International Council for the Exploration of the Sea

Mariculture Committee
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Activity Report 1991/92

Mariculture Committee

by

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Further developments and dietary testing of live (Brachionus and Artemia) and formulated (enrichment and substitution) diets for use in the larviculture of freshwater and marine fish, marine shrimp and freshwater prawn, and molluscs (in cooperation with different research laboratories and private hatcheries in Belgium, France, Greece, Japan, Norway, Singapore, Spain, Thailand, UK and USA).

Biochemical characterization and dietary testing of acid-preserved Artemia biomass for penaeid shrimp larvae.

Intensive production, processing and quality control of Artemia biomass and cysts.

Study of the variability in lipid composition of eggs of various species of marine fish and in giant freshwater prawns.

Qualitative and quantitative study of the bacterial flora of the live food department of commercial hatcheries of European sea bawss and sea bream (in cooperation with the Laboratory of Microbiology, State University of Ghent).

Development of a bioencapsulation technique for the incorporation of high doses of antibiotics in Brachionus and Artemia to be used for oral medication treatment in fish and crustacean larvae (in cooperation with the Laboratory of Medical Biochemistry and Analytical Chemistry, State University of Ghent, and the Thessaloniki University, Greece).

Possibility to use Artemia for oral delivery of vaccines to larval fish (in cooperation with the University of Stirling, Scotland, UK and the University of Wageningen, the Netherlands).

Fatty acid and vitamin C composition of turbot larvae reared in different culture systems (in cooperation with the Danish Institute for Marine Research and the Instituto Oceanografico, Vigo, Spain).

Organization of the international Fish & Crustacean Larviculture Symposium "Larvi'91" (Ghent, August 27-30) attended by 350 participants from 55 countries.

Consultancy missions regarding Artemia and/or larviculture applications for different official organizations and private companies to Egypt, Hong Kong, Norway, Thailand, Singapore, Taiwan, PR China, Vietnam, and the USA.

ARTEMIA SYSTEMS NV/SA

Development (contract research with the Laboratory of Aquaculture of the State University of Ghent) and marketing of new diets for use in larviculture of fish and shellfish.

Canada

by

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This report is a partial summary of the research and development on mariculture in Canada. Government, university and other research institutions were contacted; the following is based on reports received and presented on a provincial basis. It should be noted that this report is incomplete as some researchers were not available to report on their activities; in addition, some industry-sponsored research is not available to the public.

Newfoundland and Labrador

The Ocean Sciences Centre (OSC) of Memorial University are continuing their research on a number of marine finfish species including Atlantic halibut, lumpfish and cod. Studies on the egg quality of Arctic charr during the spawning season and comparative assessments of wild and cultured Atlantic salmon eggs are also continuing.

Research by the Canada Department of Fisheries and Oceans (DFO) has focused on four areas:

Mussel Culture - Investigations on the growth, survival, spat settlement, alternate strategies for growout, and blue mussel interactions with the phytoplankton community are continuing. This project is expected to lead to a bio-economic analysis of the mussel aquaculture industry.

Scallop Culture - A project to investigate the effects of density and environmental factors on the production technology for culture of whole, juvenile sea scallops, Placopecten magellanicus was completed. A comparative bio-economic analysis of this potential new industry, versus traditional culture strategies for "meat" production, will be undertaken in 1992. A multi-year study of the spatfall prediction and recruitment mechanisms of giant scallops continued in Port au Port, Newfoundland in relation to the physical and chemical environment and biological factors. The study will help to explain why this particular site is consistently an excellent area for spat collection. A histological study was initiated to examine the gonadal and sexual development of juvenile scallops in suspended culture.

Salmon Culture - Quantitative performance evaluation was done for Atlantic salmon broodstock of Grand Codroy (St. Georges Bay, Newfoundland) vs. Saint John (New Brunswick) stock for Newfoundland marine farming. Salmon smolts (S+1) were transferred to Bay d'Espoir marine cages to begin marine growth experiments in 1991.

Evaluation of Triploid Salmonids for Newfoundland Aquaculture - A joint government-industry project, with Newfoundland salmonid farmers, was initiated to evaluate aquaculture performance of triploid vs. diploid salmonids under Newfoundland aquaculture conditions. Pressure treatment equipment is being used to induce triploidy.

