Norwegian Salmonid Farming

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St. Andrews, N.B., E0G 2X0

April 1978

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Fisheries and Environmental Sciences
Department of Fisheries and Environment
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This is the one hundred and tenth Technical Report from the Biological Station, St. Andrews, N.B.

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PREFACE

It is hoped this report will be useful to researchers, government administrators, and teachers, as well as to private individuals now in operation or considering becoming involved in salmon farming. No special attempt has been made in this report to apply the Norwegian experience in salmonid farming to the Canadian situation today or in the future. Environmental, political, regional and social characteristics of each country will no doubt determine the way to proceed. However, a complete understanding and appreciation of the strategies used in other countries should help reveal the options available to Canada.

The unique aspects of salmonid farming in Norway lie in the marine production phase. For this reason, hatching techniques used in freshwater rearing and smolt production have been given minor attention. It should be noted that the bibliography includes many references only available in Norwegian. To assist in the translation of salient points in such articles (i.e., abstract, and table and figure legends), a glossary of Norwegian terms commonly used in fish farming is included in the Appendix III. The bibliographic section includes references cited as well as pertinent publications and has been arranged under several institute headings requiring the reader to look under several different headings to locate the author.

This report was assembled by the authors during their respective stays in Norway. Susan Merrill received funding from the Cape Breton Development Corporation and the North American Salmon Research Center and spent the first part of her leave employed by the Norwegian Directorate of Fisheries, working at the Experimental Salmon Hatchery at Matredal, western Norway. She later managed the Experimental and Production Salmon Farm at Svanøy, western Norway. Arnold Sutterlin, who was on leave of absence from the Fisheries and Marine Service, Canada Department of Fisheries and Environment, spent a summer visiting fish farms throughout Norway and the remainder of the year at the University of Tromsø, northern Norway. Special thanks are extended to Dr Dag Møller and the aquaculture group at the Institute of Marine Research, to the Svanøy Foundation and to the University of Tromsø for providing financial support as well as hospitality during our stay in Norway.

AVANT-PROPOS

Nous espérons que ce rapport sera utile aux chercheurs, aux administrateurs du gouvernement et aux enseignants, ainsi qu'aux particuliers qui s'intéressent ou qui songent à pratiquer l'élevage du saumon. Nous n'avons pas tenté, dans le présent rapport, d'appliquer l'expérience norvégienne d'élevage du saumon à la situation canadienne, actuelle ou future. Il ne fait aucun doute que les caractéristiques environnementales, politiques, régionales et sociales de chaque pays détermineront la méthode à adopter. Toutefois, l'évaluation et une bonne compréhension des méthodes utilisées dans d'autres pays peuvent aider à mieux connaître les choix qui s'offrent au Canada.

Les aspects uniques de l'élevage du saumon en Norvège résident au niveau de la production marine. C'est pourquoi nous nous sommes peu attardés aux techniques utilisées pour l'élevage en eau douce ou la production de saumoneaux. Il est à noter que la bibliographie comprend beaucoup de références qui ne peuvent être obtenues qu'en norvégien. Pour faciliter la traduction des points saillants de ces articles (résumés, légendes des tableaux et des figures), l'annexe III offre un glossaire des termes norvégiens généralement employés dans le domaine de l'élevage du poisson. La section bibliographique comprend les références des citations ainsi que des publications pertinentes, classées par instituts divers, de sorte que le lecteur doit consulter plusieurs rubriques pour trouver le nom de l'auteur.

Le présent rapport a été compilé par les auteurs pendant leur séjour respectif en Norvège. Susan Merrill a reçu des fonds de la Société de développement du Cap-Breton et du Centre nord-américain de recherche sur le saumon. Pendant la première partie de son séjour, elle a été employée par la Direction générale norvégienne des pêches, travaillant à la piscifacture expérimentale du saumon de Matredal, dans l'ouest de la Norvège. Par la suite, elle a été responsable du Centre expérimental de production du saumon à Svanøy, également dans l'ouest de la Norvège. Arnold Sutterlin, qui a obtenu un congé du Service des pêches et de la mer au ministère des Pêches et de l'Environnement du Canada, a passé un été à visiter les centres d'élevage du poisson de la Norvège, et le reste de l'année à l'Université de Tromsø, dans le nord de la Norvège. Nous tenons à remercier tout particulièrement Dr Dag Møller et le groupe d'aquiculture de l'Institut des recherches marines, la Fondation Svanøy et l'Université de Tromsø pour leur appui financier ainsi que leur hospitalité pendant notre séjour en Norvege.

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ABSTRACT

Sutterlin, A. M., and S. P. Merrill. 1978. Norwegian salmonid farming. Fish. Mar. Serv. Tech. Rep. 779, 47 p.

Norwegian salmonid farming practices from smolt production to marketing are described. Special attention is given to the marine phase of salmon culture, with social and economic factors included. The report should be useful for prospective fish farmers in North America and as a teaching aid in aquaculture courses.

Key Words: Mariculture, salmonid, Atlantic salmon, trout, Norway, cage culture

RÉSUMÉ

Sutterlin, A. M., and S. P. Merrill. 1978. Norwegian salmonid farming. Fish. Mar. Serv. Tech. Rep. 779, 47 p.

Les auteurs décrivent les pratiques de la salmoniculture en Norvège, du stade de la production des smolts à celui de la commercialisation. Ils accordent une attention particulière à la mariculture en tenant compte des facteurs sociaux et économiques. Le rapport présente un intérêt pour les éleveurs éventuels en Amérique du Nord et comme complément à l'enseignement de l'aquaculture.

Mots clés: Mariculture, salmonidé, saumon atlantique, truite, Norvège, culture en enclos

1. History and Development

The first (unsuccessful) attempts to rear rainbow trout in sea water occurred in 1912 in western Norway; it was not until the 1950's that efforts were resumed again, mainly on the initiative of private individuals. Adopting the Danish pond method of trout rearing necessitated the construction of many concrete structures and the costly pumping of sea water. Attempts to use natural bays and inlets often met with limited success because of insufficient water exchange. High operating costs and marketing problems resulted in the failure of many farms by 1966. Of the original 93 farms operating in the 1960's, only 17 remained in 1975 (Braaten 1975).

The production of rainbow trout increased rapidly from 1970 to 1973 and has remained steady during recent years (Fig. 1). Although the Department of Fisheries demonstrated that salmon smolts could be held and reared in pens, it was not until 1969 that farmers began saltwater culture. Production of farmed salmon exceeded the wild Norwegian catch in 1975 and continued growth is anticipated.

The government started showing an interest in 1970 and money was appropriated for research; that same year the fish farmers started their own organization and in 1976 began their own publication series. Federal licensing began in 1973 under the Department of Fisheries. By 1977, approximately 223 rainbow and salmon smolt production hatcheries and 384 saltwater farms were registered. The location of these farms by county shows a predominant cluster on the west coast between 60° and 64° N latitude (Fig. 2). Research and teaching are now being conducted at at least four different Norwegian universities, and a number of government departments and consulting firms are involved in research.

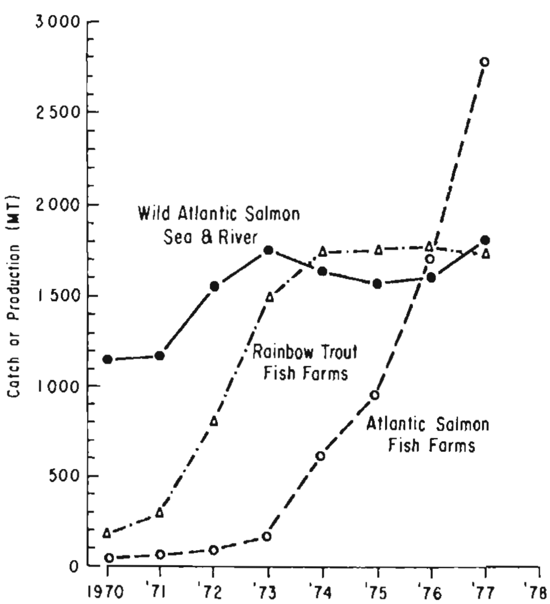

Fig. 1. Norwegian wild and marine farm production of salmonids.

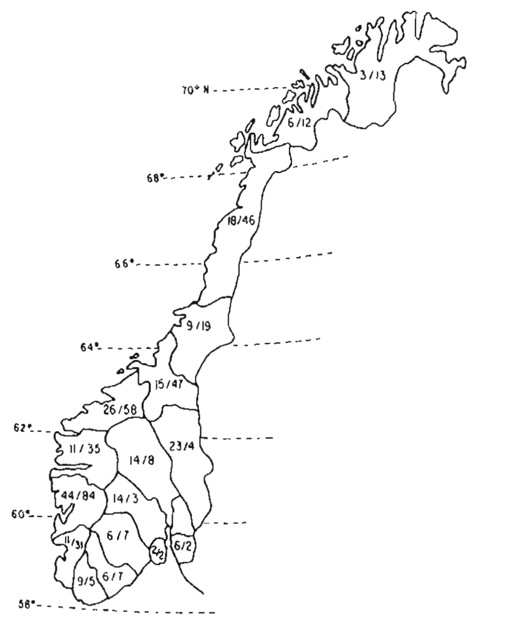

Fig. 2. Location by counties of Norwegian licensed smolt production plants (rainbows and salmon, 1977) and marine salmonid farms. Approximately 60% of those registered are at present in production; 3/13 indicates smolt plants/marine farms.

2. Hatchery Production of Smolts

Approximately 20 private companies and establishments are involved in producing smolt-size rainbow trout and Atlantic salmon to be used specifically for pen-rearing. Many are small, family-operated hatcheries, supplying local needs for rainbow trout. The plants described below are large production plants capable of supplying distant marine farms with Atlantic salmon smolts. With the exception of the large producer, Øksna Bruk (Festival Trout Company) in Sandnes, which is based on the Danish earthen pond method of propagating rainbow trout, the remainder of the hatcheries are based on piped water supplies and plastic or concrete tanks. Despite the large production of Atlantic salmon smolts, the demand by farmers still necessitates imports of smolts each year from Sweden. It is hoped that Norwegian smolt production will eventually be sufficient to supply the country's needs, reducing the risk of disease introduction from distant locations.

Rearing techniques in Norway closely resemble the Swedish system, but higher tanks are often used during the grow-out phase. Hatching and rearing techniques are described by Egidius and Hansen (1973). The following is a description of some of the larger hatcheries.

Experimental Rearing Station at Sunndalsøra

The fish breeding station at Sunndalsøra, established in 1971, was financed by several agricultural organizations and industries (Fig. 3). The site is leased from the State Electric Board. The plant is in part a production hatchery to supply fish to farmers, and in part experimental (the research program administered by the Department of Animal Genetics, Norwegian Agricultural College at Ås). Returns from the sale of smolts are used to defray the cost of research. Experimental lots of fish are transported to the marine farm at Averøy and other commercial fish farms where the growth performance of different strains is evaluated. The rearing station is operated by a staff of 9, including 2 scientists. The plant has the capacity to hatch over 4 million eggs and rear 250,000 salmon smolts and 100,000 rainbow trout fingerlings each year. Four different sources of water are available including heated water from the generators at the Aura hydroelectric station nearby. After swim-up, fry are transferred from the incubators to indoor tanks. Grading out potential for 1+ smolts begins the next fall and winter when they are transported to the cement tanks outside. Salinity acclimation begins in April and is completed by May when fish are pumped from the tanks to tank-ship or truck. This station has had some problems, most of which seem to have been solved. Addition of sea water has caused high losses of young fish due to vibriosis. Sulphamerazine has been an effective treatment. Sea water has been used in the control of eyefluke, *Gyrodactylus*. The protozoan *Costia* is treated with formalin. An undiagnosed buoyancy problem in rainbow trout has occurred periodically. Supersaturation due to insufficient degassing of the warmer cooling water and air injection through faulty pump seals have resulted in a search for more effective degassing systems. Further details of layout and production schedules are available (Kittelsen 1976 and Edwards 1976).

Fish and Research - Matredal

Construction of this station was started in 1971 and its present facilities are described in Fig. 4. Three agencies provided for the construction and operating costs. A local marine trout farmer, Osland A/S, finances a portion of the hatchery and grow-out area and sells both rainbow eggs and "smolts" to other agencies. Support for long-term projects is received from the budget of the aquaculture group (Institute of Marine Research and Vitamin Institute, Bergen). Annual granting of federal money by the Norwegian Fisheries Research Council (NFFR) supports various research projects. The yearly potential production capacity is described as: 50,000 smolts, 20,000 rainbow fry, 10,000 char and sea trout yearlings, and 1,500,000 rainbow eggs. Problems in reaching production capacity have been limited by copper toxicity and nitrogen supersaturation of heated water from the hydroelectric plant. Earlier problems with acid water have been resolved by directing the river water intake down against a bed of crushed shells in an interior tank placed within one of the large header tanks in the hatchery. This keeps the shells continually boiling, but not to the extent that they are carried over into the outside tank. This increases pH from 5.4 to 6.3. No problems with eyefluke or *Costia* are apparent but periodic outbreaks of *Vibrio* in experimental lots of fish and one incidence of furunculosis have been reported. A recent IPN outbreak necessitated the destruction of stocks.

Other private hatcheries producing smolts for sea farming do not have hydroelectric plants as a source of warm water. Smolt plants such as Sea Farms A/S in Kvalvåg (Fig. 5) and the two hatcheries of Mowi A/S on Varaldsøy (Fig. 6) and at Tveitevaag, heat water electrically for hatching and early rearing. Water is taken from lakes or rivers which receive some thermal benefit from solar heating during the summer. These plants use almost exclusively covered 4-m diameter tanks of 1-m height placed outside. Fry are placed in these tanks where they start feeding and remain there until smoltification.

3. Site Selection for Marine Farms

Norway's hydrographic and climatic features are very conducive to the marine culture of salmonids. A heavily indented coastline, myriad islands and warm water carried north by the Norwegian current provide an endless number of saltwater sites of varying suitability. Two Norwegian publications give more specific criteria for the placement of fish farms (Sundby 1976; Braaten and Saetre 1973). Today with these guidelines, greater experience by industry, and the requirement of government licensing, few poor sites are chosen.

Although not compulsory, both the fish farmers' association and fisheries personnel recommend a preliminary site investigation. Observation of temperature, salinity, and current profiles is strongly recommended for at least 1 yr before operation begins. It is possible for Norwegian farmers to obtain assistance in evaluating a proposed site from local fisheries extension personnel. Hydrographic studies may also be obtained but the waiting time is generally long and the

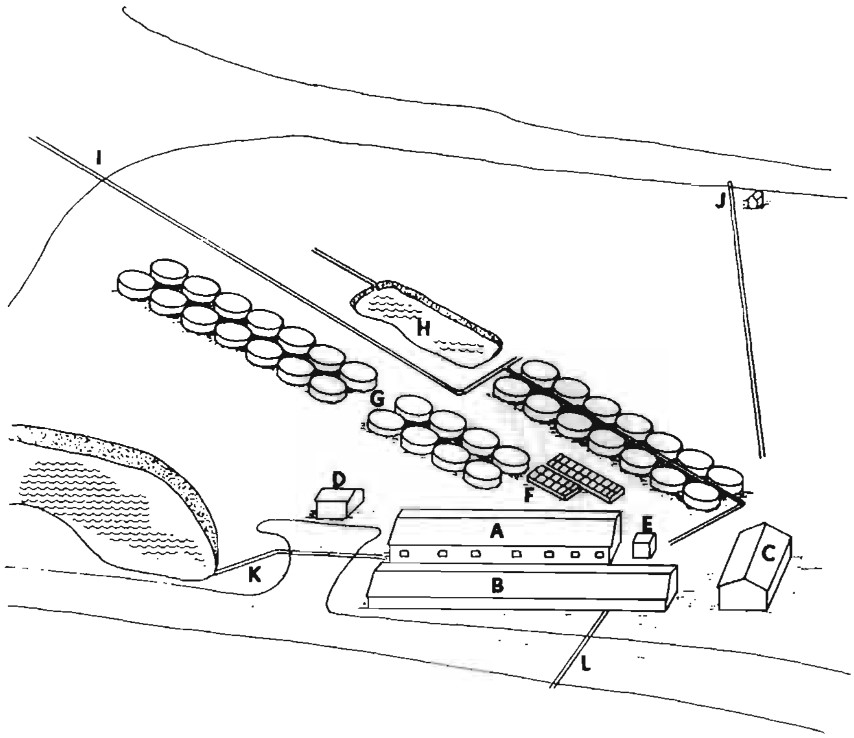

Fig. 3. Rearing station at Sunndalsøra. A. Rearing hall (550 m^2)
Fiberglas tanks: 140 - 1 m^2, 266 - 2 m^2.
B. Rearing hall and hatchery (845 m^2); C. Workshop, storage, fish food preparation; D. Offices and conference room; E. Tank house for degassing and mixing 4 types of water for independent supply to buildings A and B, hatchery and outside tanks; F. 32 4-m fiberglas tanks; G. 36 10-m diameter concrete tanks; H. Earthen settling pond; I. Saltwater intake line from 30-m depth in Sunndalsfjord; pump house at Hammerkai (6-12°); J. Freshwater intake from River Lilledal; K. Freshwater line from pump in tailrace of power station (8000 L/min; 1-10°C); L. Heated fresh water from power station generators (6000 L/min; @ 10°C; M. Outside settling tank and biological filter for recirculation system.

