Chapter 7

Marine Biotechnology in Norway

Background

Norway is bordered by the North Sea to the south, the Atlantic Ocean to the west, and the Norwegian Sea to the north. Norway's coast is indented by numerous fjords, creating 21,000 km of coastline. Many fjords offer shelter to harbors and aquaculture facilities, enabling Norwegians easy access to abundant marine resources. Traditionally, Norway's economy has been heavily dependent on the sea; its fishing and whaling fleets are ranked among the largest in the world.

Fisheries constitute Norway's third largest export industry (petroleum is the largest), with sales of fish and fish products in domestic and foreign markets totaling over $1.54 billion per year (Norwegian Fisheries Research Council, 1990) (the conversion rate used here is $1=7.4 Norwegian crowns). However, in the early 1980s, Norwegian companies, facing steadily growing costs for landing fish and increasing competition from foreign operators, began to invest heavily in the nascent aquaculture industry. The growth of the industry was spectacular, within ten years over 1,400 hatcheries and fish farms were established. By 1992, these farms were producing 70-80% of the world's aquacultured salmon. In 1990, they generated 160,000 tons of fish per year worth $670 million, or almost 50% of the value of national fisheries landings (Dodet and Malmcrona, 1991). The main crop by far is salmon; most of it is exported, principally to the countries of the European Communities (EC) (80%).
In addition to salmon, other aquaculture and aquaculture-related exports generate export income for Norway. Seaweed products earn $52.2 million annually, and the supply of aquaculture-support equipment to domestic and foreign markets nets over $870 million per year (Norwegian Fisheries Research Council, 1990).

**GOVERNMENT SUPPORT OF SCIENCE AND TECHNOLOGY**

In 1985, Norway elaborated its first national program in biotechnology, which ended in 1989. The first program was immediately followed by a second, expanded program called "National Plan for Research and Development in Biotechnology," which continued through 1992. The second plan, henceforth referred to as the National Plan, specified governmental support for R&D in cell and gene technology, medicine, agriculture, aquaculture, industry, environmental protection, and biotechnology for developing countries. Funding for biotechnology under the program in 1992 was about $24.1 million, plus support for equipment at $1.47 million, for a total of less than $26.1 million. Undoubtedly some additional funding for what may be considered biotechnology research is provided by ministries and research councils under other research areas, such as agriculture, health, environment, etc., but we were unable to quantify these funds.

As this report was finalized during the summer of 1994, we had received information that a far-reaching reorganization of Norwegian research organizations had taken place. Perhaps most important, the former system that consisted of five research councils (Fisheries, Agriculture, Technology, Science, and Humanities) is now organized as a single General Council, subdivided along new lines with Bio-production and Biotechnology in different sub-councils (Dundas, 1994). However, since we are not in a position to take into account these developments in this assessment, what follows is a description and discussion of Norwegian research as it operated in 1993 and before. Much of this structure still exists of course and, as far as we know, no drastic new directions have been taken.
Before 1993, five research councils funded basic and applied research in Norway. Two of the previous councils are relevant to this report; the Agricultural Science Research Council (NLVF) funded agricultural research, including some aquaculture-related research, and the Norwegian Fisheries Research Council (NFFR) was the major sponsor of living marine resource-related research in Norway (Raa, 1990). In addition, the NFFR developed and put into effect the “R&D in fisheries-Innovation plan,” which was a public information network that provided easy access by fishermen, industries, government bodies, and others to research results (Central Board, 1990). NFFR was mainly funded through the Royal Ministry of Fisheries; the total budget for NFFR in 1990, excluding capital investments, was $24.36 million (Norwegian Fisheries Research Council, 1990). The NFFR's three primary objectives were to: (1) promote and finance fisheries and aquaculture research and industrial applications by planning and budgeting research activities; (2) coordinate national fisheries and aquaculture research efforts; and (3) serve as the main advisory and administrative body to the Norwegian government in fisheries research and development policy. In formulating its national research efforts, NFFR was guided by certain objectives, including the continual improvement of natural resource management for fisheries and aquaculture, the improvement of aquaculture technology, support equipment, and production processes, and the development of state and local, market-oriented industry. To ensure meeting its objectives, NFFR established program boards, responsible for evaluating its research system and for choosing, coordinating, and presenting the results of specific research projects (Norwegian Fisheries Research Council, 1990).