Nova Scotia

A national workshop on the Environmental Aspects of Aquaculture was held at the Bedford Institute of Oceanography, on March 5-6. Participation included all DFO regions, provinces and industry.

Substantial progress has been made in developing a suite of scientific numerical models to help understand the fate and effects of wastes on the cage, local and regional scale. Biological, physical, chemical and sedimentological processes are included. Several of these models are generic in nature and can be applied to other areas. Progress has also been made in developing a computerized decision support system to aid environmental managers in screening applications for new aquaculture proposals.

DFO continues to fund an extensive program on marine phycotoxins on the Atlantic and Pacific coasts which studies the three classes of toxins which occur in Canada (ASP, PSP, DSP). Over the past three years, detailed information on the species composition of natural phytoplankton communities has been obtained at several dozen coastal sites, most of which are near aquaculture facilities. Summary reports have been prepared and distributed to growers.

Acadia University is conducting research in Mahone Bay, Nova Scotia, on the culture of scallop (Placopecten magellanicus) including spat settlement, stocking density, scallop rearing, gear comparison, and assessment of ear-hanging technologies. The research on stocking densities has shown that growth rates can be manipulated to provide either small numbers of large, high quality animals for the live-shell or roe-on trade, or larger numbers of smaller animals for bottom planting. This information can now be used for planning growing, harvesting and marketing strategies for different times of the year.

In other research, the two species of Mytilus edulis and M. trossulus now known to co-exist on mussel farms on the Atlantic coast of Nova Scotia, are inter-fertile in laboratory conditions, and appear to have similar timing of maturity and spawning, yet the incidence of hybrids as determined by isoenzyme analysis of wild populations is relatively low. The fertility of hybrids is being investigated. M. edulis is the preferred commercial species because of its more robust shell which is less easily fractured in processing machinery, and its slightly faster growth rate. Investigations are under way to determine whether wild M. edulis spat can be preferentially selected by farmers, and whether the population structure on mussel farms can be biased in favour of the preferred species, other than by transfer of selected spat.

A second generation of bay scallops, Argopecten irradians was successfully spawned from the F_1's of parents introduced into quarantine in 1989. These too will be spawned in 1992 and some of the progeny made available to industry. In spite of determined attempts, there is no evidence that the Apicomplexan parasite Perkinsus karlssoni of bay scallops will infect other bivalve molluscs; however, research continues into the infectivity and significance of Perkinsus karlssoni in bay scallops, but the areas where bay scallops may be cultured will not be extended pending completion of transmission experiments currently in progress. The infective stage of the parasite now appears to be a biflagellate zoospore, released from the adult bay scallop at or about the time of spawning, but the time when infection of the larvae or juveniles takes place, and the intermediate stages of the parasite in the host remain elusive. The parasite does not appear to have any deleterious or pathological effect.

Research at the DFO Halifax Laboratory has shown that the addition of feed-attractants to standard lobster diets increases the rate of response of the lobster and the speed with which the feed is consumed. There is no increase in food consumption and no effect on growth. The reduced waiting time reduces leaching of vitamins and water-soluble nutrients, thus allowing a more economical use of these constituents while reducing food waste. Deficiency of riboflavin, or other water-soluble B vitamins, contributes to molt death syndrome in lobsters fed synthetic diets.

A collaborative study between DFO and the Nova Scotia Agriculture College has shown the overall quality of fish meals produced for aquaculture in the Maritime Provinces has improved markedly over the past five years, but performance of fish when fed diets based on these feeds is still lower than that of fish fed diets based on Norsea LT 94, a Norwegian produced meal. Other work has shown that absolute levels and bioavailability of phosphorus, the higher total amount of phosphorus released to the environment by fish fed whitefish or menhaden meals also makes herring meal preferable on environmental grounds.

The role of B vitamins in disease resistance continues to be explored; folic acid appears to confer no advantage to salmon in resisting Vibrio anguillarum.

Unexpected results in a disease-challenge experiment were shown to be due to the use of a faultily-labelled commercial salmon feed, which was found to be medicated. This has resulted in a program whereby all commercial feeds used in the Federal service are tested for antibiotics.