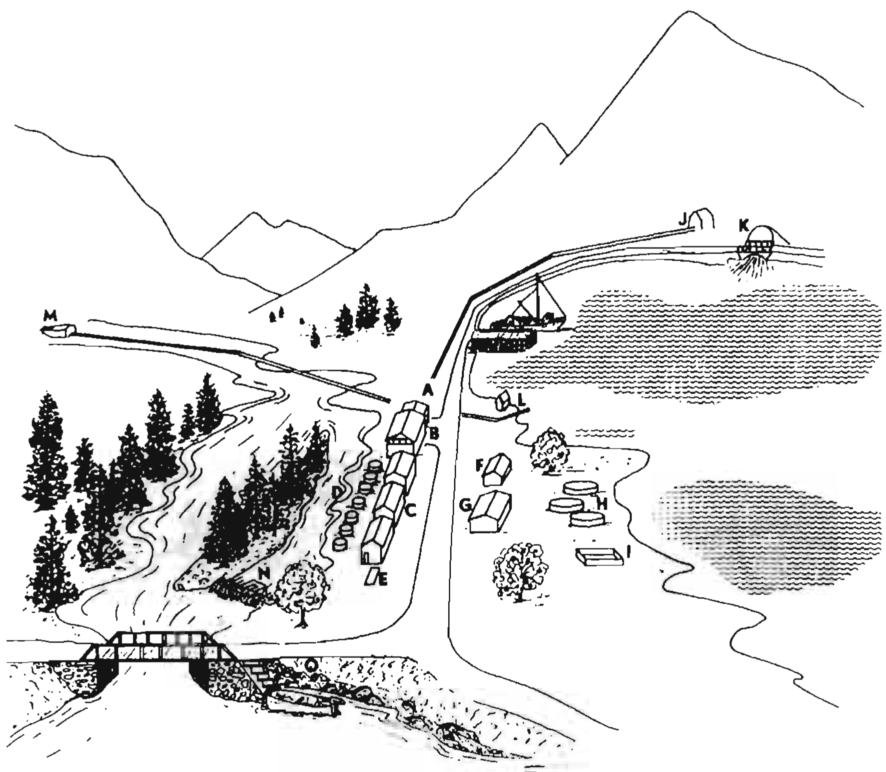

Fig. 4. Rearing station at Matredal (Fish and Research). A. Header tanks: 1. Ambient river water (0.5-16°C) with sea shell interior tank. 2. Warm water from hydroelectric plant and upwelling aerator for degassing. 3. Ambient sea water. 4. Sand filters for egg incubation; B. Top-floor offices, bedrooms, kitchen, conference room and lounge. Bottom-floor hatchery, wet and dry laboratories; C. Rearing halls containing 40, 2-m; 74, 1.75-m and 40-, 9-m fiberglas tanks; D. Fiberglas tanks; E. Cement tanks; F. Dormitory; G. Food storage and preparation, freezer facilities; H. Cement tanks; I. Settling tank for recirculating water to circular cement tanks; J. Warm cooling water pumped from power station (3,500 L/min); K. Tailrace water from Matre power station; L. Pump house for seawater supply (2 pumps, total capacity 350 L/min); M. Dam and debris screen for river water to hatchery (10,000 L/min); N. Upstream fresh trap for returning adults; O. Service boat for transport to fish estuarine pens (100 meters away).

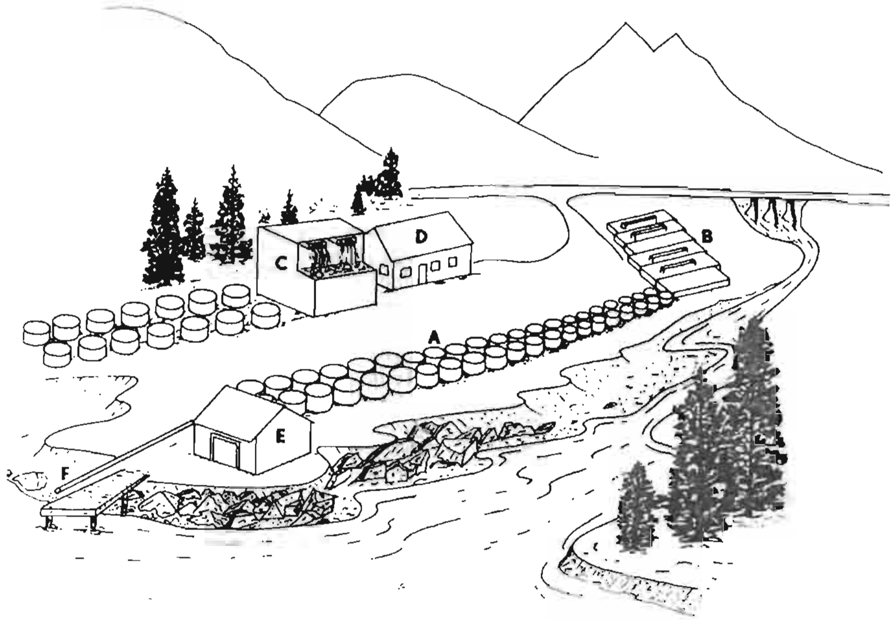

Fig. 5. Sea Farms A/S (Kvalevåg). A. 52, 4 x 1 m fiberglas tanks; B. 6 Burrows-type raceways; C. concrete header tank building (ambient river water and pumped salt water); D. hatchery building: electric heating for hatching degasser, sand filters, standby generator, office; E. workshop; F. walk and pipe-line for gravity delivery of fish to transport vessel.

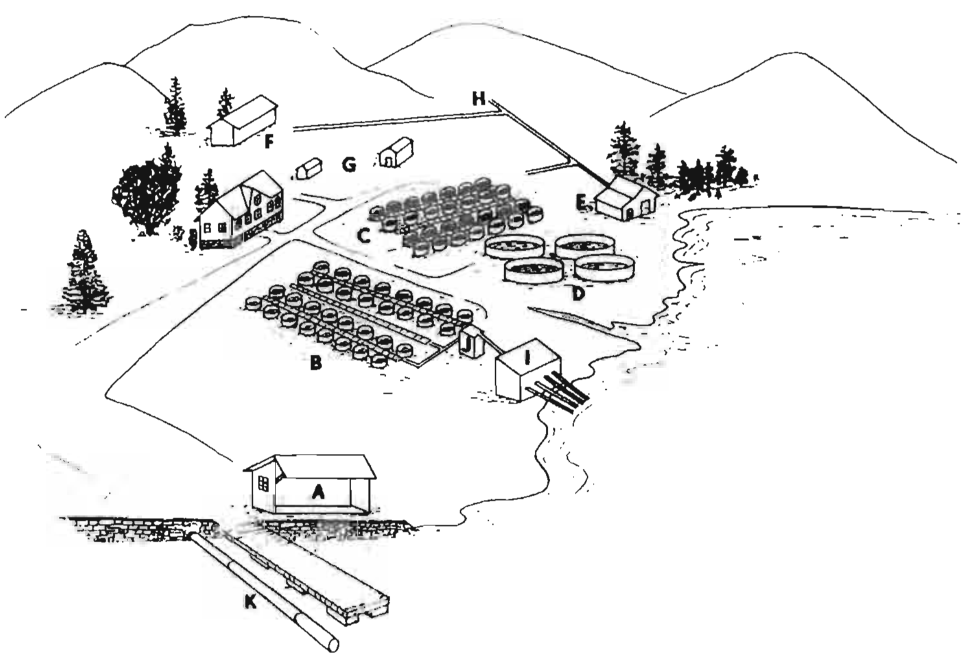

Fig. 6. Mowi A/S hatchery and rearing plant at Oeyerhamn on Varaldsøy having a capacity of 300,000 smolts per year. A. boat shed; B. bank of 32 fiberglas tanks 4-m diameter by 1.2-m high; C. bank of 28 fiberglas tanks; D. plastic pools 8- to 10-m diameter; E. water-driven saw mill; F. converted barn containing header tank, heater, degasser, sand filter and hatchery; G. storage buildings; H. freshwater supply from lake and river; I. saltwater pump house; J. header tank for salt water; K. fresh delivery pipe connected to tank drainage sluiceway.

applicant has little control over the time of year the study will be carried out.

Temperature

The latitudinal effect of temperature on growth in different farms is described in Section 10. From a Canadian perspective, Brett (1974) compares the Norwegian and Canadian west coast temperature regimes in relation to suitability for salmonid culture.

Offshore, coastal temperatures along the entire west coast of Norway from 58° to 71° N are suitable for pen-rearing. Low winter temperatures and high summer temperatures exclude the Norwegian east coast bordering the Skagerrak. Northeast of Honningsvåg on the west coast, cold winter temperatures become limiting. From Narvik to Hammerfest (68°30'-71°N), the lower yearly average temperature and the winter minimum appear to be more suitable for salmon than trout, while south of 68°30'N both species seem to thrive.

Coastal and fjord environments, however, can vary considerably throughout this range. Poor oceanic circulation in some deep southern fjords, having a ledge and a basin, results in poor flushing and high summer temperatures. Similar fjords in the north cannot be used as cold water and surface ice prevent year-round culture. Seasonal fluctuations in the degree of stratification of temperature, salinity, dissolved oxygen and industrial pollutants at the end of many long fjords make them less suitable than was originally believed. The smaller coastal fjords and protected areas among Norway's numerous islands provide a far more stable environment for marine culture despite the fact that they are more often remote from suitable freshwater hatchery installations.

Sundby (1976) gives the tolerance limits for growth in rainbow trout ranging from 3.5-20°C, but recommends temperatures over 5°C with an optimum of 15-16°C. For salmon, limiting temperatures are a little lower (2°C), with optimum growth around 14-15°C for smolts and post-smolts. Temperatures, perhaps as low as 10°C, may be optimum for larger salmon. Sudden changes in temperature (3°/h) have been shown to sharply reduce the appetite of salmon and trout.

Salinity

Numerous physiological studies conducted in Norway and other countries indicate that salinity isosmotic with the blood (8-10‰) seem to be optimum for growth and food conversion. However, very little information is available for large fish. Some fish farmers believe that salmon become "lethargic" during periods of changing salinity. Despite the apparent advantages of lower salinities for optimal fish growth and size at stocking, the inherent instability of those fjord environments offering low salinity conditions limits their usefulness.

Oxygen

A lower limit of 5 mL O_2/L within the fish pen has been judged safe for salmonids. In coastal waters, which are usually saturated with oxygen, water currents in the vicinity of the fish pen are considered to be the critical factor. A 10-20% reduction in O_2 content in the pen can exist under the recommended current speed of 10 cm/s outside the pen and a stocking density of 8-10 kg/m^3 within. In addition to water currents and stocking density, certain unexpected combinations of increased temperature, high stocking densities, a reduced flushing rate or heavily fouled netting, can reduce oxygen levels in the pen to critical levels. It is important to cease feeding until this situation can be remedied. With high winds and under special photosynthetic conditions, oxygen supersaturation as high as 150% can occur. This seems to have no detrimental effect on fish.

In eutrophied, stratified areas of low salinities and high surface temperatures, photosynthesis can raise the pH to dangerous levels for salmonids (above pH 9). This is seldom a problem, however, because such a site would have been excluded from consideration for a number of other more apparent reasons.

Water Currents

Current should be sufficient to carry away waste and bring in clean oxygen-rich water. It is recommended that the long axis of the farm be placed at right angles to the dominant current. It is also remarkable that the establishment of a fish farm can very much affect the natural circulation patterns, especially in narrow passages or confined inlets. Recycling of water through the farm such as would occur in tidal displaced water in narrow passages, or in circular patterns set up in small inlets, should be avoided. It is not easy for a farmer to recognize such patterns from the limited studies he can perform with surface drifters, and the use of fluorescent tracers (e.g., rhodamine) requires special equipment and training.

Local topography and tidal amplitudes, as well as the impinging major coastal currents, influence the prevailing currents at any one site. There is a latitudinal cline in tidal amplitude decreasing from the north to south, but natural resonant characteristics of different fjords modify this pattern considerably. Among coastal islands, a prevailing unidirectional current often exists, but even this stable situation can be abruptly modified by winds.

In the 12- to 13-m octagonal fish pen (loaded at 8-10 kg/m^3), a current speed of 2 cm/s through a moderately fouled pen provides sufficient oxygen delivery. However, the circular swimming of salmon usually sets up a circular component and current measurements within pens are difficult to interpret. A minimum current velocity outside the pen of 10 cm/s and a maximum of 50 cm/s are usually recommended. Heavily fouled nets reduce permeability to critical levels at low external current velocities. At high external current velocity, fouled netting results in pen distortion, increased stress on netting, feces and food accumulation and mooring problems.

Wind, Waves and Ice

Ice development is seldom a problem in most localities, but drift ice has caused some problems periodically in a few northern farms. Ice development and movement are usually restricted to the ends of fjords in northern Norway which are not often good sites for fish farms as discussed previously. We are aware of only one instance of a farmer routinely sinking cages below ice in the winter.

Wind-generated waves generally affect displacement in the upper 5 m. A 1-m wave can generate a horizontal particle speed of 100 cm/s. The flexibility of the home-made 12-m octagonal pen can tolerate swells up to 2 m which are periodically encountered in coastal farms. Swells exert extreme pressure on mooring lines and anchors, however, and severe inshore conditions of waves of short periods ("chop") can cause disproportionate forces on pens, resulting in metal fatigue in hinged walkways and torn netting.

An appreciation of seasonal wind direction and velocity is advantageous as protection from all sides is not necessary, nor always beneficial, from the point of view of water exchange. In addition to wind-generated waves, storm-force winds can create forces of 20-30 kg/m^3 on exposed net fences. Floating breakwaters, however, are very costly and are seldom employed around farms.

Depth and Bottom Conditions

Floating pens should be located so that a minimum of 5 m of water is below the bottom of the net. This provides for some dispersal of waste feed and fish feces, and removes the pen from the slow-moving boundary layer of water on the bottom, which is often rich in hydrogen sulfide. The extra expense involved in materials, and the maintenance of mooring lines and anchors at installations in water deeper than 25 m, should also be considered. Extremely deep water can be tolerated if convenient land points can be spanned with cable lines without creating a navigational hazard.

Restrictions to Navigation and Coastal Zone Planning

Marine farms must be located so as not to block shipping lanes or channels used by fishing boats. Farms on the edge of navigation routes must mark mooring lines with buoys and position a warning light (flashing yellow) to mark the location of the farm.

Approval for coastal zone development usually is handled by a local board at the municipal level. They review applications for building permits for private citizens and industry. Special attention is paid to compliance with zoning regulations for industry, tourism, aquaculture and fishing. It is usually the responsibility of the local fisheries leader to ensure that the application for a fish-farming license is compatible with community aspirations represented by the local planning board.

Except in heavily populated areas and special tourist and historical resorts, the conflict between cottage development and fish farming is not severe because many Norwegians living on the west coast prefer to vacation in the warmer mountain plateaus in the summer. Consequently, few cottages or huts are built near the coast.

Pollution

Fish farms should not be placed near large factories, densely populated areas, or agricultural areas with nutrient run-off from fertilizers. Strong winds during the fall can result in periodic upwelling of anoxic water containing H_2S, or nighttime respiration by plankton can deplete oxygen in surface layers and produce NH_3 resulting in stress or death to fish. Dinoflagellate blooms (*Gyrodinium aeriolum*) have been responsible for fish kills by depleting oxygen during the night, rather than by toxin production. Although turbidity is generally low in coastal waters, muddy intertidal areas at the ends of some fjords can result in considerable suspended sediments.

The recent oil blow-out at the *EKOFISK* drilling platform in the North Sea caused some alarm among fish farmers, but no damage was done. However, contingency measures, such as floating booms around susceptible farms, were being considered.

Access to Support Services

Transportation costs for food ingredients and a reliable supply of fish food are also important considerations. Accessibility to freezer and fish processing plants for food storage and product preparation might also be considered. Sharing experience, equipment costs and food preparation facilities with existing plants could reduce the initial capital investment.

4. Basic Types of Marine Salmonid Farms

The four most common types of fish farms are shown schematically in Fig. 7. Types A and B are the most common. Commercial examples of types C and D are restricted to only two companies, but account for very large productions.

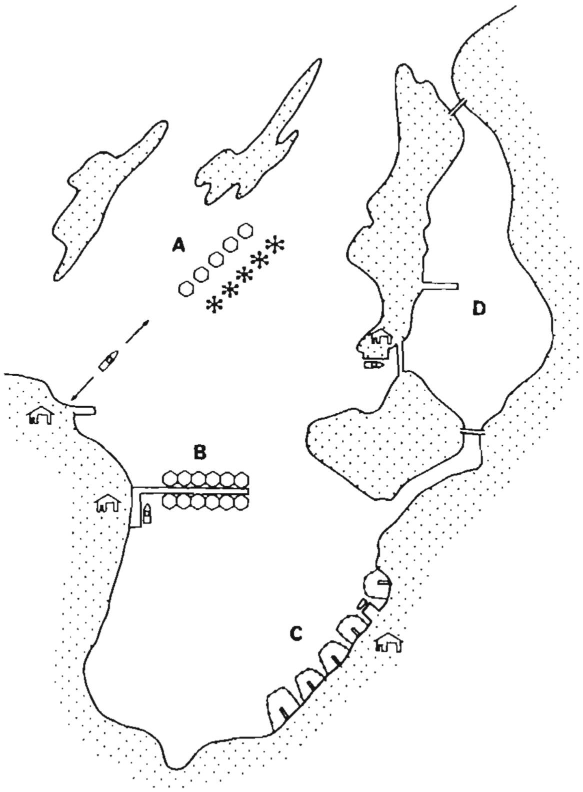

Fig. 7. Site locations of four different types of Norwegian marine farms.

A. Offshore anchored fish pens:

These may be close to shore but require the use of a boat for feeding and service. Food preparation facilities and workshop are shore-based. Food ingredients and other supplies may be delivered either by boat or truck if the building site has access by road. The available types of fish pens are discussed further on. Offshore pens are usually separated from each other but may be connected together by a hinged floating raft system, or the arrangement of rafts may permit netting to be suspended within them. The mooring system includes bottom anchors and/or lines extending to shore points. Several companies that own filleting and freezer plants have entered, or are entering, fish farming using this type of offshore plan. Many of the necessary components (wharf, freezer, machinery and supplies of fish offal) provide a natural situation for such companies to expand into fish farming. In remote areas, it is often uneconomical to transport fish wastes to distant fish meal plants and in the past, much was disposed of in the sea. Fish farming has provided a convenient and prosperous means of disposing of some of this waste.

B. Shore-based pens with floating ramp:

These farms usually have access by road but occasionally food ingredients and supplies are delivered by boat. Square or rectangular pens are sometimes used, especially if trout are being reared. Wharf and service buildings are continuous with the floating ramp, and fish food is delivered by cart or wheelbarrow (see Fig. 12). Large farms based on this principle have interconnecting or radiating walkways to accommodate more pens. A number of lines and anchors attached to the walkway provide mooring. If a freshwater source is nearby, it is not unusual for a trout hatchery and freshwater rearing facility to be incorporated with the building site. Existing facilities, such as old barns and water-driven sawmills, have been cleverly converted into hatcheries, workshops and food preparation areas.

C. Shore-side net impoundments:

For rainbow trout rearing, Mr. E. Osland of Bjørdal has constructed 8 shore-based enclosures on a sloping beach (Fig. 8). Each is approximately 800 m^2 in area, 8-10 m at maximum depth, and 4500 m^3 in volume. A double net system provides greater security and facilitates changing and cleaning. Each unit is capable of holding 40-50 tons of rainbow trout at a density of 9-10 kg/m^3.