NFFR had nine specific goals for 1990-1994. They are to: (1) develop the knowledge that will enable aquaculturists to farm new fish species that conform to the Norwegian environment and present favorable possibilities for commercial development; (2) improve the competitiveness and profitability of salmon and trout production through research that enhances fish health, prevents and treats diseases, improves feed resources, and upgrades production facilities; (3) strengthen marine and ecological research in Norway to the extent
where the country will become an international resource center in these areas; (4) develop information technology so that it can be used to increase productivity and profitability in Norwegian fisheries and may be marketed in foreign markets; (5) inform the populace about policies and regulations related to living marine resources; (6) expand aquaculture industry by providing it with good market information, promoting horizontal and vertical cooperation in the industrial sector, and developing new marketing strategies for the EC and U.S. markets; (7) improve expertise in fisheries technology in the equipment and service industries supporting fisheries; (8) integrate land and sea production to maximize fisheries output and profit; and (9) deploy and support marine biotechnology research (see below) (Central Board, 1990). Other NFFR activities include providing educational scholarships for maintaining and establishing expertise in fisheries, and international scholarships for promoting international cooperation such as supporting foreign scientists in Norway (Central Board, 1990).

In 1992, NFFR provided approximately $1.54 million per year to support some 25 research projects in marine biotechnology (Ulsaker, 1992; Norwegian Fisheries Research Council, 1991). Seven areas of marine biotechnology research were emphasized: (1) marine natural products chemistry, which concentrates on marine biomolecules such as lectins, natural antioxidants, marine lipids, marine enzymes, antimicrobial substances, and biopolymers from sea weeds and crustaceans; (2) enzyme biotechnology, which uses enzymes as processing agents in the marine food industry and as catalysts to chemically modify marine oils; (3) marine animal health, with a focus on applications for aquaculture; (4) ecosystem management, where systems of cultivation of phytoplankton and zooplankton are developed to bioassay environmental pollutants and to produce live feeds for juvenile fish; (5) genetics/biotechnology, including the study, improvement, and use of microbial genetics, recombinant DNA technology, hybridoma techniques, and production of transgenic fish; (6) marine microbiology/microbial ecology; and (7) fish feed improvement and development (Raa, 1991).
In late 1993, the University of Bergen and the University of Maryland established a cooperative program in research and education, which includes using video-teleconferencing communication between Bergen and Baltimore MD. More joint trans-Atlantic seminars and courses of instruction are to commence in the fall of 1994.

RESEARCH AND DEVELOPMENT RELATED TO MARINE
BIOTECHNOLOGY

Most of the remarkable marine biotechnology research is carried out at ten universities and specialized research institutions. Of these, two are located in Tromsø, three in Bergen, three in Trondheim, one in Stavanger, and one in Fyllingsdalen (Strömm and Raa, 1993).

In Tromsø, over 100 scientists and engineers are involved in research related to aquaculture. Approximately 50 scientists work in marine biotechnology (Strömm and Raa, 1993). Basic research is carried out in various departments of the University of Tromsø and the Norwegian College of Fishery Science (NFH), also within the university. Scientists at the NFH's Department of Marine Biochemistry perform research in microbiology, microbial ecology, genetics, immunology, and biochemistry; research in other departments encompass fish genetics, fish development, and fish maturation. Applied research is done at the Norwegian Institute of Fisheries and Aquaculture (Fiskeriforskning) that focuses on marine enzymes, enzymes in fish processing, and fish health including vaccine development. An important component of the Tromsø infrastructure is the Aquaculture Station and its laboratory where researchers can perform challenge experiments (Strömm, 1994).

In Bergen, various universities carry out research in marine biotechnology primarily focusing on aquaculture. In addition, two institutions are involved in marine biotechnology: The Bergen High Technology Center (HIB), owned by the Bergen Foundation of Science, was created to increase collaboration between basic research and industry. In 1990, HIB opened a biotechnology department
dedicated to aquaculture and marine biotechnology. The second institution, the Institute of Marine Research in Bergen, is affiliated with the Ministry of Fisheries and is funded by NFFR and various external sources (Dodet and Maincrona, 1991). A total of about 30 scientists in Bergen are focusing on marine biotechnology research (Strøm and Raa, 1993).