The Nova Scotia Aquaculture Coordinating Committee has undertaken a major initiative to prepare develoment planning reports on the culture of the mariculture species with potential for commercialization in Nova Scotia. The thirteen reports in this series, to be published in 1992, will include studies on the marine and freshwater production of Atlantic salmon and trout, alternate finfish and shellfish species, marine plants, and the molluscans such as mussels, (Mytilus edulis), american oyster (Crassostrea virginica), European oyster (Ostrea edulis), giant scallop (Placopecten magellanicus), and bay scallop (Argopecten irradians).

Prince Edward Island

There were a number of research and development initiatives by the provincial Department of Fisheries and Aquaculture, including scallop spat collection and juvenile growout trials, demonstration of improved oyster lease resource enhancement and cultivation technologies, evaluation of mussel seedstock performance, outplanting of hatchery produced quahaug (Mercenaria mercenaria) seed, and the holding and testing of bay scallop in quarantine, the assessment of longline anchorage systems. In the finfish sector, initiatives include the development of arctic charr culture, evaluation of the performance of speckled trout strains, the assessment of striped bass as a species for aquaculture, and the monitoring of effluents from fish farms and hatcheries.

DFO (Gulf Region) continues to study the recurring problem of summer die-off of mussels (Mytilus edulis) that effects a large proportion of the cultured mussel industry in P.E.I. A three-year study will conclude in 1992, which examines the influence of genetic and environmental factors on summer mortality of P.E.I. mussels using a reciprocal transplant experiment with six study sites. Experimental results showed that mortality of the different seed sources was consistent among sites and appears to be genetic in nature.

They also concluded an experimental study of the effects of site specific environmental conditions on quahaug (Mercenaria mercenaria) growth rates by using a reciprocal transplant experiment in P.E.I. The project evaluated the growth and mortality differences of these two sites (Pownal Bay and West River) using hatchery produced seed and testing a variety of culture techniques and mechanisms in order to assess the influence of various environmental parameters (temperature, water flow, seston, chlorophyll, bottom type, etc.)

DFO is continuing a multi-year survey of the parasites and diseases of the main shellfish species (mussels, eastern oysters, European oysters, giant scallops, bay scallops and quahaugs) used in mollusc aquaculture in Atlantic Canada. The basic objective of the baseline survey remains twofold: to elucidate the seasonal dynamics and species identification of specific bivalve parasites which clearly affect their host's tissues; and compare and contrast the parasites in commercially important species grown in suspension with Perkinsus karlssoni from bay scallop in ongoing studies at the Atlantic Veterinary College, University of Prince Edward Island. Results to date show no evidence of transmission. Other studies include the identification of prokaryote tissue parasites and determination of their pathogenic significance. A review of Malpeque Disease of eastern oysters is ongoing.

A brief, late summer bloom of Nitzschia pungens caused increased domoic acid content in mussels, and a harvesting closure in parts of Prince Edward Island, and allowed the testing of an experimental depuration unit using recirculated seawater sterilized with ultraviolet light. Domoic acid content of the mussels was reduced from about 80 ug/g to below the control level of 20 ug/g in 32 hours as opposed to 38 hours in running seawater. This reconfirms suggestions that recirculating systems may be used to successfully depurate mussels of domoic acid.

New Brunswick

The L'Etang estuary of the Bay of Fundy supports the most concentrated area of Atlantic salmon cage culture in Atlantic Canada. Field studies on the fate and effects of wastes from salmon farms continued, involving scientists from the Bedford Institute of Oceanography, the St. Andrews Biological Station and the Huntsman Marine Science Centre. The field data is being used in the development of a predictive model on the assimilative capacity of this area.

A workshop was held in St. Andrews to review the results obtained to date in the L'Etang program with emphasis on the modelling work. The target audience was federal and provincial managers but industry was also present.

In spite of a stringent carrier-test program, three New Brunswick salmon farms experienced outbreaks of furunculosis in 1991. There is confidence that these did not occur due to the transfer of carrier-stocks from New Brunswick hatcheries, and since the three farms are located in waters contiguous with those of the State of Maine, where outbreaks of furunculosis have been reported, it is believed that this represents cross-border, inter-farm transmission. The N.B. outbreaks were successfully controlled by medication. Research continues into the role of cellular immunity in protecting salmon against furunculosis.

