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SALMONID AQUACULTURE IN NORWAY

by

Richard L. Saunders

This is an account of a recent trip to Norway where I visited some Atlantic salmon and rainbow trout farms. During his two-year stay in St. Andrews and after his return to Norway in September 1970, Dr. Dag Møller of the Marine Fisheries Institute, Bergen, frequently told me about the increasing interest in salmon and trout farming in Norway. Following my attendance at the International Congress of Physiological Science at Munich and the Symposium on Comparative Physiology of Respiration at Göttingen, I was able to take up Dag's long standing invitation to travel with him and see some of the estimated 100-150 salmon or trout farms in Norway. Dag arranged for us to visit places along the coast from Trondheim to Bergen to emphasize the importance of local climatic conditions. We saw a wide range in size of operations from family-run plants to large installations with industrial backing.

Three types of holding facility are used: net enclosures buoyed and anchored off shore in fjords; net enclosures extending out from shore, often taking advantage of small coves or small sounds between islands; and earthen or concrete ponds to which sea water must be pumped. The type of installation was dictated by local climatic conditions as well as economic considerations. The type of installation requiring pumping seemed less desirable than the others because of the extra cost and vulnerability of the water supply. In some locations this type of enclosure was necessitated because there could be ice formation in open water.

Some plants buy their stock; most have their own hatcheries.

Both salmon and trout are gutted and sold in the round, either iced or frozen. I tasted fresh cooked trout and smoked salmon and trout. I think the taste, texture and appearance is as good as in wild fish. I've been told that connoisseurs are of the same opinion. The market for salmon and trout is good with prices of 15-20 Nkr/kg ($1.00 to $1.50/lb). People are making a living with salmonid products but beyond that I can't add anything about the economics of this venture.

There are a number of problems encountered by fish farmers. Probably the first is economics, involving capital expenditures, cost of food, labor and equipment costs and the price of the product. Disease was not a serious obstacle at most of the places I visited. Some disease problems are encountered with the young fish in hatcheries. The common practice of rearing even pre-smolts in dilute sea water probably helps to reduce disease. There is, however, a real danger from organic pollution from the heavy feeding and waste products from heavily crowded conditions. This danger exists as a potential pollution problem in fjords where there might be extensive fish farming in the future. In one case, this kind of pollution and the physical characteristics of the enclosure between two islands resulted in low dissolved O_2 levels and a build-up of hydrogen sulphide and probably other toxic substances. This problem was being overcome by increasing circulation in and out of the enclosure with electrically driven pumps. Nearly every fish farmer we talked with was concerned with the problem of early sexual maturation which results in slowing or cessation of growth before an adequate size is reached. Some thought has been given to selection of salmon from wild stocks which are known to reach a large size and to have few grilse. Rainbow trout used in the places we visited are, I understand, spring spawners from stocks reared in Denmark. Dag Møller and others are contemplating an experimental rearing plant to study selective breeding as well as nutrition and other physiological aspects of aquaculture.

Following is a list of the plants we visited and some comments about each. The map in Figure 1 gives the location of places mentioned.

1. "Eros Laks" located at Bjordal on Sognefjorden. Owned by Mr. Osland and run by him and two sons-in-law. One of the operators, Mr. Oscar Ingebrigtsen, has a Masters degree from Bergen University where he studied biology and specialized in fish nutrition. Oscar joined us on the trip to other fish farms. He and Dag Møller were my interpreters as well as a fund of information about Norwegian aquaculture.