Trondheim is the national center for technological research. Major institutions include the Norwegian Institute of Technology (NTH) and the University of Trondheim. Approximately 80 scientists and engineers are engaged in work on marine biotechnology topics, including marine biopolymers, aquaculture, molecular genetics, fermentation, enzyme technology, and environmental engineering related to marine systems. Notable research is performed at the NTH Institute of Biotechnology as part of the “European Cooperation in the Field of Scientific and Technical Research” (COST) program on macroalgae, and on salmon cell culture systems at the University’s Center for Molecular Biology (UNIGEN). Also located in Trondheim is the Norwegian Biopolymer Laboratory, which is in charge of the national program on industrial use of biopolymers. It conducts fundamental and applied research on marine polysaccharides, primarily alginate and chitosan, as well as biopolymer engineering based on genetic, enzymatic, and chemical methods. Another institution, the Foundation of Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF), is the largest institute for contract research in Northern Europe and has a staff of 2,000. It is engaged in work on enzyme technology related to marine products and bioremediation of oil spills and is highly active in the development and feeding of fish fry for aquaculture (Dodet and Maincrona, 1991). Between 10 and 20 researchers in Trondheim are working on marine biotechnology research projects (Strøm and Raa, 1993).

Following are some examples of projects being carried out within Norway’s marine biotechnology program related to aquaculture, the utilization of certain marine natural products that have applications in aquaculture, and marine animal health.
Aquaculture

Aquaculture research in Norway focuses on reduction of production costs and improvement of quality and quantity of farmed fish. Most of this research relies on the use of classical techniques to achieve advances in aquaculture production, so they therefore are not considered in this review. However, some research on transgenic fish is being performed in Norway. For example, microinjection and expression of a growth hormone gene in Atlantic salmon has been accomplished by K. Gautvik at the Institute of Medical Biochemistry, Faculty of Mathematics and Natural Sciences, University of Oslo (Zomzely-Neurath, 1989). Dr. Gautvik has also isolated salmon prolactin and growth hormone to develop methods for quantitative determination. His work on transgenic salmon may become an important model system for studying the effects of multiple copies of growth hormone genes.

Having high-quality broodstock is of utmost importance to fish farmers. A program being undertaken at the Institute of Marine Research in Bergen seeks to secure the availability of the best salmon broodstock for future aquaculture operations. Institute researchers used DNA “fingerprinting” techniques to tag a total of 70,000 individual fish representing three different salmon stocks from as many rivers that were released during the spring of 1991. Probes developed in Ireland will be used to detect “fingerprinted” individuals when they return to their release sites in two to three years, and will allow researchers to assess the return rates to select the best performers for broodstock (Anonymous, 1991a).

Also of potential value to the aquaculture of salmon is the research proceeding at the Agricultural University of Norway in Ås. A research team at the university is using fast-growing zebrafish as a model for studies on the influence of insulin on carbohydrate metabolism and on the genes involved in the sexual maturation of salmon. The zebrafish is also used at the Institute of Medical Biology in Tromsø for embryonic development studies (Evaluation Committee, 1992).
An interesting marine biotechnology-related program bears mentioning. In the past, Norway has been a major exporter of fishmeal, but after 1988 the feed demands of the burgeoning aquaculture industry forced Norway to become a net importer of fish feed. One solution being advocated by scientists is the use of Norway's plentiful mineral gas as an energy source to produce microbial biomass (single cell protein, or SCP) for fish feed. SCP could partially replace the protein, vitamins, and minerals that are now used in fish feed and, additionally, could be fortified by components that stimulate disease resistance in fish. If a well-balanced SCP feed is developed, it would help Norway save spending money on imported fishmeal and SCP could in itself be an export commodity (Raa, 1990, 1991).