D. Natural impoundments:

West of Bergen, Mowi A/S has modified two natural impoundments that exist among the islands near Movik by constructing barrier gates (Fig. 9). The enclosure at Veløy was completed in 1970, has a maximum depth of 12 m, occupies an area of 35,000 m^2 and impounds 180,000 m^3 of water. The impoundment at Flogøy contains 55,000 m^3 of water. Concrete dams have been constructed at the entrance and exit. A double set of inclined aluminum gates lie within slotted tracks and are raised and lowered alternately by winch and gantry for periodic cleaning. It was realized early that the 1.5-m tide would not provide sufficient circulation and large electric pumps (25,000 L/s) were installed at the exit gates to draw water through the enclosure. In addition, floating electric pumps, which drive propellers, are moored in the deeper areas of the enclosures to assist in horizontal circulation and to provide upwelling in order to prevent stagnation and stratification.

The enclosure at Veløy is stocked with 216,000 1+ year old smolts reared at the Mowi hatcheries. Growth for 23 mo

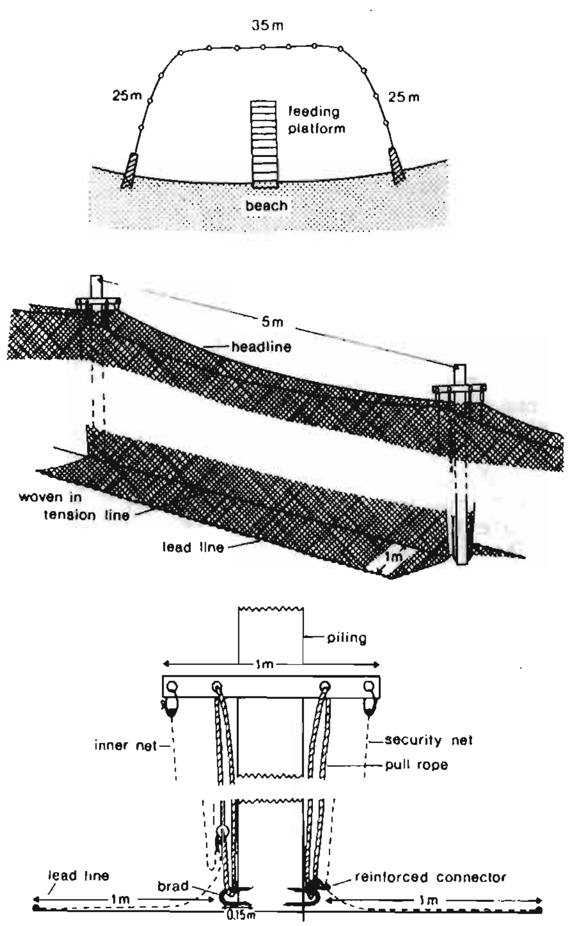

Fig. 8. Osland enclosures.

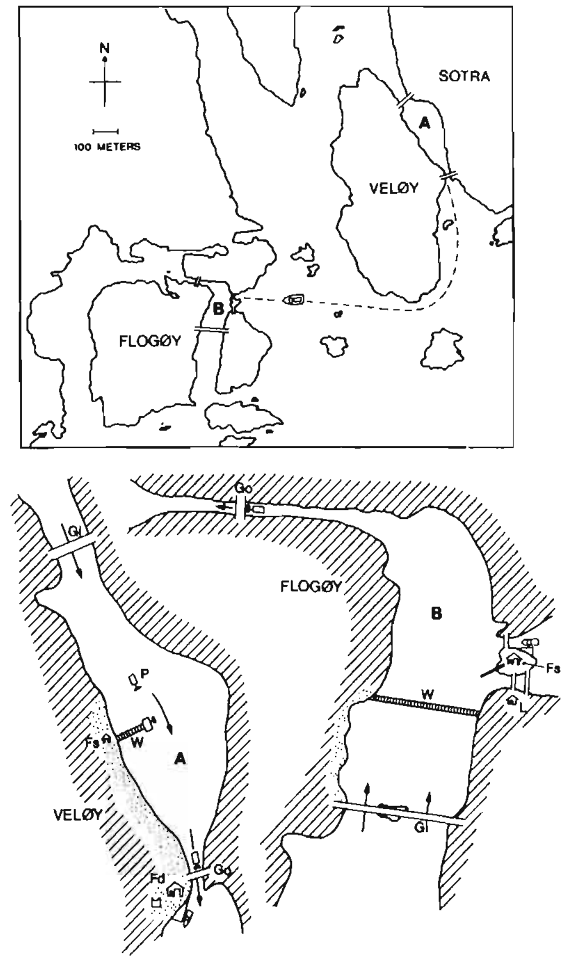

Fig. 9. Natural impoundments, Mowi A/S. Go, discharge gates; Gi, intake gates; Fd, food depot; Fs, feeding station; W, walkway; P, pump; L, laboratory.

resulted in a mean weight of 3.8 kg. At the end of the second summer, 5.6% of the salmon matured sexually, resulting in reduced growth and a mean weight of only 2.2 kg compared to 3.8 kg for the immature fish. At harvest, 15% of the smolts originally stocked were not accounted for and the impoundment produced 540 tons of salmon. The limiting factor in production capacity was clearly shown to be the period in August during the second summer's growth in which elevated temperatures (16°C) resulted in oxygen depletion. This critical period limited the carrying capacity of the impoundment to a maximum of 275 tons. Fish weight in excess of this must be harvested prior to August or some way must be found to increase the flushing rate of the impoundment (see references concerning contracted engineering studies at Chr. Michelsen's Institute - E. Hammer, and A. Nilsen). The two impoundments are employed simultaneously, but with alternate year-classes.

The impoundment at Veløy, although adjacent to the mainland, does not have access by road and food delivery and services are accomplished by boat. The Flogøy site is offshore among islands and is also serviced by boat (Fig. 9). Transportation between the two sites entails a 1.3-km boat trip. The main food depot (Fd) is adjacent to the wharf at Veløy to which raw food ingredients are delivered so that food can be prepared for both sites. The food depot consists of an outside thawing bin into which sea water is pumped and a conveyor system with which to deliver the thawed capelin or fish scrap to the grinders and mixers within the main building. A loose pasty blend of ground fish, fish meal, binder (guargum) and vitamins (Mowi's own formulation) is produced and transported in large polyethylene tubs (offal car) by fork lift and winch to the delivery boat, whereupon it is taken to the feeding station at Flogøy. A similar feeding station (Fs) exists at Veløy. At Flogøy, an electric winch at the feeding station slowly pours the food mixture from the offal car into a variable speed worm-type extruder. The wet noodles that leave the extruder are prevented from adhering to each other by spreading them on a flowing layer of sea water that is pumped from the feeding station. The sea water and suspended noodles leave the station by means of an enclosed trough and are delivered to the fish in the impoundment. The wet noodles emerge as floating strings of variable length and diameter and appear to hold together well when struck by the salmon.

Some advantages of this type of semi-natural impoundment over conventional floating fish pens have been recognized: 1. The innate swimming tendencies of the salmon are less restricted; 2. The whole population can be fed automatically at one location with a resulting reduction in labor; 3. There is a long depreciation period on invested capital because of the durability of construction; 4. There is greater security from fish escapement due to storms and torn netting.

On the other hand, such a production system in which all the eggs are in the same basket offers definite disadvantages: 1. The system requires high initial capital outlay; 2. There is a high initial risk during experimental production trials and less opportunity for experimentation; 3. The rearing area is not always under maximum utilization. Interactions between temperature and dissolved oxygen are not always seasonally predictable and are the limiting factors rather than stocking density *per se* ; 4. Inventory, inspection, selective marketing and removal of mortalities are difficult; 5. Epizootics could be of greater proportion; 6. Harvesting and control of predation by birds and fish are more difficult; dynamite has been used to clean out the impoundment prior to stocking; 7. Removing seaweed from inflow screens during some periods requires considerable labor; 8. Environmental alteration of benthos with little chance for recovery is inevitable; 9. Hydrogen sulfide buildup in bottom water could be harmful to fish; 10. Electricity for pumping sea water is costly.

5. Floating Fish Pen Design

The 12- to 13-m diameter, octagonal fish pen is certainly the most common type of facility utilized by Norwegian fish farmers (see Fig. 12). The home-made variety depicted in Fig. 10A appears to be the most common and several variations on this theme have evolved in different localities (Fig. 10C). A barrier net is attached from the base of the flotation section to the guard rail to keep "jumpers" in and the net pen is usually suspended from the outside edge of the flotation section. A circular, 13-m diameter home-made type employing concentrically joined sewer pipe is being used at some farms in northern Norway. Approximately 30 flotation sections provide the walkway around the cage (Fig. 10B). Hexagonal and circular models of various sizes, utilizing fiberglas on foam construction and hinged units, are available from commercial firms (Fig. 10D and E). The bottoms of the nets are usually weighted with lead. The depth of pens used in rearing salmon is usually about 3-4 m, sagging in the middle to 5 m. Deeper pens are often used in trout rearing. Land-based fish farms with a floating ramp usually employ foam-filled flotation sections in ramp construction and these are joined with rubber or metal hinges for flexibility. Skretting A/S of Stavanger markets two basic types of Tess floating fish pens based on air-filled flotation buoys (Fig. 11). These units seem to have gained acceptance especially where units are to be moored offshore. A hexagonal, 10-m diameter, umbrella-shaped, easily assembled model, consisting of fiberglas poles and galvanized fittings is shown in Fig. 11, top. Complete with net, this pen encloses a volume of 300 m^3. A second rectangular model (Fig. 11, bottom) constructed of salt-resistant aluminum tubing is available in 3 sizes enclosing areas of 5.3, 25 and 49 m^3. Nets of various mesh sizes are available; these extend to 4 m in depth.

The 12- to 13-m diameter octagonal fish pen (Fig. 10A and Fig. 12) of 4-m depth encloses a volume of about 500 m^3. This can be temporarily stocked with up to 5,000 smolts, with restocking of other pens occurring in the fall. At harvest, the capacity of such a pen is limited to about 1200, 5-kg salmon giving a final loading density of 12 kg/m^3 which yields about 6 tons of fish.

6. Net Construction, Fouling and Replacement

A variety of knotted and knotless netting is used in pen construction. Many of the 12-m octagonal pens have netting of 1/2- to 1-inch square weave, knotted, 2-mm diameter nylon twine. Smaller units often use a square weave of knotless nylon.

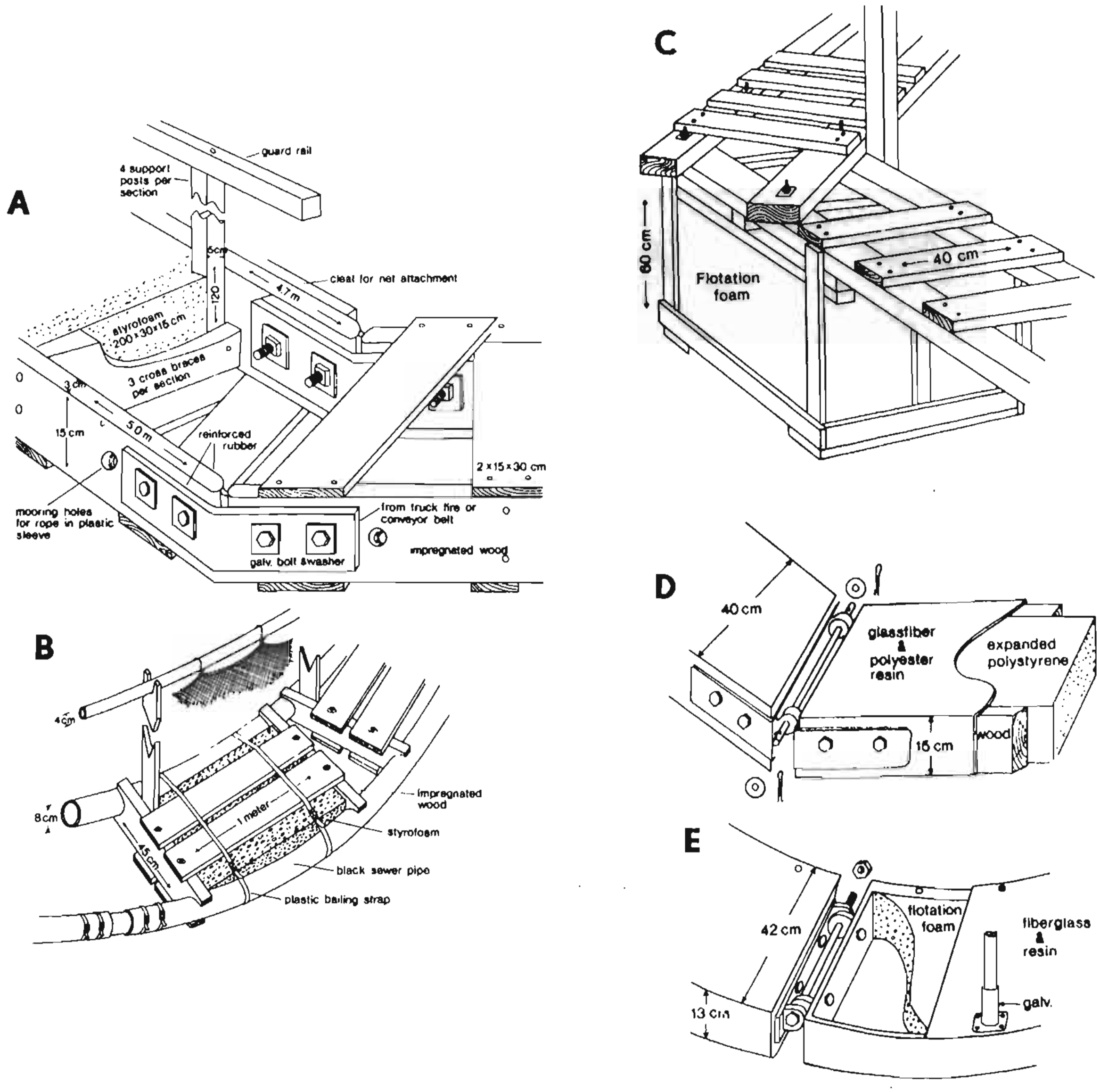

Fig. 10. Construction details of home-made pens (A-C) and commercial pens (D & E).

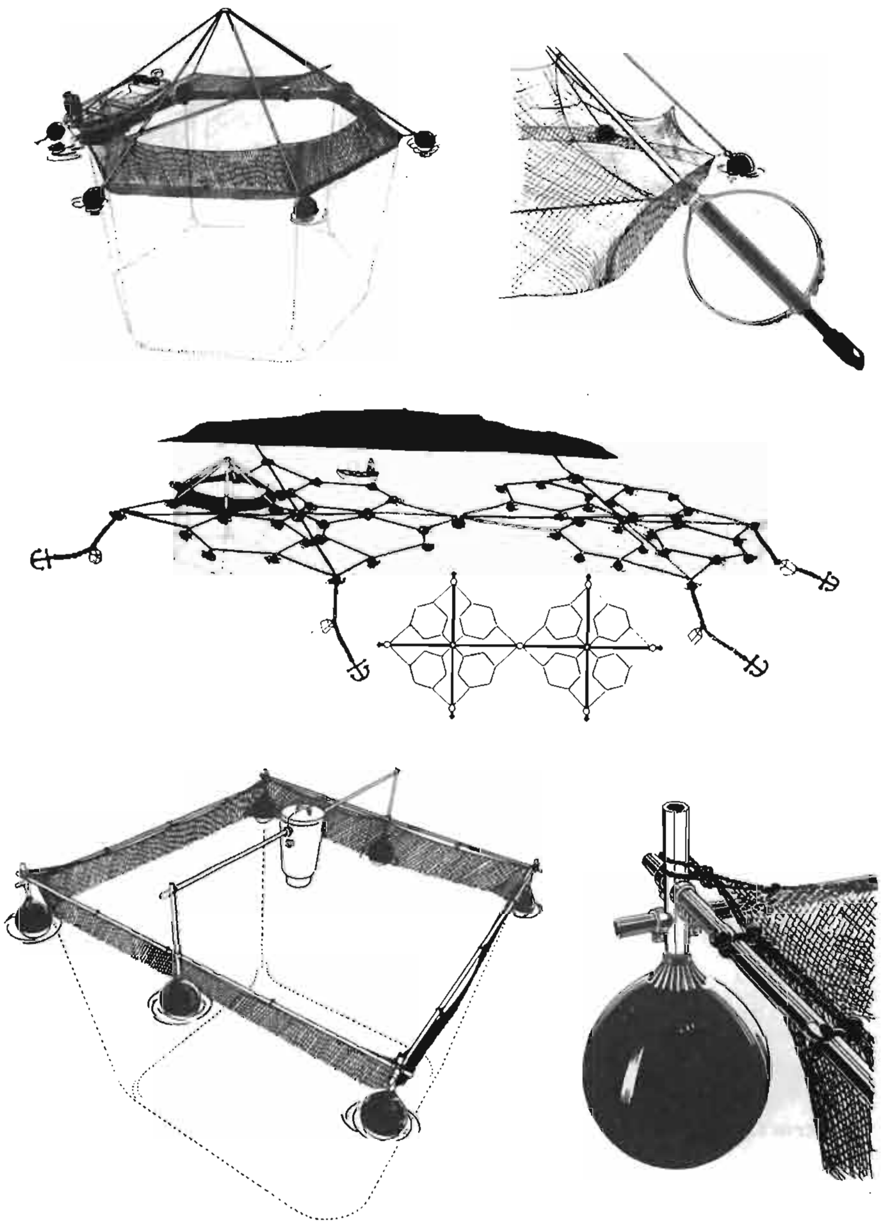

Fig. 11. Hexagonal and rectangular tubular frame types of fish pens produced by Tess; recommended mooring methods are also depicted.

Netting is usually changed twice a year in western Norway, during May and again in the winter if seaweed accumulation is heavy. In northern Norway, one change in July after maximum settlement of mussels and tunicate larvae is often sufficient. The predominant fouling organisms accumulating on fresh nets placed in early spring are hydrozoans and bryozoans, tunicates and mussels, in succession. Fouling of nets in brackish water appears to be less serious. Some farmers recommend stacking the fouled nets in a heap, covering them with plastic, and then letting the organisms decay. This should be followed by a high-pressure hosing down. A 3-day soak in formic acid (4%) and copper sulfate (9%) is purported to be effective. Heavily fouled nets are also often sunk to the bottom, where starfish and other predators clean up much of the mussel accumulation. Another method of dissolving the byssal threads of mussels is to dip the nets in Na-hypochlorite solution for 3 h. After drying, the nets are soaked in an antifouling preservative[1] and placed in the ocean while still tacky.

