DEVELOPMENT OF AQUACULTURE IN SWEDEN

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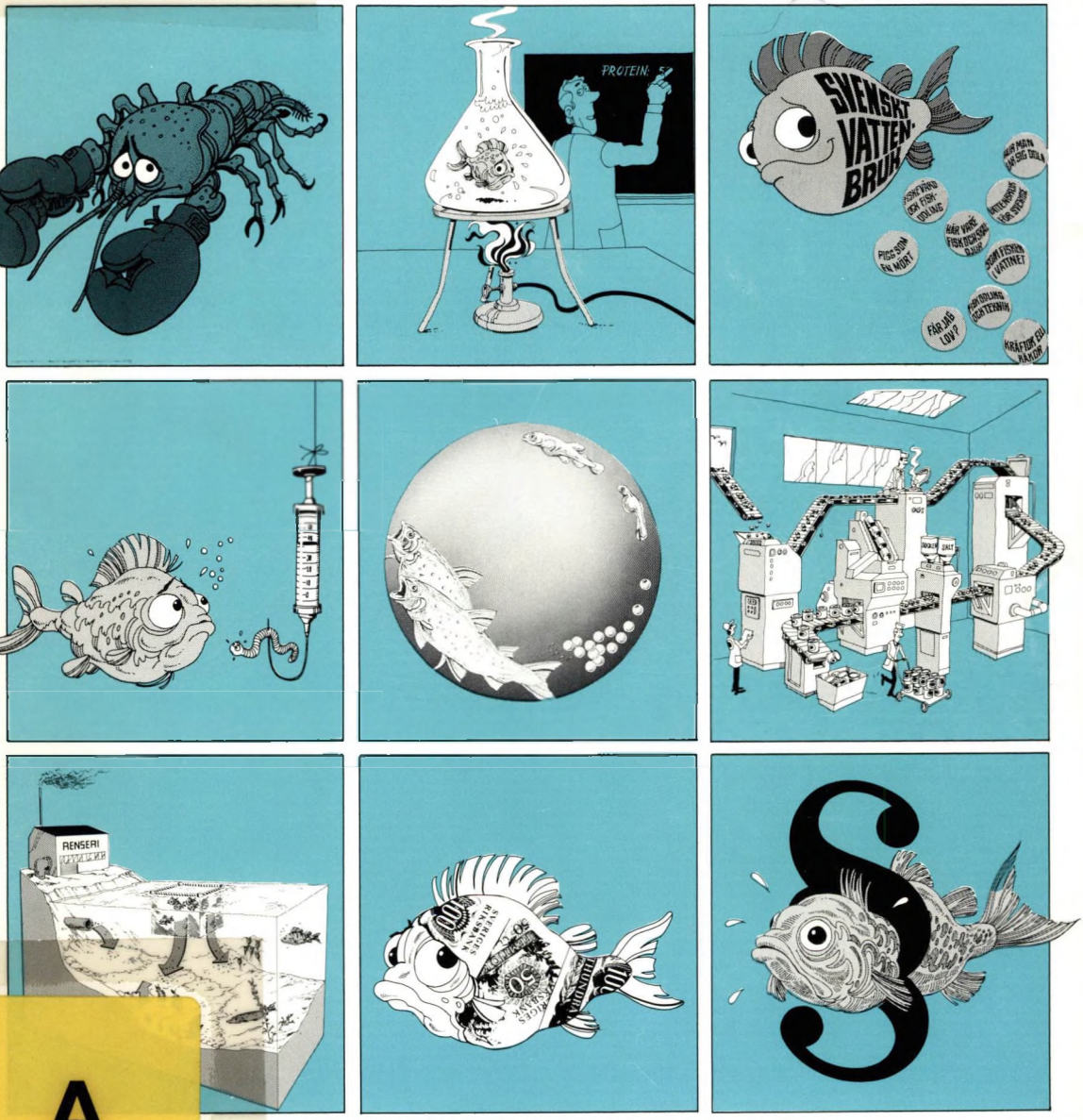
by Hans Ackefors



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THE SWEDISH COUNCIL FOR PLANNING AND COORDINATION OF RESEARCH
in collaboration with
THE NATIONAL MARINE RESOURCES COMMISSION

DEVELOPMENT OF AQUACULTURE IN SWEDEN

A collection of the summaries from the various reports made by the Swedish Steering Committee on Aquaculture and its working groups

by Hans Ackefors

Come, come a-fishing! Ready our rod is;
Fasten thy bodice,
Skirt and coat.
Cease then thy railing
Little availing;
Perch, pike and grayling
Greedy float.
Fairest Amaryllis, do not fly me,
Nor the pleasure of these hours deny me.
Where the dolphin rolls on billow briny
Let us be splashing in our little boat.

Carl Michael Bellman
Swedish poet, 1740–1795.

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Curt Ljungberg and Nils Peterson

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Carl Michael Bellman, (swedish poet, 1740—1795)
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Introduction

As part of a program for conservation and management Sweden has traditionally cultivated fish and other aquatic organisms. Fish such as salmon have long been cultivated for stocking in our rivers as smolt (fingerlings). The commercial cultivation of fish for direct human consumption has an even older history. This production has, however, not been of any significance for the national food supply.

Since the nineteenth century rainbow trout, tench, carp, and other species have been cultivated on a small scale. From the early 1970's, however, the extent of commercial production has rapidly increased through the introduction of net pens for cultivation of rainbow trout, and the line cultivation of blue mussels.

A survey made in 1981 revealed that not less than fifteen species of fish and two hybrid species are cultivated either to enhance natural populations or to be used for direct human consumption.

Rainbow trout, for example, was used in 125 separate operations in 1981. In addition to fish, blue mussels and crayfish are also cultivated. Blue mussels are produced in greater volume than crayfish but the latter are presumably of greater economic value.

Stockholm, April 1983.

Establishment of an Organization for Aquaculture in Sweden

In 1979 the Commission for Research on Natural Resources within the Swedish Council for Planning and Coordination of Research appointed a study group to survey the problem areas in the field of aquaculture. A report was published on aquaculture in Sweden and in other lands. The purpose of the report was to briefly describe and summarize the biological, economic and technical problem areas. At the end of the same year, the National Marine Resources Commission and the Commission for Research on Natural Resources, decided to follow up the report with an in-depth study. A steering committee was appointed and equipped with a small office, a full time salaried president and a part time assistant. The committee is composed of representatives from the above mentioned bodies, as well as from private fishing organizations, Swedish universities, the Institute of Freshwater Research, private industry and the county governments.

The Steering Committee and its eight working groups published their results in 1982. The subject of aquaculture is elucidated in many ways. The production of food on land and in the water as well as the international development of aquaculture are described as a background in the final report from the Steering Committee.

This booklet is a collection of the summaries from the various reports made by the Steering Committee and its working groups.

The Swedish Steering Committee on Aquaculture

President:	
Hans Ackefors	Swedish Commission for Research on Natural Resources, Stockholm, and the Department of Zoology, University of Stockholm.
Kjell Grip	National Marine Resources Commission, Gothenburg.
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Nina Holmström	National Marine Resources Commission, Gothenburg.
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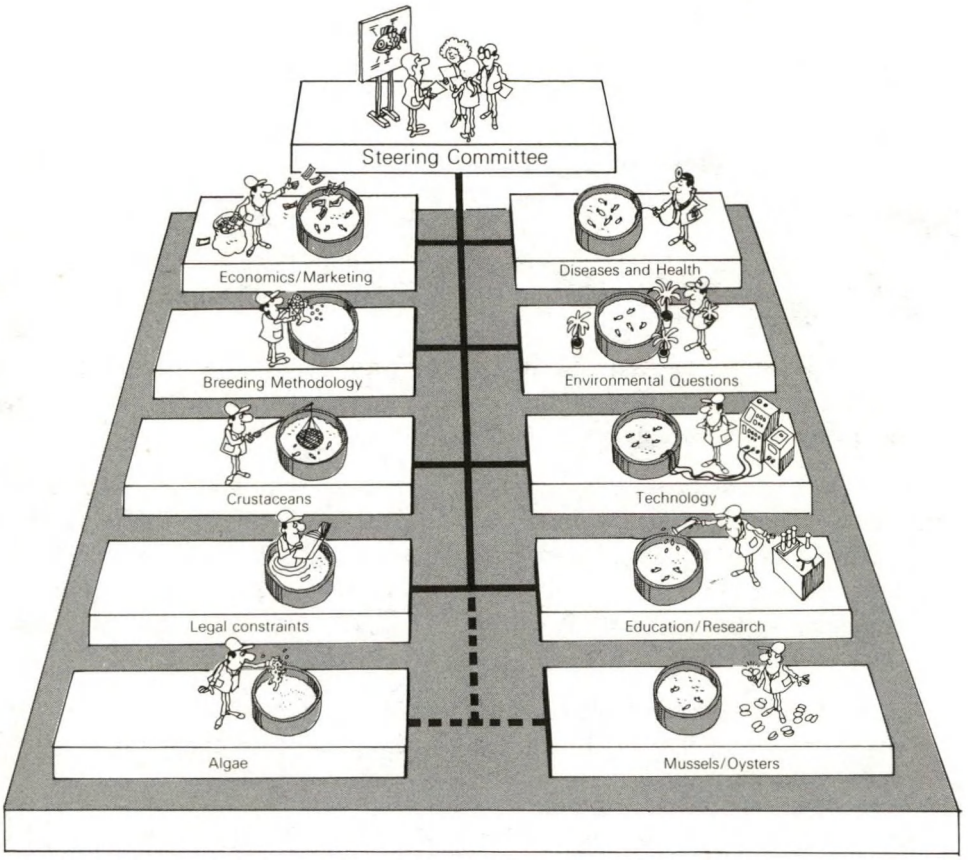


Figure 1. The Swedish Steering Committe on Aquaculture and its working groups.