Marine Natural Products and Products From Fish Wastes

While small-scale and dispersed aquaculture can be environmentally benign, the very large aquaculture industry in Norway has created problems. Some of these problems are amplified by the operation of concurrent fisheries industries. In particular, the disposal of untreated wastes, especially fish viscera, from fish processing into coastal waters has created a pollution problem in Norway. To alleviate the situation, researchers at the University of Trondheim and Fiskeriforskning initiated a study on potential applications of the complex mixture of enzymes and other biomolecules that constitute fish waste. They developed a product, a de-oiled fish silage, that can be used to feed domestic animals, including farmed fish. As a result of this development, fish wastes are now a valuable resource, collected and processed by firms to produce fish silage, thus generating additional income the aquaculture and fisheries industries. An important side-effect, of course, is that one source of marine pollution has been nearly eliminated (Raa, 1990).

Fish wastes may also be a source for biochemicals useful in research and industrial practices. For example, fish pepsins have a higher pH optimum than other pepsins and are active at lower tempera-
tures and resistant to autolysis at low pH. These enzymes act differently on various tissues due to differing pH optima, thus enabling the pepsins to separate targeted biological tissues. Enzymes that have been separated from fish wastes may be used by researchers as tools to biochemically dissect and separate biological tissues (Raa, 1990). Similar research is proceeding at the Norwegian Institute of Fisheries and Aquaculture in Tromsø for utilizing shrimp wastes. In this case, water from melted ice used to store whole shrimp after they are caught is processed to recover enzymes valuable to industry, including alkaline phosphatase, hyaluronidase, acetylglucosaminidase and chitinase (Olsen et al., 1990).

One problem peculiar to aquaculture pertains to the use of antibiotics to prevent and treat fish bacterial diseases. Antibiotics for controlling fish disease are generally administered through feed. Surplus feed and fish feces containing antibiotics settle to the bottom of fish tanks and ponds and, eventually, spread throughout the marine environment, where they are encountered by various marine microorganisms and bacteria. At one time this problem was particularly acute for Norway, where a significant amount of antibiotics was used by the aquaculture industry to counter damaging fish diseases. In particular, a severe outbreak of Hirta disease (coldwater vibriosis) stimulated a rise in antibiotic consumption, from 4.5 tons in 1980 to 48.5 tons in 1987, but down to 19.4 tons in 1989 (Anonymous, 1990b). During 1990-1992, Norway experienced an outbreak of furunculosis, which led to an increase in antibiotic usage, to almost 39 tons in 1990, but decreasing thereafter to about 30 tons in 1991 and, again, in 1992. With the introduction of new Hirta and furunculosis vaccines in 1988 and furunculosis vaccine in 1992, antibiotic usage fell drastically to about 8 tons in 1993 (Anonymous, 1994). The fear in Norway, as elsewhere, was that the aquatic environment would become a large reservoir of organisms that are resistant to antibiotics commonly used in aquaculture; some of which were also significant in human medicine and veterinary practices. Resistance genes from these marine bacteria could be transferred to bacteria that are pathogenic to man. Additionally, antibiotics could have adverse effects on marine ecosystems.
In view of the uncertainties associated with antibiotic use, researchers have been searching for alternative ways to manage fish diseases. Possibly the most important alternative is vaccines, which are discussed in the next section. In addition, some Norwegian researchers have focussed their investigations on lower invertebrates and algae, which have elementary immune systems that depend on a set of non-specific defense mechanisms. One of these mechanisms incorporates a secreted, low molecular weight antimicrobial substance that is naturally degraded in the biochemical cycles of the marine ecosystem. Researchers have discovered that ethyl acetate extracts isolated from the mussel *Mytilus edulis* contain a group of compounds that inhibit the development of the bacterial pathogens *Vibrio salmonicida*, *Vibrio anguillarum*, and *Vibrio ordalii*, but which does not affect the flora present in the fish gut (Raat, 1990).

Scientists at the Norwegian College of Fishery Science are studying the properties of specialized proteins called lectins (Raat, 1990). The immune defensive processes of marine invertebrates include lectins, which specifically bind to bacterial and viral structures of carbohydrates, glycoproteins, or glycolipids. These properties mark lectins as having possible application as therapeutic medicines and as diagnostic tools.

Researchers in Norway also have discovered a lysozyme with strong antibacterial activity that functions effectively in cold environments. This enzyme, which has the ability to kill bacteria by breaking down their cell walls, was isolated from the shell of the clam *Ctianys islandica*. The activity of the lysozyme at 4°C is 80% of its optimum level at 45°C, which is up to several hundred times more active at 4°C than lysozymes from warm-blooded animals. In addition, marine lysozymes in general have better antibacterial activity than other lysozymes due to their peculiar molecular structures (Raat, 1990).