In 1975, the Institute of Marine Research and Monopol Malling and Lakkindustri A/S tested four different antifouling formulations produced by Monopol and one Japanese product on test panels at four different sites along the west coast. An improved formulation, containing a high content of copperoxydal and a low content of an organotin complex, proved superior to a product the firm had been marketing (Monopol Ren-Not B-750). This formulation was especially effective in controlling algae and mussels. The Japanese product (Nisson Tairyo-1000) based on organotin complexes was very effective against tunicates and mussels but not against filamentous green algae. One of the earlier methods used by fishermen was to mix copper antifouling paint, a softener and solvent (xylene, varsol, white gas). This proved least effective of the five items tested. In choosing an antifouling material, the farmer should consider coverage, price and effectiveness in his locality.

Netting should not be exposed to direct sunlight during storage and those portions of netting above the water line should be periodically cut back or replaced, especially if these sections are load-bearing.

Changing nets on octagonal pens involves sliding the clean net beneath the fouled net and pulling the old net out from beneath the fish. Care must be taken when sliding the new net under to keep it close to the bottom of the old net or cod and pollock will be admitted into the clean net. Two men can usually do this in about 2-3 h. Barrier or predator nets are not customarily used outside fish pens. Bird nets are usually suspended across the guide rail to protect young fish only.

[1]Monopol Lakkindustri A/S, 5305 Florvåg, Bergen.

7. Fish Food Ingredients, Preparation and Feeding

A. Commercial dry foods

Tess foods made by Skretting A/S of Stavanger, a long-established firm in livestock foods, produces nearly all dry food used in Norwegian salmonid hatcheries and commercial fish farms. The food appears similar to Ewos food of Sweden, in that fish protein concentrate is used to boost protein content in freshwater starter foods, but differs in that nearly all food contains higher fat content (20%). This is accomplished by adding some fat before pelleting and spraying a second coat later. Because of the fat content, the pellets are somewhat softer than other commercial foods but excess crumbles are not a serious problem. There is apparently good justification for using this high fat content during the freshwater phases of salmon and rainbow trout production. Increases in fat content from 8-10% resulted in lower mortality and greater growth, and a greater percentage of 1-year smolts was produced (Austreng 1976, I, II, III). Presumably, fats are the most efficient sources of metabolizable energy, resulting in a protein-sparing effect. Despite higher fat levels in liver and carcass, no pathological symptoms were observed. Capelin and soya meal provide the bulk of protein and capelin oil the fat. Starter, grower, finisher and brood stock food are available from Skretting A/S, for both salmon and trout. For pigmenting fish, synthetic color (carophyll red) and natural red capelin oil are used in the formula of finishing diets. Natural pigments are recommended for brood stock diets to ensure good fertility and hatchability.

Because a great many fish farmers are preparing their own wet feeds, Skretting A/S provides binder meal which is mixed (10%) with ground fish. This meal consists of coarse wheat filler, vitamins, carboxy methyl cellulose binder and, upon request, carophyll red. Various meals consisting of combinations of the above ingredients can be purchased separately. A soya and fish meal combination along with the ingredients above, to be mixed with 50% fish to produce moist pellets, is now being tried on the market.

Skretting A/S cooperates with an experimental marine farm, south of Stavanger in Holmane, for research and food evaluation studies, and is involved in food trials at other commercial fish farms. An Oregon moist type of pellet is being investigated. A number of handbooks are available enabling the farmer to balance protein and fat requirements in wet formulation by mixing various proportions of scraps from different species. However, these guidelines are not always strictly followed.

B. Wet Feed

Although some farmers utilized commercial dry pellets throughout the entire production period, wet food is usually employed after the first 10 mo in salt water. Alternatively, some farmers feed wet food exclusively from the smolt stage on. The type of food and its consistency and composition depend in large part on tradition and personal preference, availability and costs of raw ingredients and competitiveness of dry food due to shipping costs to remote areas. There is a general belief among fish farmers that while dry foods give equal or better conversion efficiencies, growth rate is slower, especially for salmon. Wet feed seems to be accepted better than dry feed during winter months by salmon. This issue, however, is still very controversial. The categories of food most commonly used are described below:

1. Commercial dry pellets (previously described).

2. An extrusion of a mixture of semifrozen capelin, sprat or fish wastes with 10% binder meal containing vitamins. This can be produced in various size noodles depending on the size of the perforated plates in the grinder. Shrimp wastes (10-15%) or carophyll red is included 4-6 mo prior to marketing.

3. A chopped capelin or sprat preparation made by special blade attachments for the grinder. It is recommended that this diet along with the following be alternated with diet #2 containing vitamins.

4. Whole capelin or sprat. This is especially suitable for large fish but unfortunately cannot be used as a finishing diet because of pigmentation requirements.

5. Other home-made formulations which are modifications of #2 but include additions of fish meal or special proportions of scrap fish as ingredients (also see Mowi A/S, Section 4). The most common raw fish ingredients besides capelin and sprat are cod, mackerel and coalfish ("pollock") racks and viscera. Tables for adjusting the fat and protein content for various raw fish mixtures based on least cost per protein or energy unit are available (Austreng 1965).

A "typical" food preparation facility is depicted in Fig. 12, and may consist of the following equipment:

1. Freezer for storage of frozen blocks of capelin, sprat, scrap fish and shrimp wastes.

2. Storage area for bags of commercial dry feed, 10% binder and, in some farms, fish meal.

3. An area for handling the frozen blocks to be thawed or broken up. Partial thawing is accomplished either by pumping sea water over the blocks, using kerosene-electric blowers, or using ambient central heating. The blocks may also be broken up by a commercial block chopper or electric jack hammer.

4. A trough or work table extending over the grinder on which ingredients are distributed before they enter the grinder.

5. A large grinder, preferably with reverse mode for mixing, and accessories such as chopping blades and perforated extrusion plates of various diameters.

6. Special labor-saving devices such as a battery-operated fork lift, electric winches and overhead track and conveyor belts for transporting and lifting ingredients.

Food waste is being increasingly considered as economically and environmentally detrimental in marine fish farming in Norway. It has been estimated that in some farms up to 60% of the food placed in the pen leaves the unit as uneaten particulate and soluble material. However, 10-15% is probably more typical of farms employing food types 2 and 3 described previously. Preparation of food, especially type 2, during the warmer summer months requires special consideration. This food should not be confused with a fish meal-based moist pellet (i.e., OMP), as the extruded noodle used in Norway is of much looser consistency due to the high water content. The binding capacity of these noodles is important in minimizing food waste; they must not adhere to each other in the feeding bucket and should provide discrete bite-size targets for the fish when they are spread floating on the water surface. These properties are best ensured by grinding semi-frozen fish prior to adding binder. A second pass through the grinder with binder added, followed by feeding before thawing, seems to provide best results. Addition of shrimp waste in the finishing diet reduces the binding capacity of this mixture and it is recommended that the shrimp offal be ground before being added to the fish portion for the final extrusion.

Dry commercial pellets, unlike the floating noodles described above, sink and pose problems of their own; judicious feeding is also necessary to prevent food waste. A variety of electrical and battery-operated feeders are available in Norway but they are seldom used on a large scale to feed fish past the smolt stage. Automatically controlled demand feeding is not practiced commercially.

Salmon, more than trout, are particularly fussy eaters and do not appreciate abrupt changes in their menu. Salmon accustomed feeding on whole capelin are reticent to change to ground capelin with vitamins and shrimp waste. It is time-consuming to acclimate salmon from wet to dry food; the change from dry to wet is less difficult. Other factors such as water current through the pens and weather conditions (cloud cover and wind) are reported to influence the day-to-day feeding intensity of salmon.

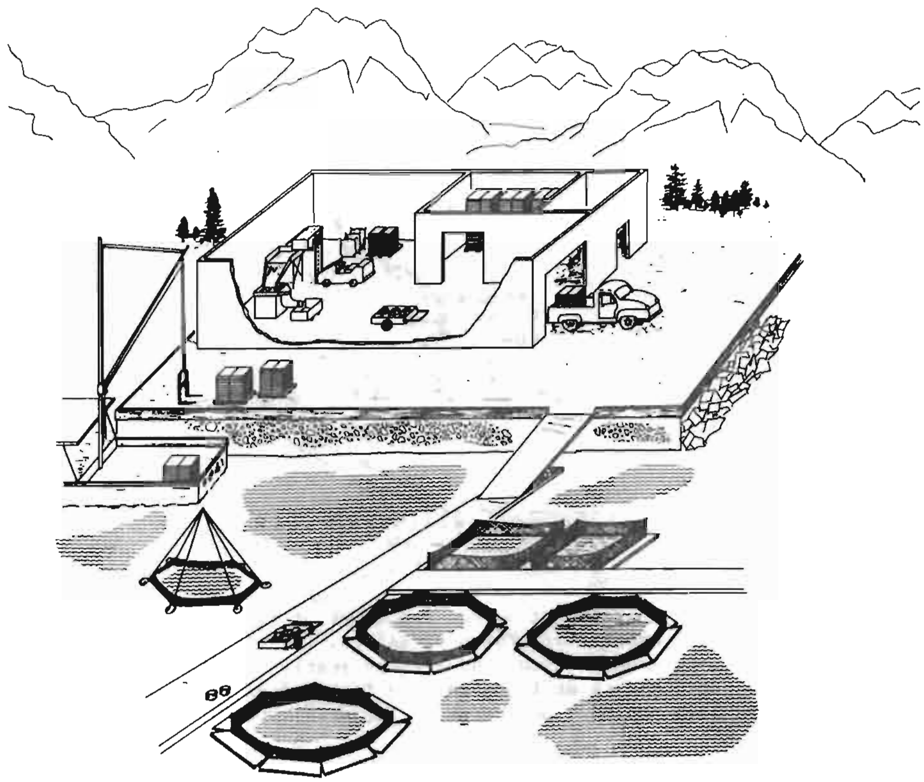

Fig. 12. "Typical" food preparation facility for a land-based Norwegian salmon farm.

The bulk of the protein and fat to support Norwegian salmonid farming comes from capelin. Since the collapse of the mackerel and herring fisheries in the early 1970's, nearly all the fish meal produced by the Norwegian plants comes from Barents Sea capelin. Lesser amounts of mackerel, Norway pout, North Sea brisling, blue whiting and various groundfish scraps are also reduced for meal. Except for export of a few thousand tons of frozen female capelin for the Japanese market, there seems at present no damand for this resource as human food at a reasonable price to producers. The cooperative marketing organization, Norsildmel, recorded 453,000 tons of meal and 240,000 tons of oil produced by approximately 50 plants in 1976, well above the average for the previous 5 yr. Increased exploitation of the Barents Sea capelin by the Russians with the prospect of an equal sharing of the stock, leads to the prospect that the Norwegian sustained catch will peak shortly. Norwegian fish meal prices received by Norsildmel varied between 1400 and 4700 kroner ($280.00-$940.00) per ton from 1973-76 and they were receiving 2650 kr ($530.00)/ton during mid-1977. Prospects of a stable capelin industry in the near future, coupled with increased utilization of vegetable proteins in salmonid foods, suggest that salmonid mariculture is capable of expanding using domestic capelin supplies as less than 5% of the landed capelin is now diverted to salmonid food for Norwegian use. A sudden increase in foreign markets for capelin as human food or for edible fish protein concentrate could, however, elevate prices making salmonid farming less profitable.

8. Growth and Food Conversion at Different Farms

Growth of the same stock of salmon and trout at six different fish farms of considerable latitudinal spread is compared in Fig. 13. There is a trend for growth to be greater at more southern fish farms which is possibly explained by temperature (Fig. 13A). Photoperiod might also be involved in that Kalfjord, furthest north, is without sunlight for over 2 mo in the winter. Lower stocking densities in the two most southern farms may have also contributed to the superior growth. A similar decline in rainbow trout growth was also observed at the six farms. If the data from the six farms are pooled (Fig. 13B), rainbow trout seem to maintain their initial fast growth over salmon until the end of the second summer in the sea. It is felt that the weight of the salmon

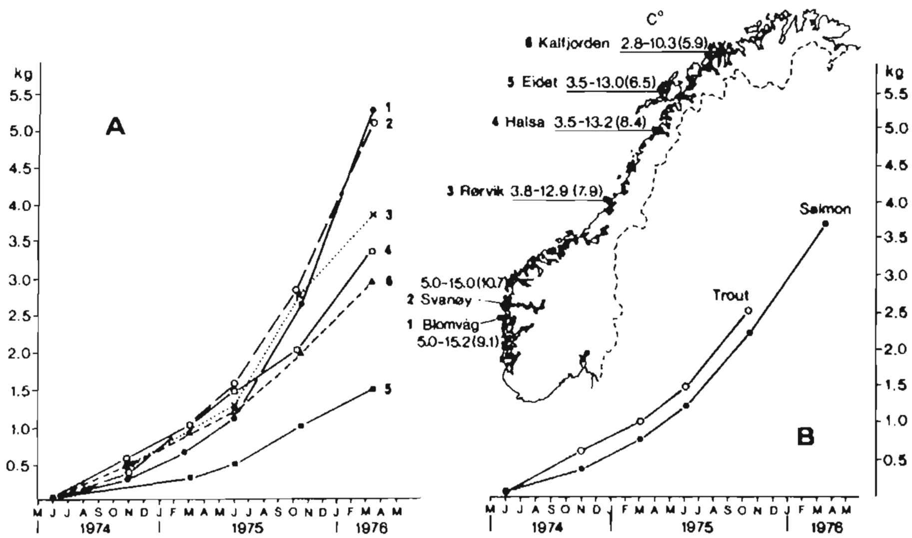

Fig. 13. Comparative growth rates of salmon and trout of different latitudes. A. Comparative growth of salmon. B. Farm location with monthly minimum, maximum and average yearly temperatures depicted. Growth data at farms rearing both salmon and rainbow trout have been pooled. Data from Møller et al. (1976).

will then exceed that of rainbows, one factor being the subsequent high percent maturation in trout. The European preference for salmon over trout, especially if they are larger, increasingly makes salmon culture more attractive simply because of market price. Specific growth rates for salmon during their first 6 mo show a 1.35% increase in wet weight per day; this falls to 0.47 during the comparable period of their second summer (0.75% overall for 21.5 mo). Some of the more northern farms harvest after the third summer at weights of 6-8 kg. Møller et al. (1976) stocked Swedish salmon of Baltic origin together with a stock of Norwegian salmon at the fish farms mentioned previously. The Norwegian fish grew consistently better than the Baltic fish.

Food conversion for these farms was also assessed and this ranged from 4-20 kg wet food per kg gain in fish (73% water content in food). The average for all six farms was 8 kg wet food per kg fish or 2.2 kg dry weight food per kg of fish. The typical composition of these wet diets is described in Table 1. Much of this variability among farms is directly attributed to food waste either from over-feeding or from the poor binding qualities of the wet feed.

The results of several studies in which the composition of the food is known, and where feeding has been done more carefully, are summarized in Table 1. Conversions between 1.5 and 2.0 can apparently be obtained regardless of the type of food.

9. Harvesting, Preparation and Marketing

Harvesting of salmon most often occurs during the spring. Some harvesting in the late fall, especially in northern Norway, provides Scandinavians with a traditional Christmas salmon. Rainbow trout are harvested in the fall after 18 mo in the sea. Market conditions, availability of wild salmon, and the percent expected sexual maturation in the stock can modify the above trend considerably.

Salmon are pursed together in the pen and are dip-netted by hand or Gilson boom into a holding tank where they asphyxiate or are anaesthetized with CO_2. If the farm is proximate to a processing plant, the pens are often towed to the wharf and fish removed. The fish are bled, gutted (roe sometimes saved for caviar), washed, weighed and iced down for fresh delivery to local or foreign markets. Salmon to be frozen are strung on racks by their tails or placed on trays, fast frozen in walk-in freezers and glazed with several layers of ice to prevent dehydration. They are then packaged for export, usually to Sweden, France, England, Denmark, W. Germany, Holland and Belgium. Salmon are most often frozen in the round.

Large salmon used for smoking are filleted, brined, and cold-smoked. Fillets are also marinated (grav laks) by soaking for a few days under refrigeration in a salt, sugar and dill marinade. Shelf life under refrigeration is of the order of 1 mo for the smoked and 2 wk for

Table 1. Growth and food conversion using wet and dry diets.

Species	Atlantic salmon					Rainbow trout	
Growth period (months)	23	9.1	9.1	16.0	21.5	16.5	7.4
Initial and final fish size (g)	74 4000	138 780	138 760	30 1700	30 3800	33 2000	70 333
Minimum and maximum yearly temperature (°C)	3 15	2.5 12.0	2.5 12.0	4.7 14.0	3.5 13.0	3.5 13.0	2.5 12.0
Specific growth rate (% wet weight/day)	0.58	0.63	0.62	0.84	0.75	0.83	0.70
Gross food conversion $\frac{\text{dry weight food fed}}{\Delta \text{ wet weight fish}}$	1.54	1.53	1.84	4.05	2.16	2.24	1.54
Type of food (homemade or commercial)	wet (HM)	dry (C)	wet (HM)	wet (HM)	wet (HM)	wet (HM)	dry (C)
Water content of food (%)	72	10	66	73	73	73	10
Composition) Fat	23	22	24	27	24	24	22
of dried) Carbohydrate	7	-	18	7	15	15	-
food (%)) Protein	61	45	45	55	49	49	45
Ash	9	-	13	11	12	12	-
Type of enclosure	natural impoundment	net pen	net pen	net pen	net pen	net pen	net pen
Farm location	Sotra	Holmane	Holmane	Hitra	Rørvik	Rørvik	Holmane
Reference (data recalculated)	Mowinckel & Kvalheim (1976)	Hallingstad (1976)		Møller et al. (1976)			Hallingstad (1976)

the marinated salmon. The traditional method of eating this raw produce is thinly sliced on dark bread smothered with sour cream. The parasitic round worm *Anisakis* is destroyed by good brining, marinating or freezing the salmon prior to consumption.

The trout marketing board (Ørret Omsettning) is the only true cooperative involved in marketing. Nothing comparable to this exists for salmon marketing. This group developed after the trout industry suffered severe price drops between 1972 and 1974, during which time many trout farms failed. They receive a commission on sales, set prices, determine distribution and exports, and set quality control levels for product acceptance.