Prospects for Aquaculture in Sweden

Final report and proposals from the Steering Committee

For two years, 1981-82, the Steering Committee on aquaculture and its eight working groups have analysed the possibility of building up an aquaculture industry in Sweden. This report summarizes the background, analyses and proposals of the different groups which briefly can be divided into four main areas: economy/marketing, administration/organization, research and education.

The whole project comprises in total nine published reports which deal with legislation, environmental effects, economy and marketing, diseases, breeding, crustacean culture, culture techniques, education and research. The culture techniques report includes a chapter on the cultivation of mussels. Nutrition and the cultivation of algae are also briefly dealt with in this report. Two new working groups will cover the cultivation of mussels and algae.

The importance of fish and shellfish cultivation for the production of food for the world is discussed against the background of the present production of food on land and in water.

Globally, aquaculture yielded in total about 10 million tons of fish, shellfish and algae in 1981 or about 13% of the total yield from all seas and lakes. In 1970 this figure was only 7%. This shows clearly that aquaculture is developing very rapidly, and FAO predicts a production of 30 million tons by the turn of the century. Of the total yield in 1980, 84% came from Asia and 13% from Europe. Although the present production from North America is only 1.6 % of that of the world, the absolute figure will probably increase very quickly.

About 50,000 tons of fish and shellfish are cultivated yearly in Scandinavia. The greater part of this is made up of rainbow trout and salmon in cultivation for consumption. Sweden cultivates only about 2 000 tons of rainbow trout and just under 1 000 tons of blue mussels.

About 10 species of fish are cultivated under the auspices of fisheries conservation in Sweden. The commercial fishery mainly favours the promotion of salmon, trout and eel. Other species such as rainbow trout, trout, brook trout, char and

grayling are important to sport fishing. Thanks to the many compensatory cultivations of salmon there is a relatively large salmon population in the Baltic.

The rapid development of aquaculture in the industrialized areas of the world can be explained by, among other things, a stagnating sea fishery, increasing energy prices, increased pollution of seas and lakes, the market demand for certain fish species plus the realisation of the value of fish and shellfish as nourishing food.

Apart from the cultivation of fish for consumption, fish are also cultivated for bait, aquaria, biological control methods and research. Mussels are cultivated for the production of pearls, and algae for the production of chemicals for amongst others the food industry, for conversion to energy or for the treatment of sewage.

Figure 2. Farming in net cages is now the most common method for the production of rainbow trout in Sweden.
Photo: Hans Ackefors

Culture techniques are developing along low-energy cultivation lines where the nutrients are recycled. Aquaculture — agriculture and aquaculture — industry will become more and more integrated so that warm water effluents and other waste products can be utilized for the production of fish food. The Chinese polycultures, where fish food is produced with the aid of agricultural and community wastes provide models for a new way of thinking for the Western world.

All use of land and water for agriculture, industry, society etc. has an effect on the environment. This is also true of aquaculture. In cultivation the surrounding water is loaded with phosphorus from feed and excretion products. Through appropriate localization and culture techniques and an optimization of the production level, the phosphorus load can be limited. Waste from cultivation must be seen in a larger context. The production of 4 000 tons of cultivated fish in the Baltic proper would result in an increase of only 0.24% of phosphorus and 0.04% of nitrogen in comparison with what is now released into the Baltic from the urban communities, industry and atmospheric deposits.

The incentives for a Swedish aquaculture industry are manifold. Roughly 9% of Sweden's surface is covered by water and the coastline is more than 7 000 km long. The quality of the water is good in most cases. The accumulation of toxic substances can be restricted in cultivation by the use of suitable fodder. The large import of fish products can be cut down. Sweden imports more fish and fish products per capita than any other country in the world today. In 1980 the budgetary balance showed a deficit of 1.1 billion Swedish crowns and in 1981 the deficit was 670 million crowns. This represented 11% and 37% of the total trade deficit respectively.

Figure 3. The cultivation of blue mussels with the long-line method is now quite common on the Swedish west coast.
Photo: Hans Ackefors

The Steering Committee envisages the cultivation of 9 000 tons of fish, 1 200 tons of crustaceans and 15,000 tons of mussels by 1990. This represents an immediate value of 343 million Swedish crowns which is the same as 66—80% of the values of commercial catches in the fisheries for the years 1979—1981.

The effect on the labour market of a Swedish aquaculture industry can be expected to be quite large. The anticipated volume of cultivated products in 1990 could well provide up to 2200 jobs and by the year 2000, 6400 people could be employed directly or indirectly in aquaculture.

Fish and crustaceans as a food source are becoming more and more usual. Economically they are cheaper to produce than meat. From the aspect of health they are perhaps even more important. The risks of heart and glandular diseases can be decreased. The importance of aquaculture for the sport fishery is also increasing.

The Steering Committee's proposals for the founding of a Swedish aquaculture industry include amongst other things guidelines for production, proposals for the combination of marketing, sales and distribution of cultivated products, for trade policy procedures, regional and fishery policies as well as administrative and organizational measures. In addition, the committee has put forward proposals for a multidisciplinary research institute for aquaculture and the educational structure which should be aimed at for the building up of aquaculture in Sweden.

The Steering Committee recommends that the production of salmon, trout, other salmon species, eel and freshwater crayfish should be sited in selected waters and combined with conservation measures. For extensive and intensive cultivation different species are recommended for freshwater, the Baltic Sea and the West coast. Special recommendations and proposals for intensive production using waste heat are given.

The extensive production should preliminarily include salmon, sea-trout, eel, river crayfish and signal crayfish. Intensive production in natural waters is most suited to large rainbow trout, salmon and char. Intensive cultivation with supplementary heat is best suited to eel and turbot. All recommendations are made taking into account the economy/market and physical conditions.

The Steering Committee proposes the foundation of a new organization with the working name "Swedish Fish Company" with a central marketing function with regard to both naturally caught as well as cultivated products. This company should embrace many functions in order to support the industry with help in establishment, product development, marketing, export and import, legal questions etc.

Trade questions regarding customs and excise and import duties are dealt with as are fishery policy. Investment in aquaculture should be assisted with the help of a new type of loan, specifically designated for aquaculture, and by the changing of present rules for the founding of companies. Total investment requirements are estimated at 48 million crowns per year for the period 1983—1987.

The Steering Committee proposes various administrative and organizational measures. Proceedings for the granting of permits for setting up aquaculture operations ought to be simplified. Water planning should in certain cases be carried out at the county and community level. Breeding and quarantine stations ought to be set up.

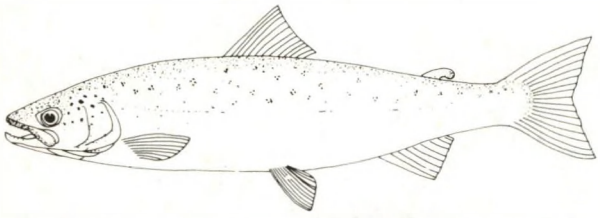
The organization for the diagnosis and prevention of fish disease should be strengthened centrally and regional advisory services should be instituted.

An aquaculture committee should be set up to temporarily guide the development of cultivation. This committee should be linked with an international reference group, a research group, a group for applied aquaculture and a group representing commercial interest in aquaculture.

Research will be of great importance in the development of aquaculture. The Steering Committee proposes the founding of a multi-disciplinary institution. The institution should be centrally situated and attached to a university. Research will take place at regional field stations or institutions. In total, it is proposed that 15 research groups in biology, techniques and economy be set up.

Education in aquaculture at different levels from high school to research training at university is proposed. Cultivators, advisors and researchers are those primarily in need of training, but administrative education should also be instituted.

Aquaculture and Economy



In the future, fish products will constitute an increasingly large share of the food consumption in many countries. Warm blooded animals such as pigs and broiler hens have a lower rate of protein conversion than fish, and therefore it has become more expensive to produce meat products. The growing public interest in nutritional issues has also led to greater interest in eating fish and shellfish. In addition, reduced food subsidies in Sweden will be advantageous in promoting the consumption of fish.