**Marine Animal Health**

Aquaculture in Norway like elsewhere in the world is susceptible to adverse effects from fish diseases. Maintaining marine animal
health is therefore vital to the economic well-being of Norway. The major bacterial fish diseases affecting Norwegian aquaculture are Hitra disease, caused by *Vibrio salmonicida*, and furunculosis, caused by *Aeromonas salmonicida*; the viral disease of importance in Norway is Infectious Pancreatic Necrosis (IPN), which is caused by the IPN virus. Much of Norway’s research effort is concentrated on increasing knowledge about these fish pathogens and their association with hosts, the prevention of disease spread, and developing vaccines to counter bacterial and viral diseases. The research program of a new fish research center, opened in June 1989, encompasses these four areas. This center, called AkvaVet is located at Vikan in central Norway, was built at the cost of about $2.61 million, provided by the NIVF, has excellent facilities and equipment, including a large hall containing about 80 test tanks, and ten “research cells,” each of which have up to 30 300-liter test tanks. The environment of the tanks is computer controlled, allowing the operator to precisely vary salinity, temperature, pH, and flow of water (Anonymous, 1989).

Some publicly funded research has led to commercial development of several fish vaccines. For example, in 1979 much damage was caused by a previously unknown disease, subsequently named Hitra disease or cold water vibriosis. The causative organism of this disease, which has a mortality rate of greater than 80%, was identified and characterized in 1981 by researchers at the University of Trondheim and the Institute in Bergen as a previously unknown *Vibrio* species, named *Vibrio salmonicida*. Close collaboration between the university researchers and industry, including heavy investment in a modern production plant, as well as cooperation from the Norwegian government, resulted in the development of a vaccine that is very effective in salmon, affording 90% protection against Hitra disease and preventing an estimated $39-52 million in losses annually (Raa, 1990; Central Board, 1990; Hitra vaccine is being produced by Apothekernes Laboratorium in Norway (and Biomed Inc. in U.S.) (Anonymous, 1994).

Furunculosis, imported in 1985 from Scotland, was present in approximately 400 fish farms in 1991. It has a mortality rate of up to 68%; stricken animals usually die within three weeks. Two paths are
being taken to fight the disease. First, research is underway at NVLE's Institute for Aquaculture Research to develop breeding stock resistant to the disease and some particularly resistant stock have been developed whose mortality rate is about 15% (Anonymous, 1993b). Second, the company Norbio in Bergen, which is owned by the Dutch company Intervet, using conventional techniques has developed a furunculosis vaccine that it claims is 87.5% effective. The high efficiency rate is achieved in part through the use of a new, powerful glucan adjuvant. Norbio's furunculosis vaccine, as well as three other vaccines from foreign sources, are presently being tested by AkvaVet (Anonymous, 1991b).

Norbio claims to have isolated an IPN virus strain common to Atlantic salmon cultured in Norway. Norbio has characterized the virus and constructed monoclonal antibodies against some of its structural proteins. Based on this work, the company is able to offer rapid diagnostic services to fish farmers and veterinarians; in addition, its researchers are well on the way of developing a IPN vaccine (Anonymous, 1991b).

Research is proceeding on developing immunostimulants, which increase non-specific disease resistance in fish or act as adjuvants in vaccines, thus increasing their effectiveness. For example, studies at the University of Tromsø have demonstrated that certain glucans from yeast enhance non-specific immunity in fish, increasing their ability to resist diseases. Administration of glucans by commonly practiced procedures, such as through feed or by injection into the peritoneal cavity of the fish, results in a high degree of protection against bacteria pathogenic to fish (Raa, 1990).

Yet another approach to protect fish health involves substances called probiotics, which are harmless bacteria that block the damaging actions of pathogenic bacteria in the gut. This work built on the fact that the fish gut is inhabited by flora that include vibrio-like microorganisms. The biochemical properties and growth characteristics of these organisms are similar to pathogenic fish vibrios and the two seem to compete for the same ecological niche in the fish gut. By selective breeding and controlled feeding, the propagation of probi-
icates is stimulated to the point where they block receptor sites by greatly outnumbering the pathogenic vibrios (Raa, 1990).