Prices in 1977 paid to the fish farmer following harvesting and bleeding (15% wt loss) by the marketer or first level wholesaler were as follows (the Norwegian Kroner (NKr) is worth approximately $0.20 Canadian):

Rainbow trout		Atlantic salmon	
wt (kg)	Price/kg (NKr)	wt (kg)	Price/kg (NKr)
1-2	15	1-2	21.5
2-3	17	2-3	26.0
3-4	19	3-4	28.5
4-5	19.6	4-5	33.5
5+	20.5	5-7	35.0
		7+	37.0

There is always some degree of market instability, especially for salmon. For example, 1977 prices for the large salmon were especially high early in the season as farmers were trying to hold the fish until they grew to a larger size. When they did finally reach the market, it is felt that the high price on the larger smoked salmon alarmed the European market, and, unexpectedly, the price of smaller salmon increased while the price for larger salmon decreased. Other factors creating seasonal price fluctuations involve some degree of consumer switching between salmon and trout depending on which is freshly available and which is frozen throughout the seasonal production cycle. Also the commercial fishery for wild salmon has in the past influenced the marketing strategy for salmon; this is less of an economic factor for exported cultured salmon than it used to be.

There are relatively few marketing companies in Norway. Some of the large salmon farms do their own marketing, i.e., Mowi A/S, Bergen; Torrisen, Bødo; Grøntfelt, Hitra; Helgesen, Hitra. Their large production capacity permits marketing year round. Four other concerns involved in marketing salmonids are: Lerøy A/S, Bergen; Oslo Beef and Pork Central, Oslo; Kvalhiem and Co., Maløy; Ingebrigtsten, Trondheim.

Until recently, the only regulations governing product preparation of salmonids were those applicable to codfish. Recent regulations for salmonids dictate that:

1. Fish should be anaesthetized with CO_2.
2. They should be cut and allowed to swim the blood out in a tank of fresh water.
3. Gutting and filleting should be done on an aluminum or stainless steel table, but painted plywood is being temporarily accepted.

4. A freshwater capacity of 200 L/min is required for washing fish.

5. Only an authorized packing plant is allowed to pack for market. However, the qualifications are not hard to obtain if a few sanitary requirements are met.

6. Fish food ingredients and frozen salmon for market cannot be held in the same freezer. Plywood partitions have been used to get around this.

Quality control is being increasingly recognized as an important marketing factor and advances in degree of pigmentation, fat quality and quantity and external appearance can be expected.

10. Behaviour of Pen-reared Salmonids

The fish farmer is very attuned to the behaviour of his fish. Sudden changes in feeding behaviour, depth of swimming, swimming velocity and jumping frequency may be indicative of pathogenic, parasitic, nutritional or physiological complications. Such behaviour is recognized as a useful early-warning index.

Rainbow trout and salmon seem to behave quite differently in pens. Trout will "tolerate" quite deep enclosures of limited surface area while salmon prefer a large surface area to accommodate their innate "migratory tendencies." Trout are soon conditioned and approach workers for food, while salmon respond by swimming deeper, altering their circular swimming pattern into an ellipse to avoid the feeder. Trout feed in a mass frenzy with tails flapping at the surface breaking up floating food particles, while salmon are very "casual" in accepting food. Needless to say, feeding salmon requires more patience but the dividend is that food waste is probably less. Salmon, especially, spend the majority of time swimming in the same direction around the 12-m octagonal pen. The rotational direction (clockwise or counterclockwise) varies among different farms. At any one farm, however, the direction for any one stock does not change with tide, season, or age of fish. A conservative estimate of swimming velocity suggests that a 30-g smolt, reared and harvested 24 mo later at 5 kg, has probably swam in excess of 15,000 km. Whether this incessant swimming is related to some migratory tendency, is necessary for buoyancy or gill ventilation, or is an attempt at filter feeding or food search has not been determined. In any event, it must contribute to an appreciable portion of food ration. The jumping behaviour of salmon which resembles a lunge followed by a sliding belly flop may be associated with swimbladder filling or an attempt to dislodge sea lice.

11. Genetics

Salmonid selective breeding programs in Norway were started in 1971 by the Institute of Marine Research, Bergen, and shortly after by the Institute of Animal Breeding, Agriculture College of Norway, Ås. Attempts are made below to summarize research results from these institutes and relate them to the practical problems of the Norwegian fish farmer. Much of the information has been abstracted from published papers, research reports and by personal communication with scientists.

A. Sexual Maturity

As mentioned previously, it is customary to harvest salmon after about 2 yr in sea water. If a high percentage of fish are destined to mature at the end of their second summer as grilse, this will result in reduced growth and some mortalities during the following fall and winter; also, the larger the salmon, the better the market value. It is understandable then that attempts have been made to choose salmon stocks possessing late maturing characteristics. Naevdal et al. (1975) examined progeny obtained from parent fish collected in 12 Norwegian, 2 Canadian and 1 Swedish river. Salmon that are destined to mature as grilse do not exhibit reduced growth until their mid or late second summer in the sea. Stocks derived from predominantly grilse rivers tended to mature at the end of their second sea summer in floating pens, while stock from rivers producing large salmon did not mature at this time. Undetermined environmental factors perhaps associated with different fish farms, different environmental factors, or different early pre-smolt history can also be expected to have some influence on the age at first maturity. In many of the stocks examined, the fish maturing as grilse were predominantly male (Naevdal et al. 1976). The possibility of utilizing this natural variability in stocks of different rivers along with further selective breeding to postpone spawning appear promising.

Most of the stock of rainbow trout available in Norway is probably of USA-Danish origin and the degree of natural variation in available stocks is probably not as diverse as in salmon. As with the salmon, a higher percentage of male trout seem to mature first. Within different sib-groups, no relationship between growth (size) and age at first maturity was discernible; however, non-additive genetic factors could be important (Naevdal et al. 1975).

B. Growth

With growth as well as other traits, Naevdal et al. (1976) suggest it is initially more prosperous to use the natural variation in existing populations for selection work than to attempt to exploit the limited variability in any single population or stock.

It has been suggested that it would be an advantage in selective breeding to be able to choose those stocks of fish that showed high growth rates during early life and use these for rearing and as a source of brood fish. Despite the disadvantage of limiting selective effort to growth considerations alone, there is a very poor correlation between stocks concerning the relative size of smolts, their size after one sea summer, and their size after two sea summers in fish pens. Similarly, the variation in egg size among river stocks did not result in large eggs producing large, 1-yr-old parr. The sea age at first maturity has been related to the smolt age in hatchery-reared smolts released at sea. We know of no clear examples of this occurring in pen-reared salmon. Thus, the growth of a population of salmon in early life is of little value in predicting the size of specific stock at harvest. However, because the age at smoltification is influenced by pre-smolt growth, and is such an important economic determinant, selection for high pre-smolt growth rates should be strongly considered (Naevdal et al. 1975; Edwards 1976).

C. Domestication

The process of "domestication" involves the genetic selection of traits that will permit fish to live and grow under conditions that are convenient for the fish farmer. These novel conditions may involve crowding, artificial diets and other unusual types of stimuli. Apart from growth and survival, attempts are being made at Sunndalsøra to discover some independent methods of assessing the genetic gains achieved towards domestication (Gjedrum, personal communication). The fright response of "wild" fish to a knock on their tank is quite different from that of a group that has been under intensive culture for many generations. The response of "wild" fish consists of a staccato of nose knocks on the side of the tank that could be recorded by microphone, quantified and used as an index of the fish's excitability.

D. Disease resistance

A *Vibrio* epidemic during a genetics experiment conducted at Sunndalsøra provided the opportunity to measure the resistance of salmon from several river origins to this pathogen. Considerable differences in mortalities were observed among different strains (Gjedrum and Aulstad 1974). Environmental tolerance of different strains of sea trout to acid water may offer some hope in rehabilitating many of the sea trout rivers in southern Norway that are being rapidly destroyed by atmospheric pollution (Gjedrum 1976).

Other important commercial characteristics such as food conversion efficiency and flesh color and quality have not, to our knowledge, received much attention. Some experiments are being planned at NLH (Agricultural College of Norway) concerning selective breeding to obtain salmonids that can more efficiently utilize vegetable and other lower-priced protein sources.

In a breeding program for salmonids, a combination of phenotypic and family selection should be used. The degree of importance of the two selection methods depends on the heritability of the traits in question.

12. Sexual Maturation and Brood Stock Conditioning

Salmon that are destined to mature sexually the following winter will cease feeding by late summer and fall. Maturing fish will often exhibit aggressive behaviour. The proportion of these maturing fish is often predictable because of past experience with specific genetic stocks; however, other factors, such as size of fish and environmental conditions, can alter this percentage. Sexual maturity is not usually a serious problem until the end of the third summer in sea water. In a group of Mowi's smolts reared at eight different fish farms, an average of less than 2% matured at the end of the second summer as grilse and these were exclusively males. If an entire pen is to be harvested in late fall and if a high percentage of salmon in the pen should mature sexually, the fish farmer is faced with a dilemma. If he has not begun feeding pigmented feed early enough, the maturing fish will never develop good color because they do not feed. By delaying the harvest, he can put more weight and color in the non-maturing salmon, but the flesh quality of the maturing fish goes continually downhill until they are practically worthless. Even 10% maturation can have dire consequences on the farmer's economic outcome.

Obtaining viable eggs from domesticated rainbow trout stocks has never posed exceptional problems. However, the propensity of pen-reared salmon to develop viable eggs is another consideration. The early stages of salmon mariculture utilized wild fish as a source of eggs, and early attempts to use cage-reared salmon as brood stock met with variable and often unsatisfactory results. However, by ensuring sufficient pigmentation and using vitamin supplements in the feeding of potential brood stock, egg quality and hatchability has improved to the extent that many hatchery smolts used in mariculture are derived from second generation pen-reared parents. There is a general belief that shrimp wastes rather than carophyll red should be used in brood stock diets.

Both rainbow trout and salmon can be stripped directly after removal from salt water. Pen-reared salmon ripen considerably later than their wild counterparts that have entered fresh water. This is probably explained by the lag in falling temperatures in the sea. While wild salmon may spawn in October in fresh water, many pen-reared salmon are not ready until December or later. For hatcheries based on a 1+ year smolt production schedule, this delay in setting down eggs could limit the percentage of early smolts produced. Potential female spawners are distinguishable, usually by August, by protruding anal papilla and some hatcheries transfer them from salt water to the hatchery for conditioning with natural sources of fresh water, the temperature of which falls quite rapidly in the fall. Experimentation with gonadtropins is also in progress.

If salmon are not spawned but allowed to remain in salt water, they either drop eggs or resorb them. Reconditioning spent fish for food value is probably not economical as they do not start putting on weight again until early summer. However, if such fish possess desired genetic characteristics, they might be worth reconditioning for their seed value. Female repeat-spawners will often skip a year before maturing again. Males have a greater tendency to spawn in consecutive years. Following spawning, some salmon returning to salt water may die immediately, others may resume feeding within a month and survive, and some will lose weight and eventually perish. Post-spawning mortality is high in rainbow trout especially if they are kept in salt water.

The stocks of rainbow trout available in Norway are spring spawners. They spawn in unheated outside ponds in April and May. In hatcheries with warmer water, rainbows are spawned in February. Thus, the production schedule for rainbows is at least 3 mo behind Atlantic salmon. With accelerated rearing, however, rainbows are usually ready for sea water the next fall, while salmon require another 7 mo of freshwater rearing.

13. Alternate Salmonid Species and Hybrids

Sea trout (*Salmo trutta*)

Hatchery-reared sea trout seem to have much in common with salmon concerning growth rate and age and size at smoltification, but performance in ocean pens is not as good as salmon or rainbow trout (Gjedrum, personal communication).

Arctic char (*Salvelinus alpinus*)

Landlocked, stationary and anadromous populations of char exist throughout Norway (Nordeng 1961). The integrity of many of the stocks is questionable because the early Lapps apparently transported stocks to different places. The anadromous char first enter "sea water" during the summer at a size of 50-150 g, spend only a period of 3-5 wk in the sea and return to the river. These summer migrations to fjord waters include immature individuals as well as those destined to mature after their ascent in the fall (Nordeng 1971). Sexual maturity in individuals often occurs in alternate years.

Experimental Arctic char rearing is being conducted at Sunndalsøra (NLH), Matredal (Institute of Marine Research) and Skjømen (University of Tromsø). Considerable variability in survival during early rearing has been observed, the critical stage being swim-up and feeding. Hatching temperatures below 7°C have been recommended but all parties are not entirely in agreement on this. Subsequent growth rates in "cool" fresh water (3-12°C) are very good, perhaps exceeded only by pink and chum salmon.

Culture of Arctic char in brackish and salt water is hampered by many of the same problems that limit the suitability of North American brook trout for marine culture. Smoltification, silvering, and an increase in salinity tolerance are not clearly delineated in time and are in part inducible. Char have to be quite large to tolerate a direct transfer to sea water and overwintering success in the sea appears to be limited by fish size, sea temperatures and the onset of sexual maturity. Male char introduced to sea water in the spring as 1+ "smolts" (100-200 g) will probably exhibit up to 25% sexual maturation by winter (Østhus 1974, 1976). Unexplained fall and winter mortalities in sea pens have been observed in stocks of two different parental backgrounds (Gjedrum 1975). A northern farm near Hammerfest (Simo Havlaks A/L) has reported to have obtained good survival and low percentage maturation by introducing 25-g char "smolts" into sea water and rearing them for two winters; however, the growth rates in the sea were not impressive relative to Atlantic salmon (Anderson 1976).

The special suitability of char for fresh water vs. salt water culture, as pan-sized vs. steak-sized, for warm water vs. cold water remains to be established. Much of the available information is contradictory as a result of different stocks being used in different environments.

Pink salmon (*Oncorhynchus gorbuscha*)

Hatcheries at Sunndalsøra and Matredal have been experimentally rearing pink salmon for the last 3 yr. At Sunndalsøra, fish are stripped in early October and have reached 400 g by the following October. Some pinks, held in sea pens at Averøy, did not perish until several months after stripping (Arne Kittelsen, personal communication).

Pink salmon (approximately 10 g) were distributed from Matredal hatchery to several fish farms in the spring of 1976. In some instances, high mortalities due to vibriosis appeared directly after transport. After 1 yr in the sea, their weight varied from 600-900 g among the various farms.

Experiments using various temperatures and salinities during hatching and early rearing of pink salmon have been conducted at Matredal (Ingebrigtsen 1975; Gjerde 1965).

Interspecific hybrids

At Sunndalsøra, hatchery growth rates of several salmonid species and their hybrids have been compared (Refstie and Gjedrum 1975). All possible crosses between Arctic char, brown trout, sea trout, and Atlantic salmon were attempted. Char grew faster in fresh water than salmon, sea trout, and brown trout. Female salmon x male char hybrids were nearly twice as large as char and three times larger than salmon after 11 mo rearing. Any viable hybrid in which char served as a parent resulted in improved growth over the straight parental cross. The salmon x sea trout and reciprocal hybrids showed good survival but no obvious growth advantage over their parents. From Swedish and Irish results, it is doubtful that they will exceed salmon in marine growth. An interesting cross completed recently between pink females x char males requires further study.

Although the suitability of the salmon x char hybrid appears promising, its long-term growth performance in salt water is said to be inferior to salmon (T. Gjedrum and P. D. Iversen, personal communication).

More work is planned in Norway to assess the suitability of these hybrids for marine culture with special emphasis on age at smoltification, salinity tolerance, marine growth rates, age at first maturity, and the characteristics of F_2 and backcrossed generations.

14. Diseases, Parasites and Predators

Diagnosis and disease certification, necessary for importing or moving eggs or fish, is the responsibility of the Veterinarian Directorate centered at the Veterinarian Institute, Box 8156, Oslo. This Directorate is within the Department of Agriculture. Other institutes involved in disease research include Veterinary College, Oslo; Institute of Marine Research, Bergen; University of Tromsø, Tromsø.

Freshwater hatchery diseases include the customary *Costia* and fin rot. The prevalence of other diseases encountered in fresh and salt water is as follows:

Vibriosis is a common problem in saltwater rearing and has been responsible for large losses in marine farms and in some hatcheries attempting to rear parr in brackish water. Presmolts are not usually immunized against *Vibrio*. Most outbreaks in marine farms occur just after transport to the farm or in September and October; a 10% loss of post-smolts during the first summer is not uncommon. Rainbow trout appear more susceptible to *Vibrio* than salmon and are more difficult to treat. Prevention of abrasion of the skin and protective mucus by proper mesh size and net construction and provision for ample swimming space can reduce losses significantly. Transferring or handling bright salmon should only be done during the winter months. A large dip-net lined with a split skin (chamois) reduces the risk of skin abrasion, split fins, scale loss, blindness and secondary infections. It had been presumed that the large aggregations of infected saithe (*Pollachius virens*) associated with fish farms are acting as a reservoir for *Vibrio*. Out of the 78 strains of *Vibrio anguillarum* associated with outbreaks at salmonid farms, 90% belong to group I (arabinose +), while the saithe outside the fish pens are infected with type II (arabinose -), indicating that infections may not be transferred in such a manner. In fact, instances of mass mortalities of saithe outside pens have not resulted in outbreaks in salmon within pens (Hastein and Smith 1977; Egidius and Johannessen 1974; Andersen and Egidius 1977).

Furunculosis was first diagnosed in Norway in 1964 and has been responsible for periodic outbreaks in salmon and trout ever since. The disease is recognized as occurring in two forms: an acute form with heavy mortalities and a subacute form apparent by the formation of furuncles (Hold and Hastein 1970). It has occurred under freshwater and marine conditions.

VHS: Viral hemorrhagic septicemia was first identified in 1968 as occurring in rainbow trout cultured in both fresh- and saltwater farms (Hastein et al. 1968). The disease was believed to have arrived from fish imported from Denmark in 1966.

IPN: Infectious pancreatic necrosis was first detected in 1975 during a routine inspection of brood stock at a fish farm requesting certification for exporting eggs. The rainbow trout were destroyed and the origin of the disease could not be determined (Hastein and Krogsrug 1976). In the fall of 1977, another outbreak at a large hatchery resulted in all stocks being destroyed.

LLD: Lipoid liver degeneration, a nutritional problem, was detected in 1974 in a saltwater farm. Atlantic salmon seemed to be affected more than rainbow trout. The disease was believed to be caused by rancid food ingredients. Additions of ethoxyquin to retard spoilage, along with vitamin E supplements, were recommended (Roald 1976). Liver degeneration has also been observed at some marine farms, resulting in high mortalities.

Acute septicemia (pasteurella-like organism) has been responsible for periodic outbreaks at a single farm since 1969. Mortalities were highest during the summer months in Atlantic salmon parr and smolts. The disease was transferred to other marine farms with transported smolts. Thirty-six different isolates were identified (Hastein and Bullock 1976).

Whirling disease was first identified in Norway in 1970 at several freshwater farms near Oslo. The stocks were destroyed and the ponds disinfected.