Our country has good prerequisites for aquaculture. No less than 9% of the land surface is covered by lakes, and the coastline is more than 7000 km long. However, the environments which are characteristic for the different parts of Sweden must be taken into account. The report evaluates the cultivation conditions for various salmonids, eel, turbot, carp, mussels and freshwater crayfish with regard to the environment, cost estimates, and market analyses for both domestic and foreign markets. In addition, the importance of marine algae for industries concerned with foodstuffs, colourings, medicine and textiles is discussed.

Despite geographical problems, the distribution of everyday commodities in Sweden is more rational and effective than in most other countries. A very strong cooperative organization for farmers produces and distributes its own agricultural products throughout the entire country, and to all sorts of consumers. Nearly all of the remaining commodities are distributed by the three large grossist firms KF, ICA and DAGAB. However, this does not apply to fresh fish, which due to its perishability, requires special, expensive arrangements.

In Sweden there is still a separate distribution network for fresh fish, which works on a strong local basis. At present, this system is poorly adapted to the kinds of distribution, product development and marketing that the modern food industry needs.

The Swedish fishing industry is mainly geared towards the harvest, distribution and sale of unprocessed, fresh fish. However, Swedish consumers have begun to demand highly processed products, which as a result are mainly imported.

The disparity between the yield of the fishing industry and consumer demands has led to a significant imbalance between exports and imports of fish products. In 1979, this deficit amounted to 861 million crowns, which was more than the total Swedish budget deficit of 779 million crowns. By 1980, the deficit in fish products had increased to 1,128 million crowns. Unless measures are taken, this negative trend will continue.

Unfortunately, Swedish fisheries and aquaculture have to overcome some major trade problems of a political nature. Sweden must pay customs duty when exporting goods to EEC countries, while her competitors on the Swedish market do not have to pay equivalent duties.

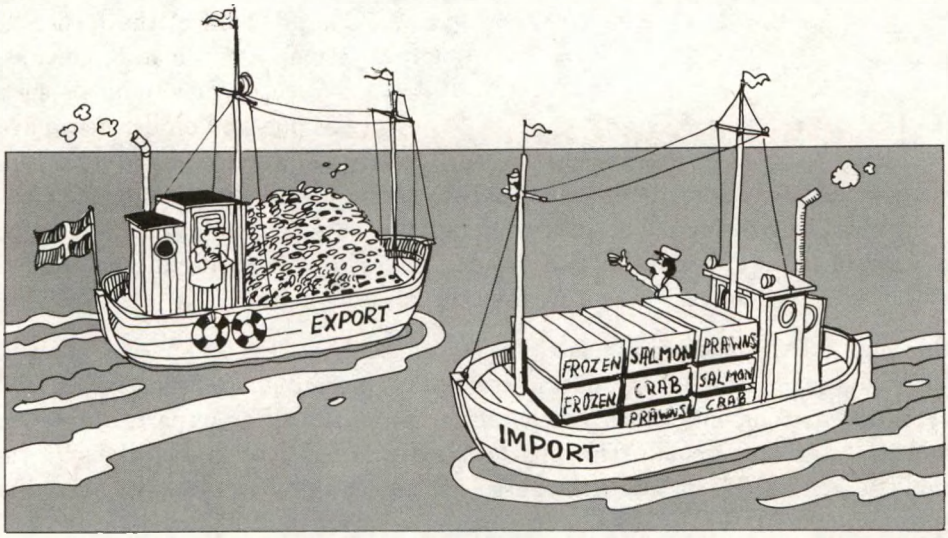


Figure 4. Sweden exports, above all, unprocessed fish of low commercial value but imports consist of processed fish, mussels and crustaceans of high commercial value.

At present, 80% of the deep frozen cod which is consumed in Sweden is imported from either Norway or Denmark. No less than 95% of the salmon is imported.

The employment potential of Swedish aquaculture may be considerable, especially in sparsely populated areas where there are few jobs. Fishermen who can no longer support themselves by fishing alone, or other qualified persons, may be able to find part-time or full-time employment in this field. It is calculated that a total of about 2000 persons will be directly or indirectly employed in intensive cultivation by 1990. Moreover, employment will be provided by cultivations producing fry for fisheries management or for the cultivation of food fish.

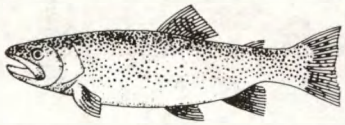
The working group for "Marketing and Economics" has devoted a large amount of time to analysing the distribution network for fresh fish in Sweden. Regrettably, this system has not been rationalized as has the rest of the food trade. This has resulted in poorer marketing practices, longer distribution routes, a larger number of intermediate steps, and consequently a greater rise in price from the producer (the fisherman) to the consumer than for other food products. A more rational distribution system must be introduced and coordinated with, for instance, new methods for maintaining the quality of fresh fish. If Swedish fish marketing bodies are not able to accept new ideas concerned with packaging fresh fish, maintaining its quality etc., both Swedish fisheries and aquaculture may be hit hard, which will also affect the Swedish economy in the long term.

Consequently, the fisheries sector must be restructured. The following report attempts to illustrate the necessity of such a measure. It indicates a number of alternatives which can and should be developed, as well as several ways in which fisheries and aquaculture should be seen in the same context.

The group has made the following proposals:

- A strengthening and restructuring of the present marketing organization of the fisheries sector.
- A reevaluation of the possibilities of political intervention concerning trade agreements.
- Political measures to aid fisheries in the form of a special aquaculture loan (comparable to fishery-loans).
- The renewal and supplementation of existing forms of support (rural support schemes, operating credit, loans for product development, and regional political support) to achieve a more suitable adaptation to the structure and needs of the aquaculture industry.
- The development of suitable insurance schemes.

Aquaculture and Pathology



The field of fish cultivation in Sweden underwent a phase of development and structural transformation in the 1950's and 1960's. The cultivation of rainbow trout changed from being a technique which farmed sparse populations of fish to one adapted to high fish densities. The hydroelectric industry built compensatory cultivation operations in order to farm salmon smolt in troughs and tanks. The transport and import of live fish became more common. All of these developments increased the risks of spreading and introducing serious contagious diseases. Same diseases resulted in severe losses. Therefore, at the beginning of the 1950's, a state-organized program was initiated to combat fish diseases. The immediate reason for this effort was the introduction of the disease furunculosis to Sweden with an import of fish material. Operations to combat fish diseases were thereafter organized in the form of a health control service run by fish pathologists at the Swedish State Veterinary Institute (SVA) and the Salmon Research Institute (LFI), whose main task was to prevent the spread of serious contagious diseases to and within the country.

During the 1970's, the farming of food fish, with the help of a new technique, net pen cultivation, increased further, as did other forms of aquaculture in Sweden. This has lead to significant changes in the disease situation and created an even greater need for a new, enlarged organization for the combat of diseases.

The following contagious diseases either occur in Swedish fish farms or risk being introduced with imported material: the virus diseases *IPN* and *VHS;* the bacterial diseases *furunculosis, vibriosis* and *contagious dermatitis;* the parasitic diseases *white spot disease* and *whirling disease;* various *skin and gill parasites* such as *parasitic nephritis, eye fluke* and the *salmon louse;* as well as diseases of uncertain origin, such as *UDN.* In the case of invertebrates, special mention should be made of *crayfish disease.* In addition, there are ailments caused by dietary deficiencies and metabolic disorders, and diseases caused by a combination of factors.

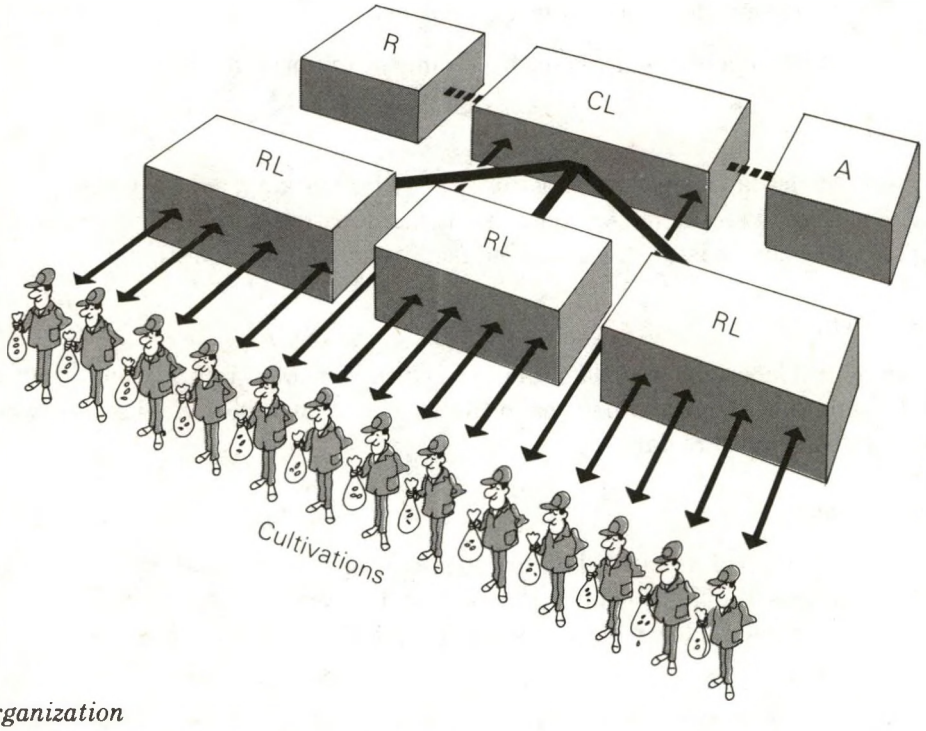
Due to the present rate of expansion within the aquaculture sector, and taking into consideration future developments, e.g. new techniques, it is likely that the disease situation will be continually changing. Large demands will be placed on health care, diagnostic methods and the combat of diseases. It is necessary to carry out research into diseases caused by viruses, bacteria, fungi and parasites, as well as those of nutritional origin in order to gain more knowledge about them. This research should be carried out in direct contact with industry and with health consultants engaged in field work.