   Eros Laks have their own hatchery for rainbow trout and Atlantic salmon. The fry at this and some other plants we visited are fed at first with Ewos (Swedish) pelleted salmon food and then with Tess which is a Norwegian product. Ewos is acknowledged to be the best artificial salmon food, especially for small fry. Because it is more expensive than the Norwegian dry food, it is mostly in use as a starter food. Salinity is gradually brought up to about 5‰ the first summer after hatching and is gradually increased to *ca.* 10‰

by the end of the year. The 7-15 cm yearlings are moved to four enclosures which are formed by the shore and nets held on stakes driven into the bottom. Enclosures measure about 20 x 40 m and vary in depth from 0 at the shore to 8 m at the outer margins. The nets forming the enclosure are small mesh, about 4 cm stretched knot to knot and with 2 cm between knots. White nylon net is treated with a copper compound (red) which is an anti-fouling agent. Oscar maintains the nets and checks for holes by scuba diving. He made the interesting observation that the trout, which had parr marks when they were moved to the sea enclosures, stayed at the surface for about two weeks. Later as they became silvery the fish began to utilize all depths. There was a thermocline as well as a halocline so it cannot be said that the fish were showing preference for the brackish surface water. The surface water is warmer than the deeper water during summer and vice versa in winter.

The feed was a ground mixture of different marine fishes such as coalfish, dogfish, and sprat, and shrimp shells. Shrimp is given for a minimum of two months before slaughtering to impart a pink color to the muscle. Without this the flesh is nearly colorless.

Climatic conditions are an important consideration of Eros Laks and other plants visited. Sea water temperatures are sufficiently high even in winter that salmonids continue to feed and grow. Although the surface water occasionally freezes, the subsurface water stays several degrees above freezing. At Bjordal the surface water rarely freezes.

Each enclosure has a capacity of 25-30 metric tons. Trout are taken at a size of 1-2 kg after 12-18 months in the enclosures (total age 2-2 1/2 years). The Eros Laks production this year is expected to be 40-50 metric tons. The fish are of high quality in both appearance and taste. Fresh cooked and smoked trout were very tasty.

Eros Laks also raise Atlantic salmon but so far only on an experimental basis. Salmon often become sexually mature before attaining a suitable size. Once they become mature, the salmon are slow to resume feeding. Some die at this time. Many such fish had fatty degeneration of the liver and were in generally poor condition. I believe that some Norwegian fish farmers would prefer to raise salmon but are discouraged from doing so because of this maturation problem. Rainbow

trout are marketable at a smaller size so for the time being are raised instead of salmon. Many aquaculturists will probably turn to Atlantic salmon when it is feasible to do so since a premium price is given for large fish for smoking.

2. Smolt production plant at Lundamo. This plant is owned by a corporation of hydroelectric companies and has an annual production of about 200,000 2-year-old Atlantic salmon smolts. A further 200,000 fish are released as fry. It is a summer plant only; the fish are transported to another place (indoors) for wintering. Egg incubation and hatching using heated water is done at a third place. The plant has automatic feeders, using Ewos as a starter and then Tess. There are standard concrete ponds and raceways with the water supply from a nearby river.

3. Havlaks located at Laxsåvika. Owned by Mr. Ove Grøntvedt. This plant is on Hitra which is the largest island in Norway. Havlaks have 13 floating net enclosures for Atlantic salmon production. The enclosures are octagonal in shape, 5 m on each side and about 4 m deep. Nets are small mesh, < 2.5 cm and treated to discourage fouling. The sides of each enclosure hang straight down and are weighted with a 2-kg stone at each of 8 corners in addition to lead lines running around the bottom of each side. Anchors hold the nets in place in open water in a protected area of the fjord. There were floating rims around the enclosures buoyed up with blocks of polystyrene so that several men could stand on the rim to work on the nets or inspect the fish. A 1-m high portion of the net extended above water to prevent the fish from escaping.

   Four enclosures were stocked in May with 2000 smolts each. The fish schooled and swam round and round the enclosure. In August these 2-year-old smolts had reached a size of 25-30 cm. Each of the remaining 9 enclosures was stocked with about 1000 3-4 kg salmon which had reached this size in only 14 months of post-smolt growth. This is the first year of operation so it is not known how large they will grow before reaching sexual maturity. Of two fish we selected, one was mature. The remarkable thing about these fish was their large size after one sea year. Canadian and Norwegian salmon of this age which are returning as grilse weigh about 1.5-2.5 kg. However, non-maturing salmon of the same age taken in Greenland weigh about 3.5 kg. Favorable temperature in combination with proper feeding is probably responsible for the remarkable growth in Mr. Grøntvedt's enclosures. Maximum

temperatures are 16° but more commonly 12° in summer and down to 4-5° C in winter. Fish are fed two or three times daily in summer and only once a day in winter. The owner also runs a capelin seiner so has an inexpensive source of food. Herring are also used for food. The operators had not begun feeding shrimp and the salmon, though tasty when smoked, was colourless.