UDN: Ulcerative dermal necrosis, although not apparent in Norwegian hatcheries, is a serious threat to many Swedish hatcheries. Authorities are concerned that the disease might be introduced to Norway as some Norwegian marine farmers are still purchasing smolts from Sweden.

Parasites: The parasitic copepod (*Lepeophtheirus salmonis*) has been responsible for heavy mortalities in some farms causing erosions of the skin and dorsal muscle in the head region. Bathing the fish in a formalin or an organophosphate solution is an effective but not a very practical method of control. Oral administration of trichlorfon (Neguron-Bayer) appears effective and practical but because of its toxicity to the fish (blindness) the effective dose is difficult to administer (Egidius and Johannesen 1974; Brandal and Egidius 1977).

An interesting condition referred to as "cold death" has been observed during the winter in some northern marine farms rearing rainbow trout. At temperatures of 0-2°C, mass mortalities have occurred during feeding time; the fish go into a type of paralysis immediately after taking food floating on the surface. The condition is probably neurogenic in origin as there is no ice formation in the tissue of the fish. This condition does not occur in salmon reared in adjacent pens.

A second undiagnosed problem in rainbow trout has occurred repeatedly in one hatchery and involves a disturbance in buoyancy and/or equilibrium. The exposed dorsal surface of the floating fish is then subject to secondary infections.

Predators: Predation in fish pens by other fish species, birds, and mammals is most serious during the first sea-year when the cultured fish are small. Losses due to predation are difficult to detect and cause special problems in inventory. Diseased fish usually sink to the bottom and can at least be accounted for, while many predators simply remove fish and leave little or no evidence. The magnitude of the problem is sometimes only realized when the fish are counted during transfer from one pen to another during net changing or during the final harvest for marketing. Adding the mortality records to the harvest figures and comparing this to the number of fish stocked can sometimes be a disheartening experience.

In addition to cannibalism, which can often be remedied by grading, the only serious fish predator is the fjord cod commonly associated with pollock that spend much time scavenging waste food beneath the pens. Dead salmon or trout sink to the bottom of the net where cod attempt to eat them through the netting. Quite sizeable holes can be chewed in the netting resulting in further losses. Early removal of dead fish and frequent inspection for holes are recommended.

Predation by birds can occur at the surface as well as through the walls of submerged netting. Surface predators include cormorants, gulls, terns, and herons all of which are capable of taking smolts and post-smolts. A criss-crossing of lines or attachment of gill netting over the guard rails of the pens is usually sufficient to discourage these birds. Dead birds with broken wings or necks are commonly observed hanging from these nets or floating in the pen. A gull or heron strung from its foot is proported to be effective in scaring off birds. Control of bird predators in large impoundments is more difficult, air cannons and other noise devices being effective for only a short time. Mowi A/S has employed a full-time person armed with a shotgun to control bird predators; in addition a bounty has been placed on herons shot on the premises. Diving cormorants outside the pen netting are capable of injuring fish through the netting (Hanssen et al. 1976). In northern localities where this is a particular problem, a second protective netting may be hung outside the pen.

Mink, which are widespread in Norway, prefer small fish and nearly every farmer at one time or another has suffered losses. Mink are especially voracious, killing more fish than is required for food. They are nearly impossible to keep from climbing over the top of the netting, and baited traps proved the best method of control.

Otters are more shy than mink and more easily frightened away if there is continual human activity at a farm. Otter are one of the few predators known to take large fish, and instances of 4-kg fish being removed from fish pens have been attributed to otter. Nervousness, loss of appetite, and skin abrasions in fish have been credited to continual visits by mink and otter.

In freshwater hatcheries and smolt farms, both mink and the domestic cat have gained access to buildings and tanks resulting in losses of fish. Mink and cats have been responsible for tearing open feed bags.

Very few instances of problems with seals are reported, even though they are commonly sighted in the vicinity of the fish farms and, on occasion, sunning themselves on the pen walkways. Before a seal can be shot, it must be demonstrated that it was responsible for some damage at a farm.

Predation by humans (thievery and vandalism) is considered much less a problem. Because most farms are located in small rural areas, general public accountability seems to discourage law breakers. Some of the larger farms, however, build booms around cages, limit access to ramp ways by fences, hire nightwatchmen or keep guard dogs. Such security measures also serve to keep curious passers-by from scaring fish or doing unintentional damage to facilities.

15. Licensing, Administration and Regulations

A translation of the application form for a salmonid rearing license can be found in Appendix I. Potential fish farmers may request assistance from the local government fisheries consultant in filling out the application. After crossing the desk of the local consultants, the applications are forwarded to Bergen where they are processed by a licensing evaluation committee. Considerable attention is focused on site suitability, possible hindrances to navigation, the effects of pollutants on the fish farm, and the fish farm itself as a pollution source. Because of the increase in applications in recent years, it may take approximately 1 yr after submission to be granted a license. Although illegal, it is not uncommon for fish to be ordered and construction to be completed before a license is received. A processing fee is not required nor is there a charge for a license.

Licensing does not entail a site visit by the review committee as the local fisheries consultant is usually familiar with the proposed location and can comment on any potential conflicts. There has been very little attempt to limit the numbers of licenses issued. In one instance, the number of farms operating on an island was intentionally limited in hopes of reducing the high losses due to sea lice on existing farms. The operating license does, however, limit the rearing volume of the farm, with a present upper limit of 8,000 m^3 in the enclosed rearing water. This limit is felt to protect small farmers from monopolistic takeovers. Also, many new farmers entering the business are restricted to considerably less than the 8,000 m^3 for their own protection until they gain experience. In reality, it is probably lack of smolts that limits the number of operators today, rather than any planned program of limited entry for market considerations.

Two sources are available for financial assistance to prospective fish farmers. A "Rural Development Fund" provides low interest loans to private individuals for fish farming to encourage employment, secondary processing of local resources, and the retention of young people in rural communities. A license, however, has to be in hand before applications for financial assistance can proceed. The Agricultural Bank of Norway provides similar assistance for fish farmers providing the applicant can demonstrate that he is or has been a land-based farmer. At present, the Federal Fisheries Directorate in Bergen is temporarily responsible for the licensing and administration of the salmonid farming industry. There is some controversy, as yet to be resolved, between the Departments of Fisheries and Agriculture concerning jurisdiction. Because of this uncertainty, both departments have been hesitant to establish a permanent administrative framework directed toward the industry.

16. Extension Work, Education and Publications

Traditionally, regional fisheries leaders (consultants) have interfaced with the general fishing industry and have provided much of the extension information concerning recent developments in research, technology, and management decisions. Although fish farming is a relatively new endeavour, and many of these consultants are not specifically trained as yet in this field, it is anticipated that government extension services to fish farmers will probably develop along similar lines. Workshops among these regional consultants, federal administrators and researchers have been conducted for the purpose of improving extension capabilities. A number of publications and reports, concerning freshwater and marine production of salmonids, are available free upon request by the fishermen. Many of these are listed in the bibliography.

The Norwegian Fish Farmers' Association publishes quarterly, the "Norwegian Fish Farmer." The Association's office address is Rosenkrantzgt 8, Oslo, and the editorial address for the magazine is: Olav Hanssen, Postboks 185-186, 5001 Bergen. Subscription costs are about $12/yr. The magazine's format, along with other hand-out fact sheets, includes new research findings by government and university programs in layman's terms, seasonally available fish food ingredients and their prices, information on marketing, translations of pertinent research findings abroad, along with a variety of new strategies and technologies being attempted at different farms. Published interviews with fish farmers commonly appear. Companies selling traditional fishing gear, and a large number of specialized firms producing equipment and supplies for fish farming advertize through the association and its magazine.

In addition to the above National Fish Farmers' Association, several local associations have appeared during the last year which have provided a more personal forum in which farmers can help each other with technical and marketing problems.

Formal education in fish farming occurs at three different levels in Norway:

1. Training courses in hatchery and marine farming techniques as part of government extension programs to local fishermen and hatchery personnel at: Fisheries Directorate, Fish and Research Experimental Hatchery, Matredal; Agricultural Department, Sunndalsøra Experimental Hatchery, Sunndalsøra; Workshops among regional fisheries consultants, federal researchers and private growers.

2. Short, 6-wk courses dealing with the practical aspects of aquaculture at regional fisheries and agricultural colleges located at: Bodø; Gjarmudnes; Austervoll.

3. Intensive practical and theoretical courses at the university level: Agricultural University, (NLH) Ås; Fisheries Science Curriculum, Univ. of Tromsø; Fisheries University, Bergen; Fisheries University, Trondheim.

Some of the present research programs concerning aquaculture can be found under the institute's heading in Part 3 of this report.

17. Economics

Although a section on theoretical economics is usually included in Norwegian university courses on salmonid farming, there are, in fact, very few in-depth studies of economic factors operative in existing fish farms. The most intensive treatment seems to have been performed by the Fisheries Directorate between 1974 and 1976 (Leidolv Berg, unpublished; Berg 1976). Economic data were obtained from questionnaires returned from 52 farms having over 1-ton yearly production capacity. Supplementary information was obtained by telephone and site visits by the above author. The profitability indices for 52 marine farms are summarized in Table 2.

TABLE 2: Summary of profitability indexes of 52 farms (from L. Berg, unpub.

	Total	Per kg	In %
1) Fish produced, in kg:	1,798,000 kg		
2) Total man-hours	262,000 hr	0.15	
3) Production revenue[1]:	Kr.33,188,000	18.46	100.0
4) - Variable costs[2]	Kr.12,890,000	7.16	38.8
5) = Coverage allowance	Kr.20,298,000	11.30	61.2
6) Coverage ratio	61.2%		
7) - Fixed Costs[3]	7,871,000	4.38	23.7
71 Indirect operating costs	2,581,500	1.44	7.8
72 Calculated interests	3,382,500	1.88	10.2
73 Calculated depreciations	1,907,000	1.06	5.7
8) = Working profits	12,427,000	6.92	37.5
9) Initial investments, total	18,010,000	10.01	36.8
10) + Stocks of goods			
11) + Diverse current assets	30,849,000	17.16	63.2
12) = Investments, total . . .	48,859,000	27.17	100.0
13) Index numbers:			
131 Yield ratio of investment at 30 Kr per hour wage	16.3%		
132 Wage capacity per hour	Kr. 47.42		
133 Investment per man-year	Kr. 372,000		
134 Investment per kg produced	Kr. 27.17		
135 Production in kg per man-year	13,725 kg		

[1] 14 kr/kg rainbow trout (1974)
24 kr/kg Atlantic salmon (1974); $1C = 5.2 - 5.6 N. Kr., 1974-1976

See section 11 for more current prices.

[2] Feed 78%
Smolts or eggs 10%
Delivery and other variable costs 12%

[3] 10%/yr earth or concrete ponds
25% floating fish pens
4% buildings
10% boats, automobiles, machines

Although the wage capacity at 23.7 kr/h is lower for small farms, it exceeds other industrial wages in agriculture and mining (Table 3). The greater profitability of the larger enterprises can be attributed to the fact that they are growing mainly salmon that receive 10 kr more per kg than rainbow trout; also, the larger farms have a lower variable cost per kg. The production costs per kg (total variable + fixed costs) were not significantly different between large and small farms. More than any other factor, the production per man-year accounts for the better performance of the larger farms (Table 3).

Table 3: Profitability of large vs. small-scale operations.

	Production per enterprise	
	Over 15,000 kg	Below 15,000 kg
Coverage ratio	62.1%	52.0
Yield ratio	17.8%	0.07
Wage Capacity per hour	52.95 kr.	23.7
Initial investment per man-year	165,654.00 kr.	61,850.0
Initial investment per plant, average	716,348.00 kr.	52,896.00
Production in kg per man-year	16,212 kg.	7,488
Production in kg per plant, average	70,104 kg.	6,543

Larger farms are often vertically integrated, in that they may operate or have controlling interests in fish processing plants, freshwater hatcheries for smolt production as well as the marine production phase. These combined plants show a profitability much higher than the single production facility measured by both wage capacity and yield ratio (Table 4).

Table 4: Plant diversity and profitability.

	Combined plants	Plants with single Production facility
Coverage ratio	65.7%	52.1
Yield ratio	21.1%	8.1
Wage capacity per hour	66.11 kr	31.76
Total investment per man-year	511,000 kr	259,400
Initial investment per man-year	205,830 kr	76,030
Total investment per kg	31.83 kg	20.49
Production per man-year	16,000 kg	12,662

In addition to specializing in salmon, there is probably an element of experience and advanced technology involved in the better performance of the combined plants.

A comparison of salmon and rainbow trout at a single production facility shows that, with the 10 kr/kg price advantage, the yield ratio is in favour of the salmon despite its higher fixed cost and lower production per man-year (Table 5). This lower production efficiency of salmon is partially explained by the fact that salmon stocking densities to produce a kg of fish are much lower than for trout.

TABLE 5: Comparison of profits between salmon and rainbow trout farms.

		Salmon	Rainbow Trout
1.	Sale price per kg	24.00 Kr	14.00
2.	Production cost per kg	13.50 Kr	11.05
3.	Coverage ratio	69%	50
4.	Yield ratio	52%	25
5.	Wage capacity per hour	158.33 Kr	73.30
6.	Investment per man-year	567,800 Kr	489,000
7.	Investment per kg produced	23.23 Kr	16.70
8.	Production per man-year	24,400 Kg	29,300
9.	Production per m^3 water volume	4.40 Kg	8.8
10.	Capacity use	88%	88

Further examination of the 52 farms revealed that the wide disparity in the food factor (conversions from 4-9) surprisingly did not alter the wage capacity greatly. This might result from either sacrificing some degree of waste for reduced labor costs necessary for careful feeding, and/or marginally better growth rates on excess rations. The significance of labor productivity was found to be more important than the feed factor. A doubling of production per man-year from 10 to 20 metric tons (m.t.) increased the wage capacity three times. Comparable growth rates and stocking density as affecting economic outcome were not fully evaluated.

It would appear that salmon farming in Norway is still quite labor intensive and, because it is doubtful that workers will or should be expected to receive less wages, increased profitability might be achieved by automation and vertical integration of existing plants. Unfortunately, this leads to a variety of social dilemmas which aquaculture was envisioned to solve, namely, traditional life styles, unemployment, worker incentive, rural development, and decentralization. It is doubtful that the Norwegians will sacrifice these factors in the near future regardless of short- or long-term trends revealed by the economists.

Bjørnerem (1974) has carried out a case study in budget development and cost accounting for a Norwegian fish farm. The example chosen by Bjørnerem was a saltwater rainbow trout farm, owned and operated by the same person. Rearing units consisted of 12- to 13-m octagonal fish pens of 130 m^2 (400 m^3) stocked at a harvest density of 30-35 kg/m^2 (11-12 kg/m^3). Total harvest was set at 12 m.t. annually, based on a 18-mo production cycle. Additional assumptions are that: 1. wet food is made at the farm; 2. treatment and washing of net cages are done on site; 3. a work-year of 2000 h; 4. accessibility to a nearby freezer plant; 5. investments in road, dock, or waterside buildings not required. Temporal aspects of this prediction strategy are shown in Fig. 14 and a financial statement for the first 6 yr in Table 6.

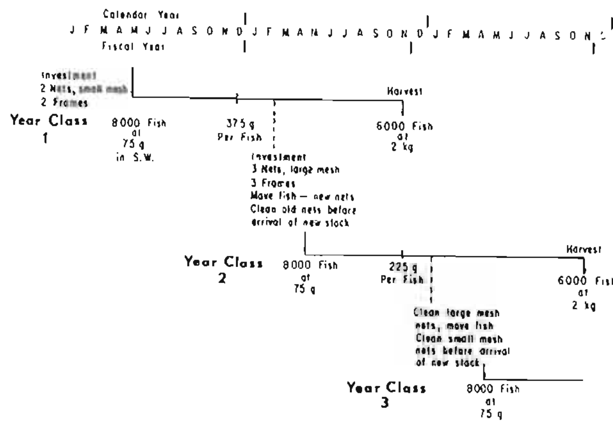

Fig. 14. An 18-mo production strategy for rainbow trout.

Investment in the Rearing Plant

How much then must be invested to get the operation off the ground? Given a yearly production of 12,000 kg, the number of frames of 130 m^2 area can be calculated: $(12{,}000 \div 32.5) \div 130 = 2.85$. Three frames are needed. If the fish double their weight the last 6 mo before harvest, only 2 frames are necessary the first 12 mo. In the second year, as production is continued, further investment in 3 more frames is necessary: 2 for new stock and 1 for thinning the previous stock. New net cages of larger mesh, which cost less, are needed for the now larger first-year stock.

Investment is also necessary for moorings, a grinder, electrical services, and a boat for feeding fish and servicing the nets.

TABLE 6: A summary of a proposed operational budget for the farms first 6 yr (Bjørnerem 1974) - Exchange rate in 1974 $1C = 5.6 N. Kr.$1 US = 5.4 N. Kr

		Year 1 1/5-30/12	Year 2 1/1-31/10	Year 2-3 1/11-31/10	Year 3-4 1/11-31/10	Year 4-5 1/11-31/10	Year 5-6 1/11-31/10
Input							
Cash Sale				144,000	144,000	144,000	144,000
Output (Operational Budget)							
Fish		9600	9600	9600	9600	9600	9600
Freight		1000	1000	1000	1000	1000	1000
Food		8600	36700	41000	41000	41000	41000
Wages (hired)		1000	5000	5000	5000	5000	5000
Cost of Living Allowance		18000	20000	24000	24000	24000	24000
Taxes		--	15000	20000	20000	20000	20000
Net Treatment		1200	3000	3000	3000	3000	3000
Misc.		2700	3000	3600	3600	3600	3600
Loan Interest		1400	12000	10800	9600	8400	7200
		43500	105300	118000	116800	115600	114400
Liquid Assets		50000	3400	-	10000	212000	336000
+ input				144000	144000	144000	144000
- output		43500	105300	118000	116800	115600	114400
Available assets		6500	-109900	26000	37200	49600	63200
Payment of debt		2500	16000	16000	16000	16000	16000
Necessary Investment	A	4000	-117900	10000	21200	33600	47200
	B	25600	18600				14200
B - A		-21600	-136500	10000	21200	33600	33000
Loan Required		25000	136500				
		3400					

Thus:

1st year's investment	
2 cage frames	6,400
2 net cages	4,200
moorings	2,000
boat with outboard	2,000
grinder	6,000
electric hookup	2,000
13% investment tax	3,000
	25,600 N.kr. ($5,120.00)

2nd year's investment	
3 cage frames	9,600
3 net cages	5,400
moorings	1,500
13% investment tax	2,100
	18,600 N.kr. ($3,720.00)

Smolts

For an 18-mo saltwater production strategy, rainbow smolts are placed in seawater pens in April-May and harvested October-November, the following year (Fig. 14). The number of smolts necessary to harvest 12,000 kg is dependent on growth capabilities and mortality rate. With a loss through the production period of 25%, a market weight of 2.0 kg per fish and a smolt size of 75 g, 8,000 smolts are required. This yields 600 kg at a selling price of 16 kr/kg or kr 9,600 ($1,920.00). Smolts must be purchased each year.