The financial consequences of these diseases are quite considerable, and the average losses in Skandinavia are on average 10 to 20% of the production value. There

are two main approaches to combatting the diseases; preventive measures and acute measures. The former include preventing the spread of disease, increasing the resistance of the animals, improving the cultivation environment and improving the nutritional status of the animals. In the case of an acute outbreak of disease, internal and external chemotherapeutic methods are used, and in case of infection under the epizootic layer (IPN, VHS), it may be necessary to slaughter the animals.

At present, the health control service, originally suited to the needs of compensatory cultivation, is completely inadequate. A new organization for combatting diseases must be dimensioned and differentiated so that there can be a gradual adaptation to a growing volume of production and increased specialization within the aquaculture sector.

Below is a proposal for the future organization of operations to combat diseases:



Organization

The organization should be responsible for:

1. Surveillance and preparatory measures as regards epizootic and certain other contagious diseases (the prevention of contagion).
2. General preventive measures and an advisory service for health issues (health control).
3. Diagnosis and treatment, or recommendations in connection with outbreaks of disease (medical service).

CL: Central Laboratory with diagnostic specialists, an advisory service, some health control.

R: Responsible Authority with a center for the prevention of contagious diseases, overall responsibility for the administration of preventive measures.

A: Advisory Board, composed of representatives from R, CL, RL and C, with the task of steering the direction of measures to combat disease.

RL: Regional Laboratories with limited diagnostic functions, consultants.

C: Cultivations.

Three steps are proposed for building up such an organization:

1. Immediate measures: an expansion of basic resources to cover present requirements; the establishment of a center for the prevention of contagion, attached to the Responsible Authority; and better resources for existing laboratories.
2. The successive development of regional centers.
3. An adaptation of resources to the volume of production.

Import

There is a need for imports as regards fish fry for stocking, breeding material and new species. Present import regulations, administration and controls must be improved and the issue of quarantine facilities should be investigated.

Information

The central laboratory should organize a continual flow of information to cultivators and other interested persons in the form of a hand book on diseases, which should be kept up to date.

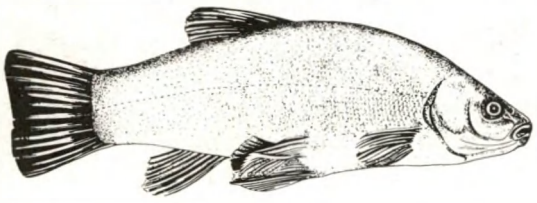
Education

Regular courses of a practical nature should be held for cultivators. Yearly orientation courses should be held by the Swedish University of Agricultural Sciences for agricultural students, science students, veterinaries, fisheries employees and cultivators.

The two year course in fisheries management at the University of Gothenburg should be extended by a third year, which should include a course in health care.

Support should be provided for graduate courses in the subject area at university institutes of veterinary medicine, zoology, limnology and microbiology. There should be more cooperation between the university institutes and the central laboratory. It should be made possible for research students to participate in relevant courses overseas.

Fish Breeding and Fisheries Management from a Biological Perspective



There is a wealth of well-documented research results of direct importance for the effective utilization and protection of genetic natural resources, but for various reasons — practical, juridical and educational — these are not always put to use in current fish farming practices. Therefore, our aim has primarily been to try and estimate 1) to what extent current knowledge is used and what prevents its application, 2) which methods within fish cultivation — especially those concerning breeding methods in a strict sense — can be assumed to improve fish cultivation and thus genetic fisheries management, and 3) how these problems can be solved practically in a better manner than at present.

By distributing a questionnaire to Swedish fish farmers we have tried to determine the greatest weaknesses of the present methods, as well as to study any other possible limitations, such as in the capacity for spawn production. As a side effect of the questionnaire we were able to see which fish species dominated current fish cultivation in the country (due to the large percentage of answers) as well as which farming methods were most widely used for the various species.

The working group has dealt foremost with the basic genetic and ecological principles within fisheries management and more particularly with those factors affecting fish cultivation. Only fish have been studied, but the resultant principles can even be applied to other aquatic organisms. Three main subject areas can be distinguished: cultivation for stocking of fry (fisheries management, including so-called compensatory cultivation), cultivation for human consumption, and preservation of genetic natural resources (species and populations threatened by extinction). There are significant differences between the aims and methods of the three areas and the genetic principles can be said to be the only common denominator. The aim has been either to tailor the fish to the requirements of cultivation for consumption, or to retain the functional characteristic features of a population for stocking purposes. Gene banks and conservation aim to adapt the preservation methods as far as possible to basic genetic principles for reducing inbreeding and

counteracting the loss of valuable alleles. As the aim of the present investigation has also been to provide guidelines for alternative breeding methods and associated fisheries management, even general biological, practical, economic and juridical considerations were taken into account.

Proposals and consequences

The practical and theoretical background to the recommendations made by the working group is an attempt to compromise genetic theory, general biological knowledge and practical circumstances. The main goal has been to allow the genetic "demands" to form the initial starting point. The various theoretical and practical judgements have not always been easy to compromise, with the result that certain parts of this report may contradict each other. This is mainly due to different opinions as to when and how the results of certain analyses should be interpreted. It should be pointed out, however, that differing opinions within the working group have led to dissimilar views on giving priority to measures for improving current fisheries management and fish cultivation in Sweden.

Administrative measures

Some proposals for improvement only concern a special category of fish farming activities, while others are more general. The proposals have further been divided

Figure 5. Sweden has long traditions concerning fisheries management in fresh waters. The strengthening of stocks by releasing juvenile fish is a common method.

into those which must be resolved within a short-term perspective and those which either depend on other short-term measures being resolved first or can be regarded as being relevant in a longer perspective.

Among the short-term goals are the presentation of advice and directions for a more biologically adapted breeding technique for all three forms of fish farming activities as well as the compilation of a standardized data base for fish and crus-

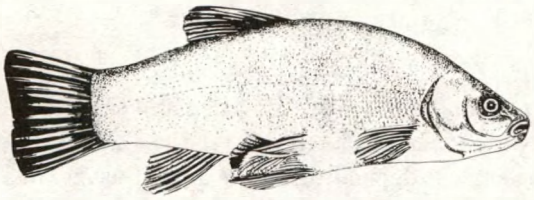
taceans. In addition, improved practical and economic resources are necessary for experimental fish farming, for the establishment of three central breeding stations for controlled breeding practices modelled on those used for domestic animals, and for the appointment of a state investigation into gene banks for fish and crustaceans so as to protect natural genetic resources. In a longer perspective it is necessary to improve juridical measures to minimize the movement of fish between water systems, to simplify the administrative procedures for creating nature reserves to protect valuable fish populations, and to establish a national quarantine farm for fertilized spawn so as to safeguard import and export prospects for expanding the domestic stocks of exotic fish species and crustaceans.

Research and education proposals

The most urgent research requirements concern the identification and characterization of fish populations in natural waters and stocks in fish farms as well as the need to compile quality criteria for fish stocks depending on the area of usage. In a somewhat longer perspective, it is important to continually evaluate fisheries management measures and to develop methods for long-term storage of spawn and milt. Educational problems are centered around the need for developing the current university course from a two year education in fisheries management to a complete three year course in fishery biology and for the establishment of a multidisciplinary institute with responsibility for organizing research and education within the aquaculture sector. Furthermore, it is recommended that continuous educational activities be provided for tradesmen and that advisory services be instituted in practical and theoretical fish cultivation.

Many of the proposed recommendations can be fulfilled by using relatively simple administrative measures and existing personnel. Others require the re-allocation of research resources for the development of methods, while a third group demands the establishment of new nationally financed services.

The Environmental Impact of Aquaculture



This report is an investigation of the environmental consequences of the cultivation of fish, mussels and algae in water bodies and coastal areas. Depending on the location of the cultivation, the volume of production, the techniques used and on whether processing takes place in the vicinity of the cultivations, the surroundings are affected to various degrees. The report deals with the composition and properties of by-products and wastes which result from different kinds of cultivation operations as well as the type of environmental effects which can be predicted. In general, the wastes consist of naturally occurring and easily degradable substances, which are quickly recycled in the ecosystem. Compared with other activities utilizing Swedish waters, the contribution from cultivation operations is, from a quantitative viewpoint, very small at present.