This plant does not produce its own smolts but the operators plan to do so when they can get control of suitable land near a river for supply of fresh water. They buy 2-year-old smolts from Lundamo hatchery and pay 5 kr (about 75¢) each. There is no disease problem but some predation of smolts by gulls and mink. Mink have been introduced to Norway for ranching. Some have escaped and are becoming a nuisance.

Parent stock is mainly from rivers entering Trondheim-fjord. Large (6 kg) females were selected but apparently no precautions were taken to exclude fish which might have spawned as grilse.

I was very favorably impressed with the operation at Laxsåvika. Mr. Grøntvedt had not yet harvested his first crop which will be satisfactory even if half of the fish have reached sexual maturity. It would be interesting to find out if any of the post-smolts become sexually mature during their first autumn at sea (as some of our fast-growing fish do in the laboratory) and what proportion of the 16-sea-month fish reach maturity this year. The enclosures seemed very effective and easy to operate and maintain. However, Mr. Ingebrigtsen says they are much more expensive to build per m^2 than the type at his plant. Mr. Grøntvedt runs another plant for rainbow trout production at Ansnes, also on Hitra Island. We did not visit that plant. It uses the same procedures as we saw at Laxsåvika.

4. Proposed experimental hatchery and rearing plant at Matre. Dag Møller and Oscar Ingebrigtsen are full of enthusiasm about plans for this plant which is in the planning stage. Together with Dr. O.R. Braekkan, from the Marine Institute of Fisheries, they plan to develop a government-sponsored research facility to look into various aspects of salmonid aquaculture. Dag's interest is in selective breeding. Eros Laks will have a part (one-half) interest with the idea of doing research related to practical fish farming. Dr. Braekkan will follow nutritional aspects of fish farming. My travelling companions frequently talked about their plans and I share their enthusiasm. Their concept of an experimental fish rearing facility is similar to the one we have envisaged for the Maritimes in Canada. They have

selected an excellent location on a fjord with favorable water temperature and at the mouth of the River Matre. A novel idea is to make use of large volumes of heated fresh water coming from a hydroelectric plant also on the river. The idea of a hydroelectric plant as a source of heated water was new to me. If the Matre plant comes into being, I'm sure it will be a success. The proposed program of research is sound and the physical conditions are ideal.

5. Smolt-rearing plant at Sunndalsøra. We visited this modern plant but nobody was there to answer questions. Professor Skjervold of the College of Agriculture, Ås, near Oslo, is in charge of the station which is expressly for studying salmon genetics. They are in their first year of production using the best and most modern Swedish (Ewos) hatchery equipment. The whole plant is enclosed in a 14 x 50 m building and uses mostly 1 m^2 and 4 m^2 plastic tanks. I estimate the annual production to be about 500,000 one-year-old smolts. There is available 24 m^3/min of water heated 18°C above natural from a nearby hydroelectric station. Some of this is to be used to maintain suitable temperatures year round.

6. Rainbow trout farm at Molde, owned by Mr. Gjerstad. This plant uses both net enclosures and concrete ponds. The latter are necessary because of icing conditions in winter. All stock is moved to the concrete ponds and subsurface sea water is pumped to them.

   The fish are older and smaller than those at Eros Laks, probably because of heavy crowding and possibly less favorable winter temperatures. Molde is in an area which has a more severe winter than other places we visited. The expected production this year is 30 metric tons.

   Mr. Gjerstad rears his own trout fry. The plant is a successful venture in its 12th year of operation. Three people, plus occasionals, run it.

   The concrete tanks seemed to be convenient to use and, unlike the net enclosures, offered some possibility of salinity control. They were using a mixture of fresh and salt water. But these tanks necessitated costly electrically driven pumps. A Diesel generator was on hand to provide electricity in case of power failure.