Other Marine Biotechnology Areas

While research related to aquaculture seems to be of most interest to the Norwegian research community, some noteworthy research focuses on environmental problems. At the Department of Microbiology of the University of Bergen, investigations are aimed at discovering and developing novel microorganisms that could be used in environmental pollution control (Zomzely-Neurath, 1989). At the Department of Microbiology of the University of Trondheim, scientists are engaged in studies of microbial degradations of environmental pollutants at low temperatures (Zomzely-Neurath, 1989). Norwegian oil companies are supporting research in marine biotechnology areas vital to their interests, such as the bioremediation of petroleum pollution in the marine environment (Dodet and Malmcrona, 1991).

INDUSTRIES

Fourteen small and medium-sized firms constitute the marine biotechnology industrial sector in Norway. Of these, five are located in Tromsö, three in Oslo, three in Bergen, and one each in Skien, Haugesund, and Drammen.

Norway's largest biotechnology company is Protan in Drammen, which is a subsidiary of the chemical and oil company Norsk Hydro. It claims that it is the world's third largest company in the microalgae sector, producing algamates, laminarin, chitin, and chitosan. Protan also has production facilities in Canada and the U.S. (Dodet and Malmcrona, 1991).

In Tromsö, several small, spin-off biotechnology companies have been formed to capitalize on promising research results. These companies typically employ approximately ten people each and maintain close connections with the university and public research institutions. They typify the new biotechnology industry as it is evolving.

Marine Biochemicals A/S, created in 1986 as a subsidiary of Norsk Hydro and now owned by private investors, concentrates on extraction of biochemicals from marine raw materials. It produces enzymes, including those from fish viscera, growth media for microorganisms, and lectins. Apothekernes Laboratorium A/S, created in 1986 by the Department of the Norwegian Pharmaceutical Group Apothekernes Laboratorium, produces classical fish vaccines and starter cultures for preservation purposes. Rieber & Company produces fish silage concentrate, attractants in fish feed, and fish feed from waste. However, of the companies located in Tromsø the most interesting, in terms of variety of products and innovative research approaches, might be KS Biotech-Mackzymal. Among its more traditional products are fish protein concentrates to be used in fish feed, peptones for use as microbial growth media, and food flavoring. More recent products include DNA, nucleosides, and marine enzymes for uses as fine chemicals, and MacroGuard, a glucon from yeast cell wall, which is added to fish feed because of its immunostimulant properties (Hoffman, 1990). Company scientists have developed enzymes found in marine organisms for use as “biological knives,” for example, in the production of caviar to separate fish roe particles from the connective tissue of the ovaries, enzymatic deskinning of fish and squid, and enzymatic cleaning of scallop (Raa, 1990, 1991). An enzyme mixture, sold under the tradename Hyzym, is used in automated processes to descale fish. In this process, gutted or un-gutted fish are immersed in a waterbath containing Hyzym, which removes slime and loosens scales. After incubation, the treated fish are treated with water jets that remove scales without damaging the fish. A completely automated process, which sells for approximately $60,000, can be operated by one person and has a claimed capacity of 1.3 tons of haddock per hour (Svenning et al., 1993). Hyzym sells for $590 per kilogram, an amount sufficient to treat
16.5 tons of haddock. Hyzym can also be used to descale ocean perch, red snapper, white fish, and silver carp.

Other small Norwegian R&D companies are BioNor in Skien, which specializes in rapid diagnostic tests for fish diseases and in bacteriological control methods for fish farms; Primex A/S, which makes a product used as an attractant in fish feed and as food flavor (Raa, 1991); and Martens and Jahres Fabrikker, subsidiaries of Norsk Hydro, which is engaged in the production of polyunsaturated fatty acids from fish oils for food and medical uses (Dodet and Malmcrona, 1991). Norbio A/S in Bergen develops and produces vaccines and diagnostics. In addition to these products, Norbio markets vaccines against various serotypes of coldwater vibrios and Red Mouth Disease (Anonymous, 1991b). It is testing vibrio vaccines for use in cod and turbot (Anonymous, 1990a). Norbio is now developing a second generation furunculosis vaccine using recombinant techniques. This work involves cloning genes that encode certain surface and extracellular proteins (Anonymous, 1991b).