The report presents means of reducing the environmental effects of aquaculture. These include the alteration of feed composition, the collection and recycling of wastes, the combination of different forms of cultivation and the use of so-called coarse fish from the recipient for feed. In addition an investigation has been carried out into the environmental effects which occur when fish production in natural waters is altered as a result of fertilization, lime treatment, stocking of other organisms, and so on.

The environmental consequences may constitute a limit for the exploitation of fresh water bodies and coastal areas for aquaculture. Therefore, finally, a number of research areas are identified as being able to provide a more detailed examination of the environmental effects of different forms of aquaculture as well as to result in methods to decrease these effects.

The environmental effects which can arise as a result of discharges from cultivations and altered production in natural waters can be summarized as follows:

- All intensive cultivation operations result in a release of nutrients and organic matter.
- The phosphorus thus released is responsible for the greatest effects in inland waters, while nitrogen is usually of most importance in coastal areas.
- The amounts of waste are dependent on the volume of production and the waste treatment measures.
- The amounts of waste which are released determine the location of aquaculture activities.
- With regard to cultivation techniques and discharges, net bag cultivations should primarily be located in coastal areas or in nutrient-poor lakes which are judged as being able to accept an increased nutrient load.
- Improved feeding techniques (better feed coefficients) and/or the development of techniques for collecting the wastes will decrease environmental effects.

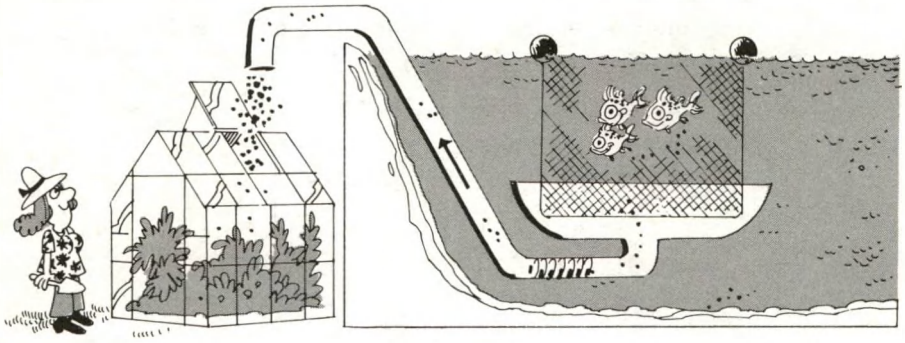
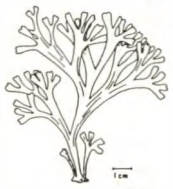


Figure 6. Wastes and excess feed must be collected under the net cages, and be recycled.

- Net pen cultivations should be located so that the wastes do not reach the deep areas of lakes, where the oxygen content is usually limited.
- Sedimenting wastes constitute a resource which should be collected and utilized.
- A combination of different cultivation techniques may be able to reduce environmental effects, as in the combination of fish farming and the cultivation of algae.
- The effects of discharges from land-based cultivations may be reduced by means of waste treatment measures.
- The fertilization of lakes in order to improve fish production should only be practised in badly damaged waters or when the effects of other activities can be mitigated or counteracted by the addition of nutrients.

- The treatment of lakes with lime is necessary to counteract the negative effects acidification may have on aquaculture activities.
- Additional stocking of existing species should only be considered when natural reproduction does not occur, or when fish recruitment is poor.
- The stocking of new and foreign fish species should be practised with restraint, as such introductions can often be regarded as irrevocable.
- The stocking of food organisms may have a positive effect on fish production in badly damaged reservoirs, but it is a measure of doubtful value in normal, unaffected waters.
- The stocking of fish in fish-free lakes should be avoided as a rule, as such lakes have become more and more uncommon and are valuable for other organisms as well as for research activities.
- Aquaculture is often "self regulating", as negative environmental consequences also damage the cultivation operations.
- Aquaculture can be integrated with other methods of utilizing water resources.
- Aquaculture techniques must be adapted to environmental demands.

Cultivation of Algae



Algal products are more extensively used in Sweden than is commonly known and the value of the products corresponds to about 100 million Swedish crowns (SEK) per year.

Today all these products are imported or are manufactured from imported raw materials. In Sweden the cultivation of algae is new. Traditionally, algae have only been used here as fertilizers and to some extent as fodder.

The development of modern cultivation techniques implies that algae in the very near future will be cultivated here in units on land and in shallow water to supply both biomass for fermentation into energy (methane) as well as fodder, raw materials for medicines and other commercial products (e.g. agar, carrageenan, alginates, algal meal). By using modern biotechnology and gene manipulation algae can in the future also be induced to provide other chemical substances on a large scale.

Algae are also a valuable supplement to human food, as well as to animal fodder, due to their high content of vitamins, minerals and protein. This resource could be still better exploited by increasing publicity about algal products.

Furthermore, it is shown in the paper that aquaculture of algae can be utilized for sewage treatment, thereby removing considerable amounts of nutrients (nitrogen and phosphorus) from the water. The importance of this will increase with the progressive eutrophication of our lakes and coastal waters. Algae also make good fertilizers. Previously in Sweden there was even legislation stating which people in the coastal provinces had the right to collect this natural resource, which accumulates along the shore. Today we could substitute artificial fertilizers with a natural product, which at the same time would improve the structure of the soil.

The cultivation techniques can be adjusted to produce either macro- or microalgae. The prerequisites, together with the intended use of the yield, will decide which kind of algae are most suitable. This is particularly important when specific chemical products are required.

The paper describes algae and systems which are already possible to use in Sweden today. Examples of macroalgae are the red algae *Chondrus* and *Furcellaria* (carrageena and similar products), the brown algae *Ascophyllum* and *Laminaria* (alginates), the green algae *Ulva, Enteromorpha, Cladophora* and the brown algae *Ectocarpus, Pilayella* and *Fucus* as well as several others (fermentation to energy). Examples of microalgae are the bluegreen alga *Spirulina* (protein), the green alga *Chlorella* and others as well as diatoms for fodder. Macroalgae can be cultivated by the spray or drip technique developed for units on land, in free-floating or rope cultures in shallow coastal areas, and in tanks and ponds. For microalgae, open or

closed tanks or ponds can be used. The addition of fertilizers, air and organic substances is also discussed and some cost analyses are presented.

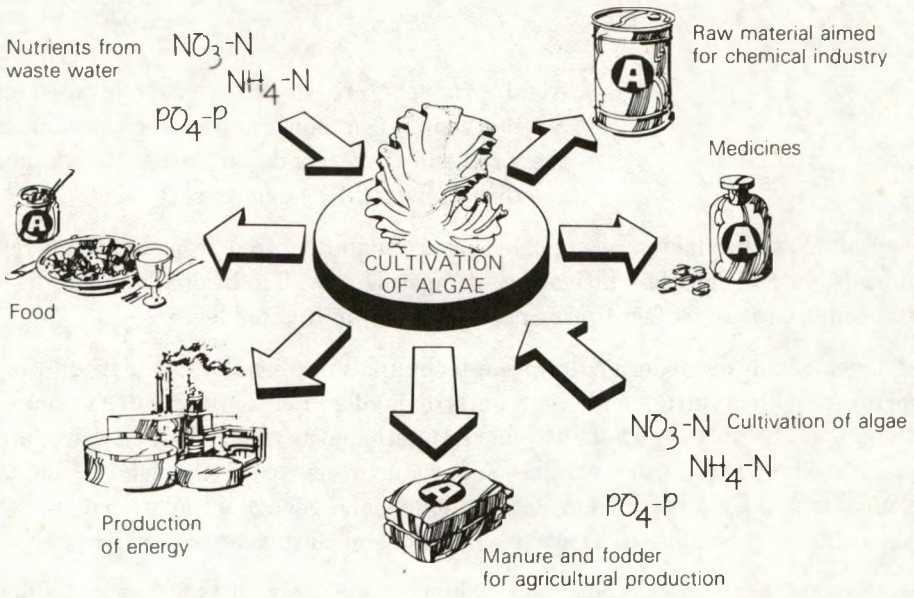


Figure 7. The cultivation of macroalgae (or wild harvest) for production of food, fodder, manure, chemicals and medicines is common in many countries. However, the algae can also be used to purify waste water and absorb nutrients from fish and mussel cultivations.

However, further development and improvements are needed before these systems can be made economically feasible for Swedish conditions, especially regarding our high salary standard and the Swedish climate. Product development and marketing are other areas needing more attention before the aquaculture of algae can be economically optimized.

The paper also reports on algal cultivation in other countries, both using traditional and new techniques. In these countries, rapid improvements in both the yield and quality of the algae have been largely due to research. International scientific co-operation and exchange of ideas are thus prerequisites for the future success of the aquaculture of algae in Sweden, particularly concerning production and product development.