7. Norlaks rainbow trout farm in Sykkylven, owned by the Vik Brothers. This is the best known trout farm and was the first to start farming rainbow trout in sea water. Norlaks expect to market 50 metric tons this year.

Norlaks have 8 floating pounds about 100 m^2 and 6 smaller ones (25 m^2). Because of ice problems, the operators kill much of the stock in October. The rest are held in concrete tanks to which sea water must be pumped. Fish are fed pelleted food and shrimp. The latter is less readily accepted by the fish so the operators offer the shrimp at the first feeding each morning when the fish are most hungry.

Vik brothers operate their own hatchery and have selected fish for late sexual maturity. They tried to raise Atlantic salmon but like so many other operators experienced difficulty and stayed with the easier-to-raise rainbow trout.

8. A.S. Mowi, headquartered in Bergen. This company has industrial backing from a large Norwegian firm. Mr. Thor Mowinckel is the managing director. They operate 4 plants, 2 for smolt rearing and 2 for large Atlantic salmon production. We visited all four plants, travelling by a seaplane which Mr. Mowinckel kindly rented for us.

8a. Varaldsöy, an island on Hardangefjord. This is a most impressive smolt production plant with an annual production of about 250,000 one-year-old smolts. There are 60 plastic tanks 3 m in diameter and 1.5 m deep, each holding 4,000-5,000 fry for final production of 3,500 smolts. An interesting departure from the Swedish system, which stresses tank bottom area rather than depth, is full use of water depth (about 1.4 m). This is achieved simply by covering each tank to shield the fish from visual disturbances from outside the tank. By carefully peeking inside, I could see that the fish were distributed from top to bottom. Full depth utilization was further accomplished by a food distribution system which introduced the pelleted food just below the surface at several points around the tank. The tanks were self-cleaning and needed a minimum of hand cleaning. I was favorably impressed with this new system of reducing disturbance of the fish and encouraging them to utilize full depth as a major advance over the shallow tank practice.

The Varaldsöy plant has its own hatchery facilities and uses electrically heated water to speed up development and hatching. Sea water is introduced in the rearing tanks and a level of 7-8‰ is maintained during the summer. This is close to the salinity we found to give maximum parr growth at St. Andrews. Sea water is pumped from a depth of 20 m to give cool water in summer

and relatively warm water in winter. The whole plant is run by 2-3 people. Smolts are transported by floating live cars to either of two large fish production units as much as 20 miles away.

8b. Askøy is the second smolt rearing plant. This impressed me less than the plant at Varaldsöy. Here they raise 2-year-old smolts so as to make possible a comparison between the post-smolt growth and size and age at sexual maturity of one- vs. 2-year smolts. They have some difficulty with disease, even when using salt water. The possible reason for this is the proximity to commercial fish handling facilities which pollute the sea water with fish wastes. In this respect, the island location of the other smolt plant is ideal. Certainly there was no sign of disease there.

Brood stock is held at Askøy. It has been found that post-spawning salmon can be induced to resume feeding early by force feeding anaesthetized fish. Such salmon resume voluntary feeding within as little as 3 days. This practice has made it possible to keep valuable brood stock for selective breeding programs.

A.S. Mowi have a professional salmon biologist, Mr. Fr. Wiese-Hansen, on staff. He and Mr. Mowinckel are keen to learn what is known about the physiology and genetics of salmonids so as to ensure success of their venture. It was most interesting to talk with these people who are indeed the chief customers for the information we produce. They are keenly interested in the work we are doing with effects of salinity, temperature and photoperiod on salmon growth and desperately want information on ways to manipulate smoltification and time of sexual maturation.

8c. Loköy is one of A.S. Mowi's two production units for market size salmon. It has a fenced-off enclosure between two islands. The enclosure contains 60,000 m^3 of water and has pumps to aid natural circulation in and out of the enclosure. It contains 150 tons of salmon of which it is hoped 100 tons can be marketed this autumn. It is planned to boost the annual production from the two plants to 500 tons.