ACADEMIA-INDUSTRIAL COOPERATION

Innovasjonssenteret A/S has been established to facilitate greater interaction between industry and research throughout Norway (Zomelz-Neurath, 1989). In addition, a unifying research foundation for the Oslo region has been established called FOSFOR. It seeks to facilitate and stimulate cooperation between research institutes and firms in Norway’s only science park at Gaustad (near the University of Oslo).

INTERNATIONAL TECHNOLOGY TRANSFER AND INTERNATIONAL RELATIONS

NFFR was Norway’s primary agency for promotion of international research cooperation and technology transfer. Presently, cooperation is maintained through informal contacts between scientists and research centers around the world, or between organizations through participation in international projects, multilateral and bilateral agreements, or organizations such as the International Council
for the Exploration of the Sea (Central Board, 1990). As this is written, the Norwegian Research Council has a scholarship system to support visiting scientists.

Norway also participates in the "Nordic Collaborative Program on Biotechnology," a collaboration between Scandinavian countries. This program supports marine biotechnology projects through the Nordic Industry Fund and falls under the jurisdiction of the Nordic Council of Ministers (Döder and Malmerona, 1991). Another Nordic collaboration, the "Nordic Council Project," commenced recently and involves Norway, Sweden, and Iceland. This project focuses on the control of sexual maturation in salmon, the area's most important aquaculture crop. Currently, Norway is negotiating to develop additional international projects and collaborations with the EC.

CONCLUSION

The condition of marine biotechnology in Norway may be discussed in terms of research, development, and industry. Observers agree that some research teams are performing world-class research, but the general level is mediocre. One analyst has, for instance, compared the Scandinavian countries and found that biotechnology research in Norway is more conservative and less innovative than that in Denmark and Sweden (Zomzely-Neurath, 1989). A more definitive assessment of Norway's biotechnology program supported this view. An international scientific team that reviewed Norway's National Plan and its accomplishments noted the high quality of some research teams, most of whom we have mentioned above. But in the final analysis, the team summarized its findings about biotechnology related to aquaculture as follows (Evaluation Committee, 1992):

It must be concluded that fisheries, aquaculture and marine biotechnology research is scattered in Norway. The quality and international competitiveness varies among the groups and from location to location. It may be suspected that the patchiness observed is partly the result of the organization
and different grant application policies practiced by the research councils in Norway.

It is particularly important to abolish the conservatism practiced today and to increase the use of modern biotechnological techniques as tools in the research laboratories.

The total area as such is of obvious importance to the Norwegian industry and society in general. It is thus imperative that the research is competitive on an international basis. The potential for strengthening the research is clearly present. However, the research groups today are too small, making it difficult for them to compete at an international level. Furthermore, small groups are liable to sudden changes due to e.g. individuals dropping out of the group. It is believed that a strengthening of the basic science will lead to the required advancement within applied research and, in due time, industrial development.

We have noted that even though Norwegian marine biotechnology research mostly is directed towards aquaculture, its achievements to date are impressive. However, the sector it serves is in trouble, and this may ultimately affect Norwegian research institutions. To illustrate, in 1989 approximately 700 fish farms operated in Norway. Lately this industry has experienced financial reverses, and an estimated 150-200 farms have closed down operations (Larsen, 1992). Production decreased from a record high of almost 160,000 tons in 1990 (Anonymous, 1991c), to 146,000 tons in 1991 and 138,000 tons in 1992 (Hempel, 1993). Four factors have contributed to the crisis in the industry: First, an over-production of salmon has created an oversupply situation in world markets (Anonymous, 1992a). As supplies continued to increase and prices dropped, profits for farmers have become marginal. Second, a general downturn in the market for salmon has occurred and the decreased demand has exacerbated the oversupply problem. Third, U.S. and EC, Norway’s primary foreign markets, have raised their tariffs on imported Norwegian salmon (Anonymous, 1992a). Fourth, the bankruptcy of the Norwegian Fish Farmers Sales Association at the end of 1991 has re-
sulted in a loss of faith by investors in the industry (Anonymous, 1992b). These convergence of these factors resulted in diminishment of the profit margins for fish farmers, and the climate of economic recession and elusive profits led to investors being unwilling to inject additional capital into what has become a risky venture. It is reasonable to believe that salmon production in the future will probably reflect these problems and uncertainties.