Combined aquaculture (polycultures), including both primary producers (algae) and animals (fish and shellfish) have interesting possibilities in the future and seem to offer better economy. At the same time these systems are also more environmentally suitable, since the algae can take up and utilize the animal excretion products to a very large extent.

Algal diseases and other threats (epiphytes, grazers) are briefly summarized. The risk that algae which produce toxic substances will appear in the cultures is considered to be small.

Plant breeding through the selection of suitable clones, hybridization, mutagenically induced characteristics or tissue and cell culture techniques offers still better possibilities of optimizing the usage of algae or of concentrating their production to a specific chemical substance. This is exemplified by microalgae which can be induced to produce almost solely ammonium compounds, amino acids or other highly desirable substances, and by the fact that tissue cultures of red algae have produced an agar content of up to 75% of the dry weight.

The need for research and development to make the aquaculture of algae economically profitable in Sweden has been analysed. An annual investment of about 2.5 million Swedish crowns (SEK) is needed for biological research (salaries) on macroalgal culture, microalgal culture and polycultures. To this have to be added the costs for genetic and chemical research, which should be included in the biotechnological program.

Swedish Aquaculture and Crustaceans

The demand for various crustaceans, such as freshwater crayfish, European lobster, Norwegian lobster, crab and the northern shrimp, *Pandalus borealis,* is considerably greater than the natural supply in Sweden. The trade deficit is 290 million Swedish crowns. New crustacean products, in particular prawn tails, have been introduced during the last few years. This is because food habits have become internationalized, freezing has become a more common method of preservation and because crustacean products are very tasty, even after being deep frozen. The consumption of crustaceans deserves to be promoted, on both ecological and nutritional grounds. One problem is, however, that the large and increasing international demand for these products keeps prices at a high level.

The investigation has carried out an inventory of the natural yield of crustaceans in Sweden and an attempt has been made to judge whether it would be possible to replace imports by improving the management of Swedish resources or by means of cultivation.

The possibilities of developing cultivation operations have been investigated in more detail. Species such as crab, Norwegian lobster and the northern shrimp, *Pandalus borealis,* were not considered in this discussion. The cultivation of lobster is not economically justifiable at present, even though the techniques are wellknown. Neither would it be justifiable for Sweden to concentrate on developing her own methods for cultivating these species. Instead, Swedish researchers should follow the work being carried out in other countries.

The European crayfish, *Astacus astacus,* the most popular Swedish crustacean, has been hard hit by the crayfish-plague and there seems to be no possibility of the affected populations recovering. Research has not been able to yield any practical methods for protecting healthy populations from the disease.

The signal crayfish, *Pacifastacus leniusculus,* imported from North America, is a suitable substitute for the native crayfish, and it is resistant to crayfish-plague in natural surroundings. Experimental introduction of this species into plague-ridden waters has been successful. However, many valuable crayfish lakes have

been affected by acidification and will be unsuitable for stocking unless lime treatment is carried out regularly in the future. If the remaining populations in healthy waters are to be managed effectively, it is necessary to conduct more research into the ecology of crayfish. The signal crayfish has the best qualifications for cultivation in small or large ponds and lakes which have been cleared of coarse fish and in which the crayfish can be combined with suitable fish species. Sometimes, different species may favour each other so that their combined production is greater than the sum of the production yielded by separate cultivation of the species. Crayfish can probably be combined with other species such as salmonid fishes, which are popular among sport fishermen.

There are several interesting species of crustaceans which are adapted to warmer climates and thus cannot reproduce naturally in Swedish waters. Such species could, however, be cultivated in heated water which is filtered and recirculated through the cultivation several times. In many parts of Sweden, warm waste water is released, for instance by industries, without being utilized. This is a cheap

Figure 8. The signal crayfish, **Pacifastacus leniusculus,** *imported to Sweden from North America in 1960, is a suitable substitute for the native crayfish in areas where the latter species is attacked by the crayfish-plague.*
Photo: Magnus Fürst

source of energy if it can be combined with cultivation operations. Species which could be suitable for this type of intensive cultivation are crayfish such as the American *Procambarus* and the Australian *Cherax,* the very large and tasty freshwater shrimp *Macrobrachium* and possibly the signal crayfish.

In many countries, extensive cultivation can be operated profitably without being highly efficient. On the other hand, intensive cultivation has not proved to be completely sound economically. Despite this, it is of economic interest, as further research is thought to be able to develop this field considerably during the coming decade.

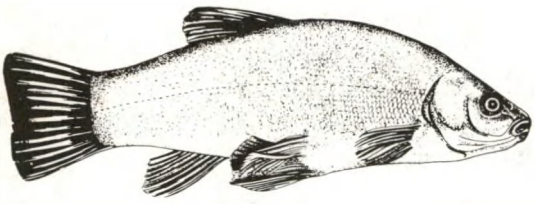
The kind of research which is a prerequisite for the development of economically sound aquaculture has been specified in a number of projects. The projects have been listed according to priority, so that the most important ones can be initiated first. This also enables a valuable continuity to be maintained within the research field.Combined, the projects are estimated to require approximately 100 man-years of research.

It seems that the best way of achieving results would be to initiate and organize research activities using a small number of researchers during the first few years. During the following five to ten-year period, intensive research would be carried out by researchers employed by various projects to solve the most important problems which do not require lengthy follow-ups. At the end of this period, long-term research should continue into breeding programs, the combat and control of diseases and the testing of new species. Long-term aspects should be considered when improving methodology while at the same time, developments in other countries should be followed. It is of the outmost importance that economic analyses be carried out parallel to developmental work, in order to continually choose the lowest costs in relation to the production results.

In Sweden, the total budget deficit for crustaceans is 290 million crowns per year. This includes the import of 2 000 tons of freshwater crayfish (see table 1, figure 6). If fisheries management can be improved as a result of increased research activity, while signal crayfish are stocked at the same time Sweden's production of crayfish can probably be increased from the present value of 50—75 tons to a maximum of 1 000 tons. It is likely that the demand for crayfish can be completely satisfied if the proposed research projects, which also deal with cultivation, can be carried out. The value of 2 000 tons of Swedish crayfish would be approximately 100 to 150 million crowns if the price paid over the counter was 50 to 75 crowns per kg. The present price, due to the great demand, is about 150 crowns per kg. The aim is to reduce the budget deficit for other crustacean species as well. A comparison should be made with the cost of the research, which is estimated to be about 3 million crowns per year in salaries and social fees over a ten-year period. After this period, research activities are to be halved. One of the investments would be premises for experimental work, covering an area of about 250—300 m^2.

Research into ecology, behaviour, breeding and diseases should be solely state-financed, as the application of such knowledge concerns a broad and diverse group of customers. As regards species with higher temperature requirements, however, it should be possible to count on support and cooperation from those industries which have access to heated waste water.

Technology and Aquaculture



Fish have been farmed in Asia for several thousand years in a truly ecological manner through recycling and multi-species culture. Fish farming and agriculture have been integrated.

In the Western world a development of techniques primarily for intensive culture systems and monocultures began in the 1950s and 60s. Cage cultivation, tanks, silos, troughs etc. replaced the old dam cultivation system.

Several countries have also invested in highly technical recirculation or through-flow systems built upon advanced techniques. Warm water cultivation has been developed to utilize geothermal energy, waste heat from industry, domestic sewage etc.

Interesting methods for the cultivation of algae or other water plants for the reduction of nutrient levels in receivers are being developed. The algae produced is thereafter transformed through fermentation into biogas. The cultivation of algae on land using the spray technique is on the way to becoming a reality.

Integrated systems utilizing solar and wind energy for fish, algae and tomato growing are in the experimental stage. Methods for the production of ethanol, where the waste products are used for fish farming are being tried out. Industrial and agricultural waste is used either as food or as a substrate for the growing of food for fish. A model for broiler production, worm cultivation and fish farming has been outlined.

Experiments using OTEC plants for the production of electricity are being made in the tropics. Water pumped to the surface from a depth of 800—1000 m contains large concentrations of nutrients which are used in aquaculture.

Feeding techniques and nutritional physiology are of prime importance in all intensive culture systems. Fresh, semi-moist and dry feeds are used on a large scale. Methods for the ensilage of fish waste and industrial fish are being developed for adaptation in certain cultivation systems.

Systems using integrated microprocessers, tabletop and micro computors are used in the so-called automatic control technique for the manipulation of daylight length, regulation of feeding automats etc. The aim among other things is to increase the ratio of growth to food and to retard sexual maturity.

Sexually mature fish are one of the biggest problems in fish farming. The breeding of late maturing strains, single sex populations or sterile fish is being achieved with different techniques.

A method for the overwintering of fish in water which freezes during winter is being developed. Techniques for the avoidance of super cooled water and the creation of artificial currents and the development of new types of feed adapted for the winter needs of fish are important research objectives.