The enclosure is of irregular shape but probably about 150 x 75 m with a depth of 8 m. Large nets divide the area so that newly introduced smolts are in one part and the larger fish in another. Salinity is nearly constant at all depths and year round at *ca.* 32‰.

Fish offal is ground to a paste and mixed with a binding agent (guagum) to make moist pellets which persist long enough to be pumped out into the enclosure and be eaten. The combination of natural and artificial circulation was sufficient to keep the water clear. Viewed from the air, water in the enclosure had the same color as in other areas between islands.

The larger fish stay in deep water and few come to the surface to feed. The operators think this indicates that these fish are mature and have ceased feeding. They plan to remove fish this autumn to determine the extent of sexual maturity. It seems to me that catching the fish from such a large enclosure will prove difficult because of irregular shore line and bottom topography. They plan to sweep nets through the pond.

8d. The second production unit, also at Loköy, is 2 km from the first. This is a fenced area about 400 x 100 m with concrete barriers with straining surfaces formed by 1 cm diameter steel rods 1 cm apart. As seen from the air, this pond is grey-green in color, much lighter than surrounding water. Natural circulation is not sufficient to carry away uneaten food and waste. A pump system is not yet installed and there is much difficulty with hydrogen sulphide and low dissolved oxygen. Sea fish enter the enclosure when they are small and grow to a large size inside the enclosure. The extent of competition between these and the salmon is not known. It is possible, however, that certain species of wild fish might be helpful by eating any food which falls to the bottom and is lost to the salmon. The poor water conditions have resulted in much reduced growth of the salmon which were less than *ca.* 1 kg after one year of post-smolt growth. Plans are to install pumps to remove the polluted water from the enclosure and to bring in clean water. This could lead to difficulties during the winter if the water removed is replaced with cold surface water. The advantage of warm subsurface water would then be lost. Perhaps with reduced feeding in winter little pumping will be necessary. Remote O_2 and temperature sensors in the pond will activate pumps when necessary.

The two plants at Loköy are run by only 5 men, one serving as foreman for both plants.

From my limited opportunity to observe different kinds of enclosures, I would favor the smaller types as used by Eros Laks and the floating nets used at Hitra.

Disease prevention, cleaning, feeding and harvesting should be easier in smaller enclosures. Perhaps, however, there are economic factors in favor of larger enclosures.

Discussion

Salmonid aquaculture is already well advanced in Norway. With a continued demand and high price for the product, there should be room for many operators. Procuring adequate quantities of the right food at reasonable prices could be a problem. Pollution and disease are relatively minor problems and can probably be overcome with adequate planning. Delaying sexual maturity in salmon can probably be achieved by manipulating endocrinology of the fish.

The main factor responsible for success of Norwegian aquaculture is the favorable water quality and temperature. Eastern Canada is not suited to similar aquaculture without costly heating of water in winter. But we should not attempt to copy the Norwegian pattern but try instead to develop a plan compatible with our peculiar water and climatic conditions. Considering the huge market for pond-raised, pan-sized rainbow trout from Idaho, Japan and Denmark, perhaps we could take advantage of the favorable temperatures which prevail in the Maritimes during May to November. Surface temperature at St. Andrews, N.B., is between 6 and 15°C during this period. It is probably possible to raise rainbow trout starting with 10 cm yearlings in May to 0.5 kg by November. If growth in salt water results in a better product than from fresh water, there could be competitive advantages with the former. A major disadvantage of trout farming in the Canadian Atlantic region during May to November would be seasonal production. The product would have to be frozen and stored to supply a year-round market. The possibility of salmonid aquaculture on a seasonal basis in the Canadian Maritimes seems worthy of serious study.

