industrial structure.

The aquaculture sector contains no obvious examples that research projects have led directly to industrial development. The innovations are incremental, as they have contributed to continuous development of the industry. But there is an important dichotomy here, on one side research that is defined by an operative industry, and on the other side the belief that research can end up as industrial activity. In the aquaculture sector it is a paradox that research rather leads to rationalisation and destruction of employment opportunities in the industrial segment.

New directions

Within salmon farming a homogenous, generic "salmon" product is developed. The biology of the fish makes it easier to model supply to the demand curve. This trend can end as the industry may be confronted by new requirements. The consumers increasingly demand additional properties of food aquaculture products included. The importers and wholesalers will become a stronger group. This group has particular demands on how food must be produced, and they have sophisticated tools to ensure that they will have their needs covered. Documentation of how the food is produced will be among the important tasks for the producers. Regardless of what form this will take it is a development the industry hardly can protect itself from. The power balance between producer and consumer will be displaced again, a displacement that also will influence the research agenda. This situation may again may put Norwegian producers in a difficult position as they are dependent on export markets where the Norwegian industry must adapt to the standards that are decided in commissions Norwegian producers have little or no influence over.

Final discussion

The institutions that organise research and industry within the field of "new species" vary. While cod farming borrow institutions from the fisheries, halibut farming, for example, will have predefined elements that can be used to establish new production forms. However, the

research is conducted as everything will be developed from "nothing". These processes can acquire the character of something "wanted". Agents for various interest groups can "market" tentative solutions and different potential paths of development due to the lack of actual production. Some might have an interest in enlarging the need for a particular research project, others for the development of a particular type of technology. Nevertheless, the effort may be too labile and the direction imprecise. Within salmon farming the situation was different. Here the industry delivered ideas to the research sector and participated in the selection of research questions. This industry could also use new research results and send new signals to the research sector based on new production experience. The model for the relation between industry and research and the way this was practiced in the early phase of the salmon farming industry, provided the industrial actors with the opportunity to develop an industrial structure and solve different organizational tasks simultaneously as they participated in the development of the competence the industry has been based on since then.

Under the "old" (corporate) regime the fish farmers had relatively little opportunity to influence the articulation of single research projects directly. It was, on the contrary, a contradiction between the single fish farmers and the single researchers. Many fish farmers felt that they received little from the researchers and that their researcher used good money to open already open doors. However, the industry supported and influenced the research. This use was of course also an important source in connection with the R&D environments improvement of the products. In addition the need for research was also communicated by the fish farmers association (NFF) and into the research institutes by breeding programs and other programs where the association participated.

According to the "new" (market based) regime the company itself develop its ideas in correspondence with its own needs. New projects are required to have industrial participation. The arrangement ensures that the research involves an industrial partner. A criticism to the "old" regime was that the industrial partners were not sufficiently involved. Lopsidedness in the "new" regime can occur as the research environment can establish industrial partners as straw men. The industrial partners are necessary as partners, but are not always competent to meet the research environment and to use the content of the project directly (Arntsen et al., 1996). This situation can have consequences for the knowledge that is generated in the project.

The industry has tight margins, and the research projects are formed by this new situation. Even if there is a political wish for a diversified industry, competition, large-scale production, and owner concentration lead to a systematic focus on production of fresh salmon. Feeds, breeding, and technological development are designed by this situation, where the industry demands products that can help the actors in an increasingly sharper competition. But this situation might be a "lose-lose" situation, where a more sophisticated technology is the mean in the fight over ever-tighter margins. An increasingly intensified production creates new problems. Such a serious problem now is the sea lice situation that has a connection to the concentration of salmonids in the coastal waters.

In the post-industrial society, competence as basis for innovation has an increasing significance (Hallenstvedt, 1997). This development points to a transition from the value chain model and back to a cooperation model. But in contradiction to the cooperation model as it functioned in the salmon farming industry in the 1970s, the cooperation model now will rather take place with little or no involvement from the state, but be dependent on input from the market, which the "old" cooperative model effectively protected against. So the hope is that such a "new" cooperative model also will manage to support qualitatively new initiatives.

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