Food

Food costs are dependent on food factor and price. In practical application, food factor includes food waste and indirect food losses because of mortalities.

At a cost of 0.60 kr/kg wet food, a food factor of six and an assumed five-fold increase in weight by the end of December, the food cost for the first year can be calculated:

(0.375 kg - 0.075 kg) 8000·0.60(6) = kr 8640 ($1,728.00)

After the initial year, food must be calculated for 2 year-classes. The budget for the second year (Table 6) extends from November to October 31, permitting the fiscal year to terminate with the sale of fish. Food costs for the second year can be calculated as such: new stock (0.225 kg - 0.075 kg) 8000 · 3.60 = 4300 kr ($860.00) plus old stock (2.0 kg - 0.225 kg) 8000 · 3.60 = 36700 kr ($7,340.00).

Salaries

Even though the operation is planned as a one-man operation, there are some jobs such as harvest and net changing which require additional manpower. Also, after the first year, temporary help is hired while the owner takes a vacation. Some capital is needed for private necessities, here set at 2000 kr ($400.00) per month.

Net Changing

The nets are treated against fouling twice a year at a cost of 300 kr ($60.00) per net (Fig. 14).

Miscellaneous

This includes electricity, administrative costs, rent, taxes, travel and insurance. After investigating similar size farms, Bjørnerem sets this at approximately 300 kr ($60.00) per month.

Loans and Interest Payments

After a personal investment of 50,000 kr ($10,000.00), 25,000 kr ($5,000.00) is borrowed in the first year and 136,500 kr ($27,300.00) the second year, at 7.5% interest over 10 yr. In the first year (9 mo), interest is therefore: (9÷12) 1225,000 x 0.075 = 1,400 kr ($280.00) plus a payment of 2,500 ($500.00).

In the second year, taxes begin. In this case, 20,000 kr ($4,000.00) is paid in four installments, three of these before product sales date in the second fiscal year.

Depreciation

Replacement of frames, nets and mooring equipment is necessary after 5 yr. The useful life of boat, grinder and electrical hook-up is approximately 10 yr.

Variables and Profitability

Based on total sales of 144,000 kr ($28,800.00) for each year-class, with production costs for this year-class at 85,600 kr, and 40,000 kr retained as wages for the owner-operator, the farm operates at a surplus of 17,400 kr (Fig. 15). Growth rate, mortality, sale price, and food cost are the most important factors affecting profitability. Although all three can be changing at the same time during production, it is important that the farmer appreciate how each factor can singularly affect his profits. One method is to determine the necessary magnitude of the variable to reduce his cash surplus to zero. For example, what final weight (w) of fish must be harvested to reach a "break even" point given, at a sale price of 12 kr/kg, food costs at 3.60 kr/kg ($0.72) fish growth, fixed costs at 85,600 kr ($17,000.00), and 75% survival from the initial 8,000 smolts.

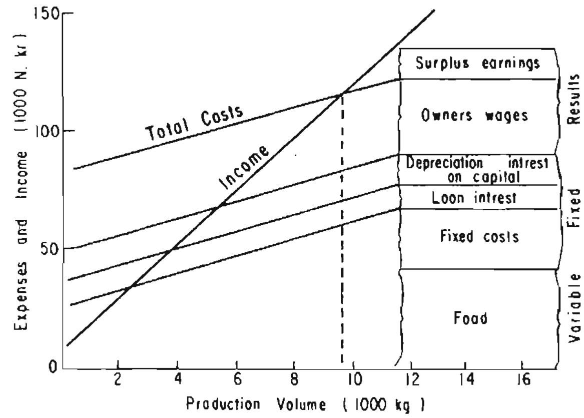

Fig. 15. Farm production affecting yearly costs and income; based on an 18-mo rearing schedule for rainbow trout.

$$12w = 85,600 \div 3.60\ (w-600) \qquad w = 9933\ \text{kg}$$

This means that each of the surviving smolts must grow from 75 g to at least 1.65 kg by harvest time. It may be useful for the farmer to periodically plot the growth rate of his fish for reference other years.

Starting with 8,000 smolts that grow from 75 g to 2 kg, what is the percent mortality (M) before his surplus is reduced to zero, other conditions remaining constant?

$$8000\ (1-\frac{M}{100}) = \frac{9933}{2} \qquad M=38\%$$

A complication exists in the above calculation because as the mortality factor increases, the food used to feed the fish prior to death has not been included. If, for example, the apparent food factor, due to mortality, increases from 6 to 7, what production volume (w) would be necessary to break even?

$$12w = 85699 + \frac{7}{6}(3.60)\ (w-600) \quad w=10651\ \text{kg}$$

The true mortality that corresponds to this production is:

$$8000\ (1-\frac{M}{100}) = \frac{10651}{2} \qquad M=33\%$$

Needless to say, if the farmer has kept good records of the time period and size of dead fish removed from the pens, a more sophisticated equation may be developed for predicting potential profit margins. The biological factors, such as growth rates, food factor and survival, often require several years of production at the same plant by the same operator before they become predictive.

A second example presented by Bjørnerem (1974) considers a rainbow trout farm based on a 7-mo production schedule. Stocking of 200-g trout takes place in April-May and harvesting occurs in October-November of the same year. Average harvest weight is 1 kg and mortality after 6 mo of rearing is set at 10%. The price of the smaller trout is assumed to be 10 kr/kg ($2.00). Four pens are necessary to produce the 15 tons that a single operator can manage. Yearly costs for this operation amount to 121,190 kr ($24,000) with 150,000 kr ($30,000) received from the sale of fish. For the 7-mo work the owner might expect approximately 23,300 kr ($4,600) in wages, resulting in a surplus of 4,800 kr. This is considerably lower than a plant based on year-round production because of high smolt costs to market price ratio.

18. Sea Ranching as an Alternative

A. Atlantic salmon

Salmon and sea trout enhancement programs in Norway, unlike many other countries, have consisted of planting fry and underyearlings rather than smolts. One reason for this is that many of the upper stretches of the precipitous Norwegian rivers have suitable rearing areas but are not accessible to spawning adults. The cost of providing fish-pass facilities in these numerous but inaccessible areas would be more costly than the present stocking. Secondly, damage from the intensive hydroelectric development in Norway is probably less severe than in other countries because water is stored at high elevations and upstream power plants operate on the low flow-high pressure principle. Thus the lower, more productive stretches of rivers are provided with some degree of flood control and by-pass facilities are not required for adults. Power companies are responsible for stocking smolts in instances where the plant is downstream and water is diverted from rearing areas. In addition, local community and angling organizations operate small fry production hatcheries throughout the country.

Returns from wild and hatchery-reared salmon smolts in Norway are difficult to assess in that there are at least four fisheries concerned: high seas international (longline), inshore (drift-nets) and fjord (bag-nets, gill-nets, bend-nets), and angling within the river. In addition, large-scale smolt plantings with counting-fence assessment have not been conducted. Returns by wild salmon to inshore fishermen and anglers within the rivers make up about 8-12% of tagged smolts released (Heggebert and Rosseland, personal communication). Most of Norway is devoid of warm ground-water sources and, except in the southern part of the country where solar heating of river and lake water provides some marginal conditions for smolt production, producing smolts on a large scale has not been practical until recently. With the advent of the newer types of hydroelectric plants and prior planning to ensure their compatibility with salmon-rearing installations, large sources of warm fresh water will increasingly be available for smolt rearing. In addition, waste heat from various industries might also be used. The possibility of passing river water through a heat exchanger in warmer fjords to use in the hatching and rearing of pink and Atlantic salmon has been examined in a pilot project at the Sjomen Field Station, University of Tromsø. With the current supply of salmon smolts insufficient to meet the demand of marine fish farmers and with smolt prices approaching $1.50 apiece, it is doubtful that they will be released in larger quantities in the near future, with the low returns of hatchery smolts to date.

The possibility of ranching Atlantic salmon on a more intensive basis has not been dismissed altogether. Results in the early sixties by Magnus Berg (personal communication), employing the technique of 6-mo to 1-yr saltwater rearing of smolts prior to release, obtained 10-14% returns. Using early saltwater rearing and delayed release to increase oceanic survival and influence migration patterns is at present being examined at the hatcheries in Matre, Sunndalsøra and Fjon (D. Møller and Leiv Rosseland, personal communication).

B. Pink salmon (*Oncorhynchus gorbuscha*)

Between 1956 and 1975, the Russians released 154 million pink and chum salmon fry into rivers in the Murmansk and White Sea areas. Pink salmon were recovered in the summer of 1960 in the Barents Sea, White Sea, and the N.E. Atlantic from Scotland and Bergen to Iceland. In northern Norway, the catch of pinks was estimated to be about 100 tons between 1971 and 1975, mostly obtained in mixed catches of salmon and sea trout. They were observed in salmon rivers 300 km from the sea. They averaged 1.5-2.0 kg in size (Berg 1961; Bjerknes 1977). Runs have occurred every other year, starting in 1971, and spawning and emerging fry have been observed in some rivers. Adults enter rivers in the last half of July to the first half of August and spawn well before Atlantic salmon in September. If competition for spawning areas occurs, Atlantic salmon will probably have the final choice. It has not been established that the Norwegian pinks are self-sustaining and the odd year runs could continue to be strays from the Russian stocking program. The Russian populations have not been self-sustaining. The Russian chum plants have not given good returns and none were recovered in Norway. There is some indication that pinks may be more resistant to acid water than Atlantic salmon and sea trout, which perhaps possess an interesting prospect for some damaged rivers in southern Norway.

Encouraged by some of the recent techniques giving good returns in Japan and Alaska, pink salmon are strongly being considered for sea ranching in Norway. When pinks first turned up in 1960 in Troms and Finmark, they were marketed for the same price as Atlantic salmon. Although smaller than most commercial Atlantic salmon, if returning pinks are caught before August in salt water, they appear to be of good quality and are now smoked or marinated (grav laks) in the Tromsø area.

The Institute for Marine Research, Bergen, has reared pinks at their hatchery at Matre, and several strategies to enhance survival and returns are planned:

1. Delayed releases of larger pinks after spring rearing in fish pens;

2. Releases associated with a river system as a potential homing site;

3. Releases outside of fjords away from large concentrations of demersal fish predators;

4. Combinations of the above.

Part of the Norwegian Sea was, until 1977, fished internationally, the Danes often taking more than 50% of the catch on longlines. Even after the 200-mile limit is imposed and foreign exploitation is reduced, it is questionable that this type of ranching program will be undertaken on a large scale because a large part of the salmon will still be taken offshore beyond the ground line by Norwegian drift nets (Grinnlinge). There is little precedent and little incentive, therefore, under current Norwegian commercial salmon regulations to encourage this type of fjord ranching approach with pink salmon. In any case, its commercial feasibility will first have to be demonstrated by the research now under way. Other factors, such as their homing capacity, ability to reproduce naturally in Norwegian rivers, and the feasibility of culturing them economically for releasing, must be assessed.

C. Arctic char

A proposal to use anadromous char in ranching has been made by Nordeng (1972). Their tendency to remain in the vicinity of their river of origin does offer an advantage, but the short feeding period in the ocean will require high supplemental food costs.

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21. Appendix I

Application Form for Licensing (Translated from Norwegian)

The application together with information and documentation is submitted through the Chief of Fisheries or the Inspector of Fisheries for saltwater fishing in the districts or where those offices are not established, directly to the Director of Fisheries.

If an establishment/expansion* of facilities on several localities is applied for, an application form is filled in for each locality. All sections must be answered.

In accordance with a provisional law of 8 June 1973, it is herewith applied to the Department of Fisheries for permission to establish/expand* a facility for hatching/raising* of fish.

A. GENERAL INFORMATION

1. Information about the applicant:

1.1. Name: ....
Address: .... Postal no. ....
Postal Station: .... County: ....
City, town or village: ....
Telephone exchange: .... No: ....

1.2 Qualifications: Attach information regarding the professional qualifications and practical experience of the applicant, or probable operation manager.

1.3 Is the facility going to be operated as sole occupation? Yes/No*
Is the facility going to be operated as main occupation? Yes/No*
If the answer is no, please provide information about the other profession:
....

2. Information about the plant

2.1 Name: ....
2.2 Address: ....
2.3 Ownership: ....
If the application applies to expansion, please state the registration number: ....
If the application applies to new establishment, please state:
Corporation? Yes/No* If yes, starting year: ....
Private Ownership? Yes/No* If yes, starting year: ....
Other form of ownership to be specified: ....
Starting year: .... Number of owners: ....
Name/Names of the owner(s): ....
Number of employees/planned number of employees* at the plant: ....
2.4 Location: Please attach a land map or sea chart showing contour lines and depth and indicate location of planned facilities.
2.5 Design: Please attach a perspective map on a large scale of existing and planned facilities.
2.6 Title relationship: Please attach a desaription of the site of the layout (including existing facilities) with information about the applicant's title relationship to the property.
2.7 Electricity: Please attach information regarding access to electric power.
2.8 For freshwater plant, does there exist any method for treatment of effluent water from the facility? Yes/No* If yes, please specify: ....

3. Water conditions:

3.1 Is the farming environment in freshwater/saltwater/mixed water?*
Are there any sources of pollution close by? Yes/No* If yes, please indicate.

---

*Please delete what is not applicable

3.2 Distance in meters to silos, cow barns, sewers, or industrial plants: ....
Distance in meters to other fish farms (name): ....
Distance in meters to other pollution sources: ....

3.3 Please indicate for freshwater plant.
Freshwater supply: Open/Closed (in pipes)*
Quality of water: Can the water be used as drinking water? Yes/No*
Has the water source a natural stock of salmonid fish: salmon/trout/other fish?*
Amount of water (L/m): Maximum supply: ....
Minimum supply: ....
Temperature (in °C): Maximum: .... Minimum: ....

3.4 Please indicate for seawater plant:
Formation of ice: Yes/No*
If formation of ice, duration in months: ....
Seawater temperature: Maximum: .... Minimum: ....

B. SPECIAL INFORMATION

1. Planned Production

	Planned production 1 and 2 years after establishing		
	Salmon 1 yr 2 yr 197..	Rainbow trout 1 yr 2 yr 197..	Other (specify) 1 yr 2 yr 197..
1.1 Hatching of eggs	....	....	....
1.2 Pre-smolts production (thousands)	....	....	....
1.3 Smolt production (thousands)	....	....	....
1.4 Freshwater production of fish for human consumption (tons)	....	....	....
1.5 Saltwater production for human consumption (tons)	....	....	....

2. Brood fish

2.1 Salmon-number .... Liters of eggs ....
2.2 Rainbow trout-number .... Liters of eggs ....
2.3 Other-number .... Liters of eggs ....

3. Inventory of rearing facilities

Anticipated Facilities of New Plant After Expansion

	Number units (hatching trays, tubs, etc.)	Size, length width & depth	Water flow liter/minute/unit

3.1 Hatching
Equipment
Type: ....
Type: ....

3.2 Grow out
Tanks
Type: ....
Type: ....

*Please delete what is not applicable

3.3 Smolt
Rearing
Land Plant: ....
.... Size, square meters, and average depth
Floating cages: ....
Enclosures: ....
Natural closures: specify (round fjords with narrow inlets, channel with current): ....
....
Other kinds, please specify: ....

C. OTHER INFORMATION IN CONNECTION WITH PLANNED OPERATIONS

1. What kind of feed are you planning to use? Wet feed/dry feed*

2. Facilities for wet feed production:
2.1 Own wet feed facilities: Yes/No* If yes, please indicate:
2.2 Equipment for pumping sea water: Yes/No*
2.3 Equipment for grinding and mixing (grinder, screw, etc.): ....
2.4 Is the feeding going to take place manually/automatically?
2.5 The capacity of the feed facilities (in ton/24 h): ....
2.6 Is the facility certain to obtain regular supply of feed? Yes/No*
If no (see 2.1), please indicate:
2.7 Distance from the farm to the wet feed plant which you have planned to cooperate with (km):
....
The name of the feed plant: ....

3. Cold storage plant:
3.1 Do you have your own freezer plant? Yes/No*
If yes, please state number of registration: ....
If no, are you seeking a permit for a freezer plant? Yes/No*
3.2 Other freezer plant, state distance: ....

4. Fish processing and market preparation:
4.1 Do you have your own plant for processing fish? Yes/No*
If yes, please state registration number: ....
If no, are you applying for approval of a processing plant? Yes/No*
4.2 Please state distance in km to the nearest processing plant (please state the place):
....

D. FINANCING

1.1 Estimate of cost for expansion of facilities*
Investment ....N.Kr.
Calculated operating costs per annum ....N.Kr.
1.2 Financial outline
Own capital ....
Loan capital ....
Sum ....
If promised a loan for the expansion, please state the size of the commitment ....
and the lender ....,......................

E. REMARKS

....

Place Date

....

Signature of the applicant/ Possibly firm stamp

---

* Please delete what is not applicable

To be filled in by the Chief of Fisheries of the County/the Inspector of fisheries of the district.

Should the applicant receive the approval?

Yes: .... No: ....

Has the Chief of Fisheries/the Inspector of Fisheries obtained special information on his own initiative?

A short justification for the approval and possible other comments: ....

The recommendation and possible comments of the Chief of Fisheries/the Inspector of Fisheries ....

The signature of the Chief of Fisheries

....

The Inspector of Fisheries

....