Within the farming plants water must be checked and purified in the containers with the help of both biological and mechanical filters, ultra violet and ozone treatment. A new environmental technique is being developed to reduce the outflow of nutrients, particulate matter, food remains and excrement produced in cultivation and carried out in the outflowing water.

Size sorting, handling and slaughter are operations which to a certain extent require new techniques although there are certain mechanical aids available on the market. Methods using for example mobile slaughter machines ought to be developed.

Distribution and refining are important operations in the marketing of cultured products. Filleting, freezing, smoking, drying and packaging are some of the different processes in the handling of the raw products.

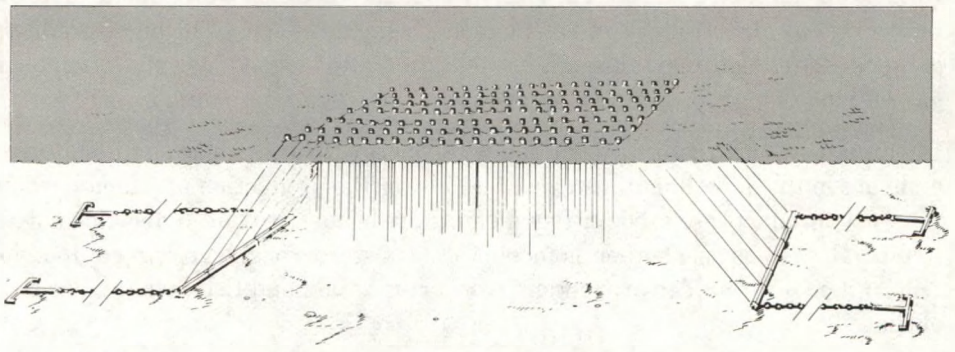
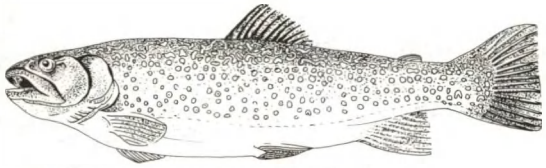


Figure 9. A mussel operation for the cultivation of 200 tons of blue mussels.

Research and the development of techniques must be stimulated in all spheres of cultivation. Proposals for research objectives in general cultivation techniques, water quality, feeding and biological techniques, automatic control, environmental energy, transport and mussel culture techniques as well as handling, treatment and refining are put forward in this report.

The formation of research groups for the development of general culture techniques and biological techniques as well as a working group for the evaluation of equipment and machinery are recommended.

The Legislative System for Aquaculture in Sweden



Applications for proposed aquaculture in Sweden have to be considered by two, or sometimes three, authorities before permission is granted:

— The County Administration
— The Swedish National Board of Fisheries
— The Water Rights Court (occasionally)

The County Administration examines applications in accordance with the provisions of the Environmental Protection Act and the Nature Conservancy Act, and refers the matter for comment to various regional and local authorities. The replies received from these authorities are studied, and regional economic aspects also taken into account, before a decision is made.

The Swedish National Board of Fisheries examines applications in accordance with the provisions of the Fisheries Act. This examination is mainly conducted internally by the fishery authorities at central and regional levels and is concerned with the risk of spreading fish diseases and introducing more vigorous fish species. The decision by the Swedish National Board of fisheries generally precedes that of the County Administration. Replies to referrals by the regional fish authority (the Regional Fishery Office) are passed on to the County Administration to assist it in arriving at a decision.

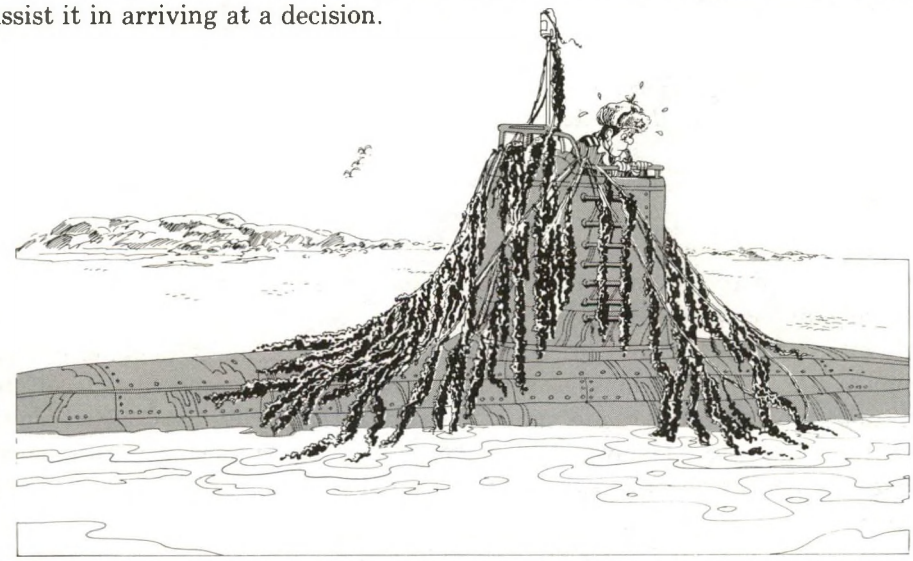


Figure 10. Competition for the usage of waters can bring about conflicts between different interests . . .

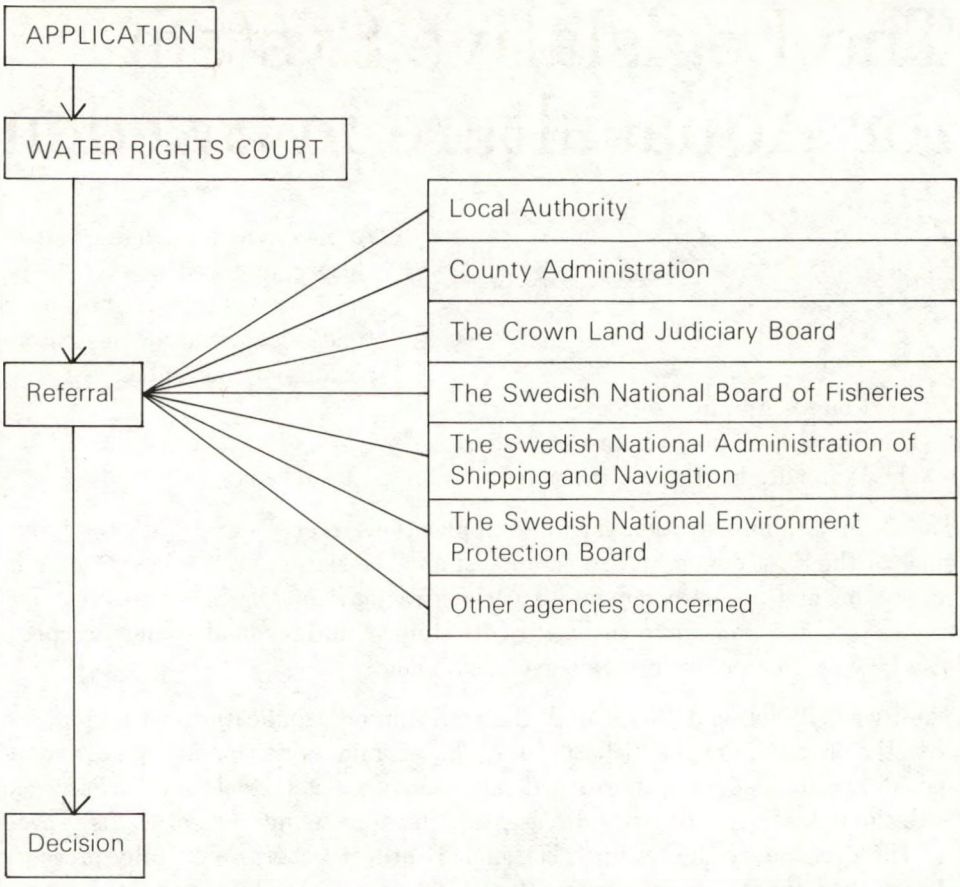


Figure 11. How an application for aquaculture is dealt with by the Water Rights Court in accordance with the Water Rights Act.

Occasionally, an application for aquaculture has to be dealt with according to the provisions of the Water Rights Act. Up to now, very few cases have had to be dealt with in this way. There are six Water Rights Courts in Sweden. Permission from a Water Court is always needed if there is a risk that proposed aquaculture will transgress public or private rights. The relevant Water Rights Court consults the various authorities involved. If, however, it is clear that there is no question of transgression of public or private rights, permission does not have to be obtained from the Water Rights Court.

Figures 11 and 12 show in outline how an application for aquaculture is dealt with in Sweden.