Norway has several major barriers to overcome before it once again can become an international competitor in marine biotechnology: (1) The lack of financing has led to Norwegian business making minimal investments in production facilities so in many cases only laboratory scale production of products is possible, limiting marketing possibilities. (2) Since Norway's small biotechnology companies do not possess the resources and credibility needed to serve international customers and markets, commercialization of research results may be delayed five to ten years (Raa, 1991). (3) Scientists at universities and research institutions tend to neglect to adequately document their work, thus decreasing the credibility of products. (4) Technical solutions must be developed in order to overcome problems in the aquaculturing of species such as cod that result in 50-90% losses between metamorphosis and harvest, including adequate supplies of live feed, the recapture of cod fry, and the weaning of fry from live to artificial feed (Holm, 1989). (5) The Norwegians' level of distrust towards biotechnology is high, possibly equal to, or exceeding, the level found in Denmark and Germany. This creates problems pertaining to the public acceptance and commercial authorization of biotechnology products. For example, the company Marine Genetics in Bergen worked on the transfer of the growth hormone gene in salmon. Despite what appeared to be successful research, it failed due to difficulties related to public acceptance of its work (Dodd and Malmerona, 1991). (6) Unlike the past when Norwegian biotechnology companies were able to open and begin operations on shoestring budgets, new companies must invest $13-18 million in equipment, facilities, and documentation before start-up. This amount of money is considered very high in Norway, making it difficult for entrepreneurs to raise capital (Raa, 1991).
A major difficulty facing Norwegian aquaculture concerns trade barriers. The U.S. once was Norway's second largest market for aquacultured salmon. However, in 1991 the U.S. raised the import tax on fishery products from Norway, primarily because Norwegian products were being sold cheaper than those produced by U.S. fishery companies, helping drive these companies out of business. Practically no Norwegian salmon is now imported by the U.S. Even if Norway succeeds in lowering the cost of aquaculture production through, for example, the application of efficacious fish vaccines and improved feed conversion, the U.S. can offset the gains by continuing to raise import taxes. A similar scenario may evolve in Europe where the EC has placed tariffs on Norwegian value-added products and imposed minimum-price levels on fresh and frozen salmon. Although minimum-price levels and tariffs were discontinued as of, respectively, January and February of 1992, a precedent has been set for the implementing of future restrictions (Anonymous, 1992a).

In 1993, the situation improved for Norwegian salmon producers due to a reorganization of the industry, a relaxation of strict ownership rules by the government, and the sell off of frozen salmon surplus stocks (Hempel, 1993). Total production of salmon increased to 175,000 tons in 1993 and is predicted to surpass 200,000 tons in 1994 (Ström, 1994). Further increases are expected for 1995 and thereafter (Hempel, 1993).

To sum up our assessment of marine biotechnology in Norway, Norwegian research is internationally competitive in selected areas, e.g., fish vaccines, DNA tagging to monitor wild salmon, and development of fish species new to aquaculture. Norwegian research pertaining to the utilization of by-products from fish processing is the most advanced of its kind in the world. Overall, the level of Norwegian marine biotechnology research is one of, as yet, unfulfilled but tremendous potential.

The Norwegian aquaculture industry, although beset with problems, will continue to be the world's foremost. Eventually, production of salmon in Norway could peak at between 350,000 and 400,000 tons in 2010 (Hempel, 1993). Applications from marine biotechnology research can have important local effects, helping the
industry cement its already powerful competitive position, but little of this research is likely to be applicable to aquaculture in other countries. Only limited applications can be expected in other areas of marine biotechnology. Possibly fish vaccines developed in Norway will find world-wide markets, but this particular market niche is a small one and specialty companies in Canada, Scotland and U.S. will be competitive. Perhaps R&D to discover and develop marine products from microalgae and other marine organisms found in Norwegian waters will be productive, but this will not happen unless funding for this purpose is increased and the effort is better coordinated.

REFERENCES