22. Appendix II

Norwegian Distributors of Fish Farming Equipment

1) Asimco A/S
   2400 Elverun, Norway
   Grinders and blenders.
2) Bakelitt Frabrikken A/S
   Drammenveien 30, Oslo 2, Norway
   Seafarm walkways, hatchery tanks, troughs and plastic equipment.
3) Berdal A/S
   Maries vei 20, 1322 Høvik, Norway
   Building, planning, and engineering hatcheries, smolt farms and fish ladders.
4) Bergen - Bartz Industri A/S
   Att.: Mr. Hauge
   Bergen 5000, Norway
   Manufacturer and distributor for several firms of grinders, choppers, blenders, specialized for fish farms and mink farms.
5) Brunswick Nøt Fabrikk
   Kristikansund, Norway
   Net fish cages for standard frames or made-to-order.
6) Çatamaran Fibreglas (SIAS A/S)
   Alesund, Norway
   Fiberglas net cage frames and walkway parts.
7) Dansk Ørredfoder
   P. O. Box 39
   7330 Brande, Denmark
   Specialized equipment of all kinds for fish farming.
   - Fry, smolt, holding and transport tanks
   - Chopping and grinding machines
   - Automatic feeders
   - Aeration equipment
   - Sorting equipment
   - Brushes, shovels, dip nets, chemicals, and clothing.
8) Fredrikstad Glasfibreplast A/S
   Fredrikstad, Norway
   Smolt tanks 1-12 m^2.
9) Helgeland Betongvarefabrikk
   8600 Mo i Rana
   "Polarcirkel", floating frames for net cages.
10) Monopol
    Maling and Lakkindustri A/S
    5305 Florvag, Bergen
    Fish farm antifouling chemicals.
11) Nesseplast A/S
    5920 Nessane, Norway
    Transport cases for living fish eggs.
12) Norsk Landsbrukkjemi A/S
    1473 Skarer
    Suppliers of Astra Ewos AB (Fack-15120 Sodertalje, Sweden)
    Dry food for fresh and salt water, trout and salmon, with or without pigment added in 8 pellet size groups.
    Automatic feeders
    Hatchery troughs and baskets
    Fish tanks and transport tanks
    Sorting equipment
    Egg counters
    Fish and waste pumps.
13) Norsidmel
    P. O. Box 1034
    5001 Bergen
    Fish meal and oil for fish food.
14) Silver Cup Ørredfoder
    E. Langvad Jensen Aps
    Ødsted, 7100 Vejle, Denmark
    Dry food for salmon and trout, fresh and salt water.
15) T. Skretting A/S
    Boks 319
    4001 Stavanger
    Now represented in USA by:
    Heli-Trade Corp.
    P.O. Box 10 332
    5815 Airport Road
    Eugene, Oregon 97401
    Telex 36 4419
    Dry food for salmon and trout in salt and fresh water, with or without pigment added, in 10 pellet size groups.
    Binder meal to be mixed 5, 10 or 50% in wet food with or without 10% vitamin package.
    Pigment (carophyll red)
    Fish oil with pigment
    Medicated food
    Tess equipment system including automatic feeders, net cages and frames, hatchery equipment, egg transport cases and disinfectants.
    Fish farm financing.
16) Magne Strand
    6684 Valsøyfjord
    Floating fish net frames.
17) Vesta Hygea, all major towns in Norway
    (Fish farm insurance)
18) Greigg Forsikering Selsap, agents for The Aquaculture Insurance Service Limited.
    26 Fenchurch St.
    London EC3M 3DR
    England.

23. Appendix III

Glossary of Common Norwegian Terms used in Fish Farming

A.

AFRED - behaviour
ALDER - age
ANDRE - other
ANLEGG - plant, facilities, operation, equipment
ANTALL - number
ARBEID - work
ART - species
A/S - Ltd.
ARVE - to inherit
AURE - trout
AVHENGIG - dependent
AVLE - to breed
AVLØP - outlet, drain
AVSTENGINGER - enclosures

B.

BEDØVE - to anesthetize
BEFRUKTE - to fertilize
BEHANDLING - treatment
BEGRENSE - to limit
BEGROING - fouling
BEREGNINGER - calculations
BESTEMME - to determine, decide
BETYDELIG - significant
BLANDEMASKIN - blender
BLY - lead
BLOD - blood
BLØDT - soft
BLASKJELL - mussels
BRISLING - spratt
BRYGGE - walkway
BUKT - bay
BUNN - bottom
BYGG - building

D.

DAG - day
DAM - pond, net enclosure
DEMNING - dam
DIREKTORATE - Department
DYP- deep
DØGN - 14 hours
DØD - death
DØDLIGHET - mortality

E.

ERFARING - experience
ELV - river
ER - is, are

F.

FANGE - to catch
FARGE - colour, RØD - red colour
FETFIN - adipose fin
FETT - fat
FISKEOPPDRETTER - fish farmer
FLYTE - floating
FLÅTE - float
FORANDRING - change
FORBEDRING - improvement
FORHOLD - conditions
FORINGSAUTOMAT - automatic feeders
FOR - food
FORSIKERING - insurance
FORSKER - scientist
FORSKJEL - difference
FORSKRIFTER - regulations
FRESK - fresh
FORSLAG - to suggest
FRISK - healthy
FROSSEN - frozen

G.

GJELL - gill
GJENNOMSNITT - average
GJERDE - fence
GYTE - to spawn

H.

HADDE - had
HALE - tail
HAN - he, male
HAR - has, have
HAR HATT - has had, have had
HAR VERT - has been, have been
HAVFORSKNINGSINSTITUTT - Institute of Marine Research
HAVN - harbour
HAV - ocean
HELSE - heath
HJERTE - heart
HODE - head
HUN, HO - she, female
HVA - what
HVEM - who
HVILKEN - which
HVOR MANGE - how many
HYDROGRAFISK - hydrological
HYSE - haddock
HØST - fall (season)

I.

I - in
INNHOLD - contents
INN - inside
INNLEDNING - introduction
ISOPOR - styrofoam
IS - ice

J.

JERN - iron

K.

KALKULERE - to calculate
KAR - tank
KILDE - source
KJEMISK - chemical
KJØNNS - sex
KLEKKE - to hatch
KLEKKERI - hatchery
KRAFTVERK - electric station
KRYSSINGER - crosses
KUNSTIG - artificial
KVERN - grinder
KYST - coast; -VANN - coastal water

L.

LAGRE - store
LAKSEFISK - salmonids
LAKSELUS - salmon louse

LAKS - salmon
LANDBRUK - agriculture
LENGDE - length
LODDE - capelin
LUFT - air
LYS - light
LAN - loan

M.
MAGER - low fat, thin
MATFISK - fish for consumption
MEL - meal
MERKE - tag or mark
MAER - net cage, also MER, MAR, MIR
MILJØ - environment
MODEN - ripe
MØRK - dark
MÅNED - month
MÅLING - measuring

N.
NORD - north
NORSK - Norwegian
NOT - net
NY - new
NYRE - kidney - NYRESKYKE - kidney disease
NAERING - business, profession, nutrition
NÅR - when

O.
OM - about
OMKOSTNING - expense
OPPDRETT - to culture, raise
OPPGAVE - problem
OVERFLATEN - surface
OVERFØRING - transferral
OVERLEVELSE - survival

P.
PALLE - small saithe
POSE - bag
PUKKELLAKS - pink salmon
PUNKT - point
PÅ - on, at, about

R.
RAMME - frame
REDSKAP - equipment
REGLER - rules
REKE - shrimp; -SKALL - shrimp shells
RENGJØRE - to clean
RETNING - direction
ROGN - roe
RØKT - smoked
ROR - pipe
RØYE - arctic char
RAUDATE - red copepod, *Calanus finmarchicus*

S.
SALG - sale
SALINITET - salinity
SALTGEHALT - salinity
SAMLE - to collect
SAMMENSETNING - composition
SEI - saithe, coalfish
SETTEFISK - hatchery fish for stocking in fresh or salt water
SILD - herring
SJØDYKTIG - fish capable of transfer to salt water
SJØ - sea
SKALLDYR - shellfish
SKYLLE - wash
SLAKTE - to harvest or butcher
SMÅ - small
SNØ - snow
SOL - sun
SOPP -fungus
SPISE - to eat
SPILL - waste
SPØRSMAL - question
STADIUM - stage
STAMFISK - brood fish
STAMMER - races
STILLING - position
STOFFSKIFTE - metabolism
STOR - large
STRØM - current
STØRRELSE - size
SURSTOFF - oxygen
SURTVANN - acid water
SVINN - disappearance
SVØMMEHASTIGHET - swimming speed
SYD - south, also SØR
SYKDOM - disease
SAED - sperm
SÅR - sore

T.
TAU - rope
TETTHET - density
TID - time
TILSKUD - addition
TØRR - dry
TOM - empty
TORSK - cod
TALE - tolerate

U.
UAVHENGIG - independent
UKE - week
UNDERSØKE - to investigate, research
UTBRUDD - outbreak
UTNYTTE - to use, apply
UTSETTING - stocking
UTSTYR - equipment
UTVALG - committee, selection
UTVIKLING - development

V.
VANN - water; - UTSHIFTING - water exchange; SALT- saltwater; FRESK - freshwater; TIDE - tide.
VANSKELIG - difficult
VAR - was; HAR VERT - have been
VEKST - growth
VEKT - weight
VERDEN - world
VEST - west
VIRKSOMHET - undertaking
VOKSEN - adult, full-grown
VAER - weather
VÅG - bay
VÅR - spring (season)
VÅT - wet

Y.
YNGEL - young (fry and parr)

Ø

ØRRET - trout
ØST - east
ØYEROGN - eyed eggs
Øv - island

Å

ÅR - year
ÅRSAK - reason, cause

24. Appendix IV

Research Establishments, Focus and Facilities

A complete list of Norwegian institutes involved in salmonid aquaculture research, their facilities, projects and number of personnel has been provided by Møller (1976). This list has been reproduced here with some modifications and updating.

1. Fiskeridirektoratet (Directorate of Fisheries), Møllendalsvn. 4, P.O. Box 185, N-5001 Bergen
   Serves as an administrative and regulative function in addition to supplying research funds, and extension services.
2. Fiskeridirektoratets Havforskningsinstitutt (Institute of Marine Research), Nordnespk. 2, P.O. Box 2906, Bergen-Nordnes
   Personnel:
   10 scientists
   9 technicians
   4 students

   Laboratories and other facilities

   Laboratory for growth and energetic studies
   10 special tanks (175 L) and seawater aeration tank
   10 special tanks (175 L) for photoperiod studies
   Laboratory for disease studies, 8 tanks (200 L) with chlorination of effluent
   Laboratory for general studies of the biology of fry and smolt, 28 tanks (200 L)
   3, 30-m^3 concrete storage tanks (sea water of 9°C)
   Hatchery units of different types
   Water: Sea water and fresh water of 5, 10 and 20°C

3. Fisk og Forsøk (Fish and Research)
   Postal address: N-5198 Matredal
   Personnel:
   2 scientists
   5 technicians

   Laboratories and other facilities:

   Hatchery for 1 million eggs in groups
   40 square tanks (2-m^2)
   74 round tanks (1.75-m^2)
   40 square floating cages (9-m^2)
   Building for administration and laboratories under construction
   Water: Fresh water 2000 L/min; heated water 1000 L/min; sea water 1000 L/min

   Current program

   Comparative growth studies of fish density in floating pens.
   Comparative growth studies of rainbow trout and Atlantic salmon in floating pens at different latitudes from Bergen to the North Cape.
   Growth and energy metabolism studies.
   Analysis of food value of different fish species and fish offals.
   Thiamin studies in rainbow trout.
   Protein qualities of fish meals.
   Silage conservation of fish for salmonid feed.
   Feeding behaviour with different feed types.
   Studies on salmon lice (*Lepeophtheirus salmonis*).
   Studies on vibriosis.
   Hygienic-bacteriological studies of wet feed and sea water in fish farms.
   Selective breeding of Atlantic salmon from different Norwegian rivers.
   Selective breeding of rainbow trout.
   Studies of other salmonids (*Salvelinus alpinus*, *Oncorhynchus gorbuscha* and hybrids).
   Photoperiod and saltwater tolerance of Atlantic salmon.
   Salt feeding and saltwater tolerance of Atlantic salmon.
   Aggression in Atlantic salmon parr.
   Hatching and early rearing of non-salmonid fish fry.
   Rearing of halibut through the larval stages.
   Polyculture: rainbow trout - different flatfish species.

4. Marine Station at Austevoll

   Marine facility associated with the Institute of Marine Research, Bergen.
   Proposed opening of first building in 1978.
   Will assume some of research presently done by the Fisheries Directorate at Matre and Flødevigen, and will focus on salmonid pen rearing, nutrition, physiology and egg, larval and adult rearing of demersal, pelagic and groundfish species.

5. Fiskeridirektoratets Vitamininstitutt (Government Vitamin Institute)
   Postal address: Lars Hilles gt. 26, P.O. Box 187, N-5501, Bergen
   Personnel:
   3 scientists
   6 technicians
   2 students

   Laboratories and other facilities:

   Laboratory and advanced analytical equipment for nutrient analysis.
   Microbiological laboratory
   Numerous joint field projects with Institute Marine Research at Matre.

6. Institutt for Husdyravl (Department of Animal Genetics and Breeding), Agricultural University of Norway. Postal address: N-1432 AS-NLH, Norway
   Forsøksstasjon for Fisk (Fish Breeding Experimental Station)
   Postal address: N-6600 Sunndalsøra
   Personnel:
   5 scientists
   1 manager

5 technicians
2 students

Laboratories and other facilities:

Laboratory and offices 72 m^2
Hatchery for 2 million eggs and 600 groups (see section 4)
Plastic tanks: 1 m^2, 140 units
" " 2 m^2, 268 units
" " 4 m^2, 32 units
Concrete ponds: 75 m^2, 36 units
Recirculation unit for smolt production
4 m^2 plastic tanks, 8 units
Plans for expansion
Water: four different sources including sea water and cooling water drom a hydroelectric plant.

7. Forsøksstasjon for Laks (Salmon Breeding Experimental Station) at Averøy
Postal address; N-6530 Bruhagen

Personnel:
1 manager
1 technician
1 student

Laboratories and other facilities:

Storage house 84 m^2
Floating bridge 220 m
Floating cages 200 m^3, 16 units
500 m^3, 10 units
27 m^3, 24 units
Sea water

Current program:
a) Comparison of species: Atlantic salmon, pink salmon, sea trout, rainbow trout, Arctic char and brown trout.
b) Crossbreeding between the species mentioned in a).
c) Comparison of production traits of Norwegian salmon strains.
d) Selection of rainbow trout for growth rate.
e) Inbreeding experiment with rainbow trout.
f) Development polyploidy and sterility.
g) Chromosome study.
h) Estimating phenotypic and genetic parameters.

Environmental work:

a) Water re-use for smolt production.
b) Effect of different density of fry and fingerlings on growth and survival.
c) Production of brood stock.
d) Effect of different hormones on growth rate and smoltification of salmon.

Nutrition experiments: (carried out by Department of Poultry and Animal Science, Agricultural University of Norway, AS-NLH, Norway)

a) Comparison of different fat content and fat quality in dry diets for rainbow trout and Atlantic salmon.
b) Comparison of different protein content and protein quality in dry diets for the same species.
c) Effects of high carbohydrate levels on 10 full subgroups of rainbow trout.
d) Comparison of different slaughter house by-products in wet diets for salmon.
e) Pigmentation of rainbow trout by different carotenoids.

8. Direktoratet for Vilt og Ferskvannsfisk (Directorate for Wildlife and Freshwater Fish)
Postal address: Elgesetergt 10, N-7000, Trondheim

Personnel:
1 chief biologist
4 research scientists (2 biologists, 1 chemist and 1 fish pathologist)
1 station manager
7 assistants and office personnel

Laboratories and other facilities:

1 biological laboratory
1 chemical laboratory
Pathological laboratories at the Veterinarian Institute, Oslo
1 field research station (under construction)
Plans for expansion
The research department will later be moved to Trondheim and will then be expanded.
The field station will get 2-3 assistants.

Current program:

Research and biology of anadromous and other Norwegian freshwater fishes, fish farming, etc.

9. University of Tromsø, Institute of Biology and Geology
Postal address: P.O. Box 790, N-9001, Tromsø

Personnel:
Total staff involved in the aquaculture research program:
2 professors
3 lecturers
4 technicians

Laboratories and other facilities:

a) Experimental hatchery at Forsheim Research Station in Skjomen (near Navik), with 3 floating ponds and hatchery capacity for 50,000 smolts.
b) Marine Biological Station, Tromsø (8 km from University campus), with open seawater system 30 m^3/h for laboratory experiments.
c) Institute building at University campus with laboratory facilites for biochemical and physiological work.

Salt and fresh water

Current programs:

a) Optimal production in relation to food costs.
b) Factors influencing growth rate and mortality at commercial fish farms in the region.
c) Physiology and energetics of Arctic char.
d) Heat exchange and heat production in fish.
e) Biochemistry and physiology of growth and survival of *Vibrio anguillarium*.
f) Fish digestion and suitability of fish silage as a feed ingredient.
g) Early development requirements of pink salmon and Arctic char.
h) Speciation and stock variability in Arctic char.

10. Veterinaerinstituttet (National Veterinary Institute)
Postal address: P.O. Box 8156, N-Oslo-Dep, Oslo 1

Personnel:
2 scientists
1 technician

Laboratories and other facilities:

Laboratories for histology, microbiology, virology

Fresh water

Current programs:

Registration and studies on *Vibrio anguillarium* and vaccine development
Other infectious diseases, botulism, lipoid liver-degeneration.
Toxicological and fish disease problems also studied at Norges Veterinaerhøyskole (Veterinary College of Norway)
Postal address: P.O. Box 8146, N-Oslo-Dep, Oslo 1

Personnel:
2 scientists

Laboratories and other facilities:

Laboratories for histology, microbiology and virology.
Water: fresh water

Current programs:

Pharmacological studies

11. Selskapet for De Norske Fiskeriers Fremme (Society for Promotion of the Norwegian Fisheries)
Postal address: Nordahl Brunsgt 9, N-5000 Bergen

Personnel:
1 scientist
1 technician

Laboratories and other facilities:

Laboratory
Research pool for oyster studies (N-5980 Harbakke, Solund)

Current programs:

Control of oyster pests
Selective breeding of oysters

In addition to the institutions mentioned above the Directorate of Fisheries has a marine Biological Station at the south-eastern coast (Flødevigen, N-4800 Arendal), where work is done on cultivation on different flatfish species, lobster and mussels. For the moment, this Station is heavily involved in research on ecological changes due to thermal pollution and therefore it is not possible to state how much effort is put into aquaculture research.

12. Chr, Michelsens Institute, Nygårdsgaten 114, 5000 Bergen Laboratory facilities.

Personnel:
4 staff

Research programs:
Instrumentation, physical, chemical engineering as applied to water requirements of fish farms.

13. District vocational schools in Navik and Bøda have teaching staff involved in aquaculture research as part of fisheries curriculum.

14. University of Trondheim Marine Station, Technology Institute in Trondheim
Development and testing of a variety of underwater telemetry and acoustical gear, potentially useful in studying the behaviour of fish in enclosures; the use of impoundments in rearing flounders and plaice.