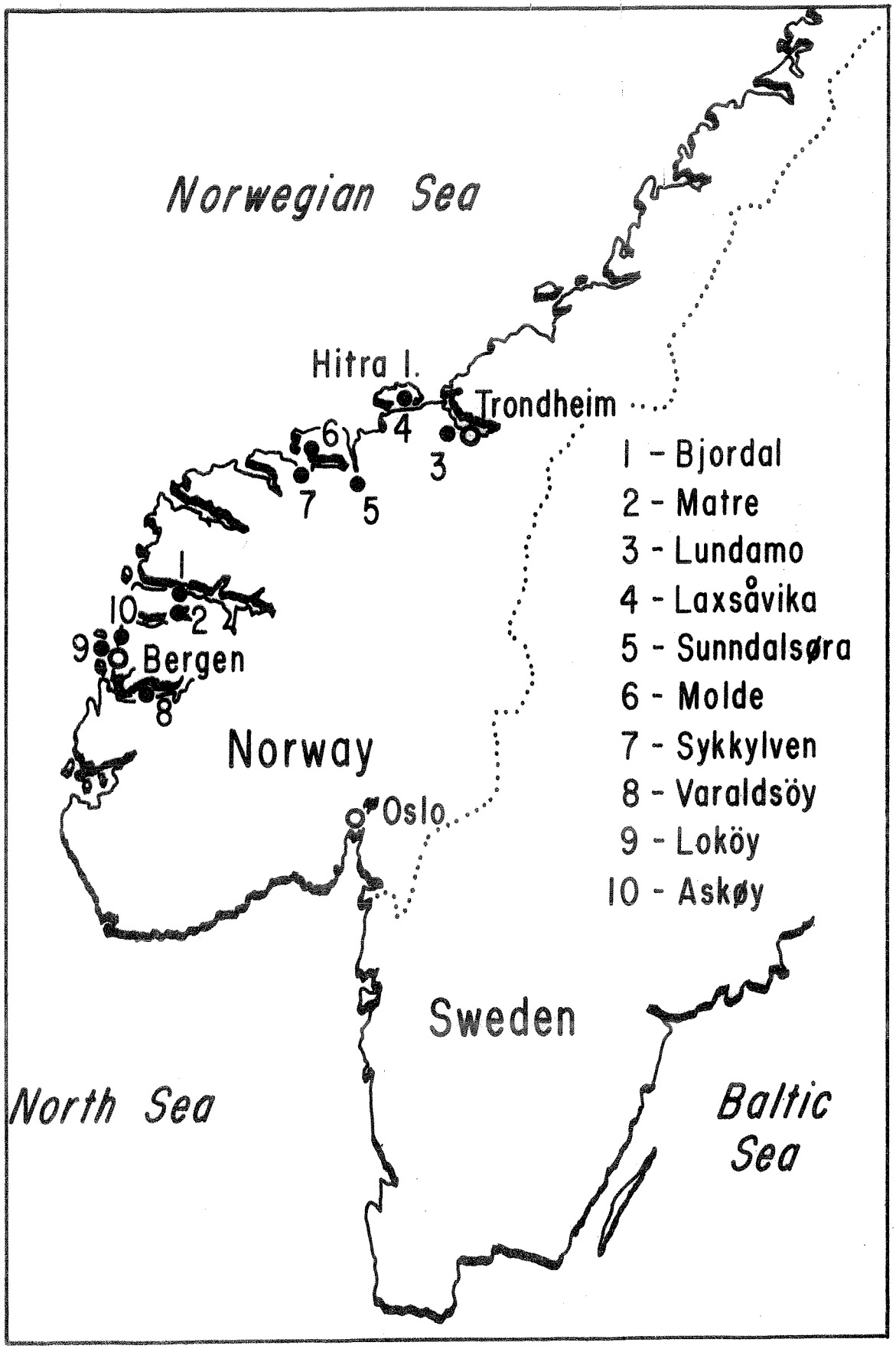
Norwegian Sea
Hitra I.
Trondheim
1 - Bjordal
2 - Matre
3 - Lundamo
4 - Laxsåvika
5 - Sunndalsøra
6 - Molde
7 - Sykkylven
8 - Varaldsöy
9 - Loköy
10 - Askøy
Bergen
Norway
Oslo
Sweden
North Sea
Baltic Sea

Figure 1.