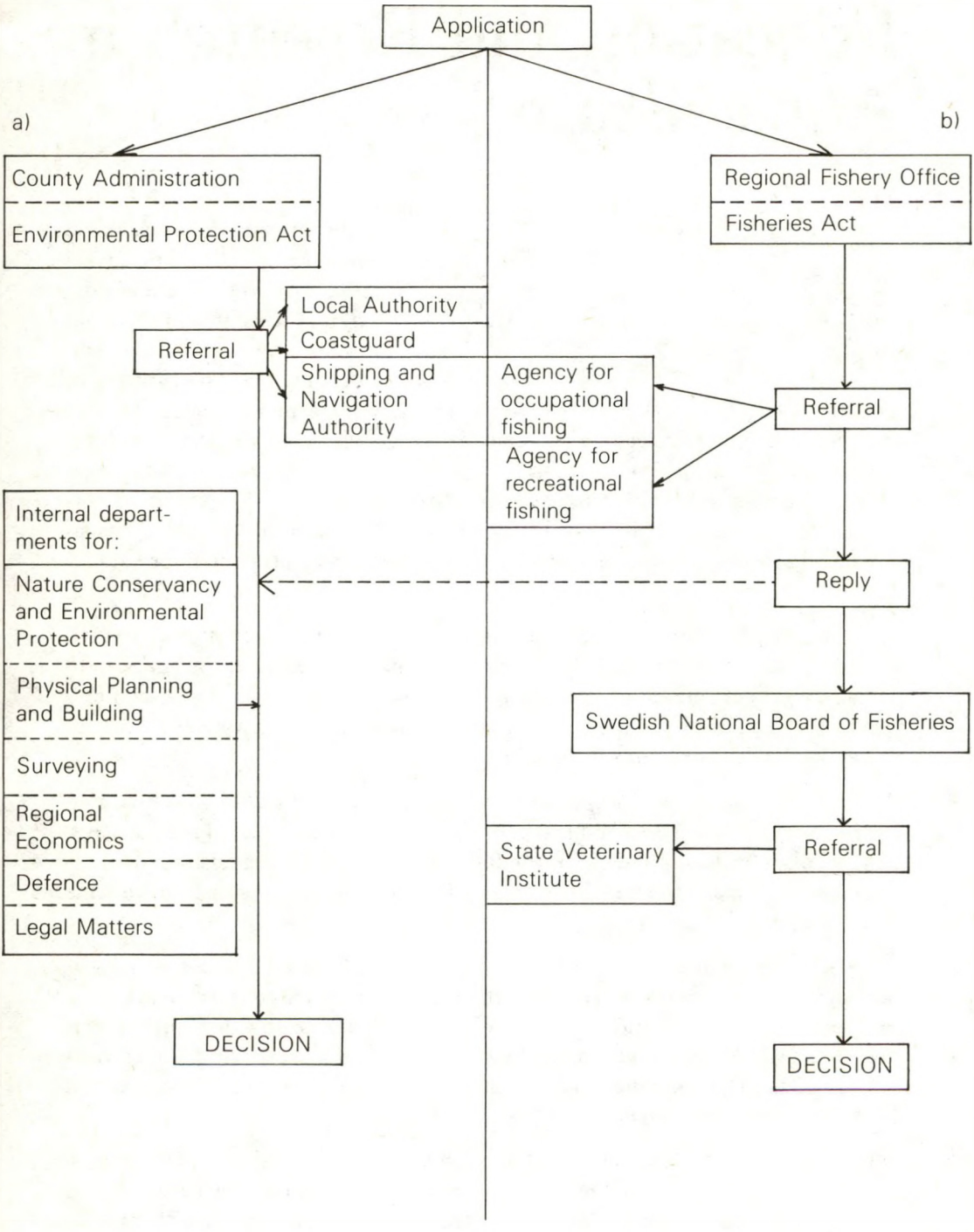


Figure 12. Routes by which an application for aquaculture is dealt with (a) by the County Administration in accordance with the Environmental Protection Act, and (b) by the Swedish National Board of Fisheries in accordance with the Fisheries Act.

Education and Research in Aquaculture

As the interest in aquaculture increases, the lack of knowledge within research and development and education in this field becomes more and more evident. There is no institute in Sweden which deals solely with research and development in aquaculture nor even one which has this as its main objective. In a questionaire sent out to different institutes it transpired that research related to aquaculture is in fact carried out all over Sweden but that this covers a relatively small area. Despite this, a certain amount of research and development work is going on in the biology, technique and economy of aquaculture at state supported institutes and in private industry.

Seen from an international viewpoint these research efforts are limited and relatively insignificant. In contrast, purposeful attempts are being made by our Scandinavian neighbours and other industrial countries by both state agencies and universities as well as by private firms. Large international corporations are also involved in the development of aquaculture.

The yield of cultured products is increasing enormously and in 1980 constituted 12% of the yield from seas and lakes for the whole world. Cultured mussels, oysters and algae yielded 70—80% of the total harvest of these organisms. Great efforts are being made to increase the percentage of marine fishes and crustaceans such as lobsters and shrimps.

In Sweden, aquaculture is poorly developed. In total, only about 2 000 tons of rainbow trout and 500 tons of blue mussels are produced per year apart from smaller quantities from approximately 10 other fish and freshwater crayfish species. Denmark, Norway and Finland have a significantly larger volume of cultivated products. The combined fish production for human consumption reached 40 000 tons in Scandinavia in 1981.

In the development of any new industry such as aquaculture education is obviously essential. Many countries have therefore provided training for eventual growers, consultants and researchers. Apart from short courses however there is no comprehensive training available in Sweden although several courses are being planned at both high school and university levels.

Although the need for research in aquaculture is greatest within the biological disciplines, it is also essential to support technical and economic research. This re-

port presents several different research models which describe various methods for the development of aquaculture. Within the biological sphere, ecology, ethology, physiology and genetics are foundations in such a development while knowledge in reproduction, breeding, nutritional physiology and pathology are important if optimum culture conditions are to be obtained.

Culture technique encompasses many different technical disciplines such as automatic control, water recycling and environmental engineering. Also important is development work on apparently simple things such as the shape of culture tanks, the construction of net bags etc. New technical measures are needed to integrate aquaculture and agriculture, or aquaculture and industry. Waste products from farming and industry could be of great importance in future cultivation.

Figure 13. Training courses for farmers, people in extension services, scientists and administrators, are of the utmost importance for the development of aquaculture.

Economic evaluation of culture techniques, and community and regional economic appraisals, are a few important points for economic research involved in aquaculture. Other examples are marketing and distribution analysis.

A proposal for a research organization for aquaculture is presented in this report. In order to guarantee a cohesive and aim-related research programme the establishment of a multi-disciplinary institute for aquaculture (TVV) is proposed. It is

suggested that the institute should consist of 1) A Steering committee, 2) An Accounting department, 3) A Computor department, 4) An Extension service department, 5) Eight different research departments. These latter would be responsible for research and development of breeding techniques, nutritional physiology, fish disease, culture techniques and economy. Besides the internal research within the framework of the institute it is proposed that external research be undertaken to examine the environmental effects of aquaculture including slaughter, refining and distribution. Research at different universities and institutes etc should be stimulated by the setting aside of funds ear-marked for the purpose. In addition the establishment of research and training for developing countries should be instituted.

Education should cover all stages ranging from high school level to research training at university level. Practical training should be started at school level either as a long term course within the school's own trade course or as short term courses assisted by the aforementioned extension service officers, local consultants, fishery consultants etc.

It is proposed that the undergraduate training should be based at the University of Gothenburg by the extension by one year of the fisheries course. In addition other universities should be stimulated to arrange shorter or longer courses within different fields.

Research training should in general be undertaken at the proposed TVV. Special research scholarships for studies at foreign universities should be made available. Education of students from developing countries should be instituted at the TVV in cooperation with SIDA and SAREC.

Local advice and information should be supplied by consultants in the various counties.

Figure 14. Training courses for people from developing countries are important even for Swedish aquaculture.

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DEVELOPMENT OF AQUACULTURE IN SWEDEN

The subject of aquaculture is elucidated in many ways. The production of food on land and in the water, as well as the international development of aquaculture, are described as a background in the final report from the Swedish Steering Committee on Aquaculture, which was published for the first time in 1982.
This booklet is a collection of the summaries from the various reports made by the Steering Committee and its working groups.

THE SWEDISH COUNCIL FOR PLANNING AND COORDINATION OF RESEARCH (FRN)

The FRN is a new element in the organization of the Swedish research system. The back-ground to the establishment of FRN in 1977 was a need for more cooperation and closer contacts, not only between the different Research Councils but also within the research and development system in general. FRN's main tasks are:

- to initiate and support research within areas important to the society
- to further cooperation between the Research Councils and other research bodies and financiers
- to encourage the spread of information about research and its results, and to stimulate the dialogue between researchers and society in general
- to further international research cooperation in those areas not taken care of by other bodies.

THE NATIONAL MARINE RESOURCES COMMISSION (DSH)

The National Marine Resources Commission (DSH) is a governmental agency set up to coordinate Swedish marine resources activities. Its aims are to work for and support these activities by coordinating research and development in this field, to promote Swedish trade and industry in the marine sector, to suggest changes in existing law and administrative practices and to work towards international cooperation in the short- and longterm management of marine resources etc. One of its chief tasks is to develop and propose to the government a comprehensive program for the Swedish marine activities.
The first proposal was delivered to the government in 1982.

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