A serious outbreak of bacterial kidney disease (BKD) at a New Brunswick salmon hatchery resulted in selective slaughter of stocks. The incident is believed to be due to infected eggs which had escaped the broodstock screening program. The site has been sterilized and is back in production. The broodstock monitoring program for BKD continues. One grower has detected a possibly significant increase in the incidence of BKD in brood fish during the course of the breeding season. This is being investigated and its implications for the monitoring program assessed. Resistance of certain stocks to BKD or furunculosis is higher than in other stocks; experiments involving disease challenge of selected crosses are planned to measure the heritability of disease resistance factors.

The Salmon Genetics Research Program, a collaborative program of DFO and the Atlantic Salmon Federation, is conducting a broad enquiry on the genetics of Atlantic salmon on such topics as: tank and density effects in conjunction with family variation in fry and parr growth; triploidy and sex reversal; parental sea age as a source of within stock variation in ovarian development; comparison of early growth between individual and family rearing using DNA fingerprinting; effects of semen cryopreservation; genetic resistance to furunculosis; use of methyltestosterone implants in the reconditioning of salmon kelts; and the interactions between wild salmon and escapees from sea cage operations.

In a controlled selection experiment using Saint John River strain, an increase of approximately 340 g in market weight has been realized along with a reduction in the grilsification rate from 11 to 6 percent when no grilse were used as breeders in the selection line. Contemporaries of this select line are being reared by the industry to accommodate the commercial advantages of these genetic gains.

The DFO Biological Station continued research on alternate species for finfish aquaculture, in particular, Atlantic halibut. Broodstock and spawning facilities were upgraded and growout trials using juvenile halibut in modified salmon sea cages (in cooperation with a local salmon grower) yielded a three-fold increase in growth rates and showed that ongrowing of halibut is technically and economically feasible. Other halibut research included studies on the effects of flow rate and salinity on halibut egg fertilization and early development and studies on methods for the first feeding of halibut larvae using marine zooplankton. Research continued on other candidate aquaculture species, including: haddock, striped bass, lumpfish, eel elvers, lobster, and sea scallop. Transfer of scientific and technical information on aquaculture was facilitated through editing and publishing of World Aquaculture Magazine and the Proceedings of the Aquaculture Association of Canada annual meeting. Research on the production of underyearling Atlantic salmon smolts by photoperiod manipulation continued. A study was also initiated, in cooperation with industry, to determine the effect of winter starvation on sexual maturation in Atlantic salmon. In addition, a study was initiated to examine transgenic salmon with added growth hormone.

Monitoring of the dynamics of phytoplankton blooms in the Bay of Fundy continued. A project was initiated on the factors controlling domoic acid production in Nitzschia pseudodelicatissima.

Studies continued, in collaboration with the University of New Brunswick, on the environmental factors affecting bivalve feeding rates. Studies also continued, in collaboration with the Habitat Ecology Division, on the effects of salmon mariculture on the benthos and seawater column; a goal of this project is the development of a holding capacity model for the salmon culture industry in the L'Etang area of the Bay of Fundy.

A consortium of New Brunswick researchers continue a research program on fish diseases in farmed Atlantic salmon. Coordinated by the University of New Brunswick, this research program includes the monitoring of sea lice in sea cages and studies in the immunization of salmon against sea lice, disease prevention in triploid salmon, and the development of rapid response testing for BKD.

Within the framework of a federal-provincial agreement on aquaculture development for New Brunswick, a number of applied research projects were initiated and included are:

- research on the influence of temperature and salinity on the growth of juvenile striped bass in ponds and sea cages;
- arctic charr research on the adaptability and growth when raised in tanks using brackish water (8-12‰) from wells;
- haddock and halibut studies to determine growth rates, survivability and over-wintering mortality in modified salmon cages;

- drug residue studies to determine withdrawal times for the reduction of oxytetracycline in salmon under commercial scale conditions in the Bay of Fundy;

- monitoring of oyster growing areas to determine the biological and physical characteristics of a good site for oyster production;

- environmental studies on the effects of salmon cage farming on benthic community organisms and the effect of aquaculture on the juvenile nursery grounds and spawning areas of Bay of Fundy lobster.

Quebec

PÉTONCLES

1. REPERE

Le programme REPERE (REcherche sur le Pétoncle à des fins d'Elevage et de REpeuplement), annoncé publiquement en avril 1991, est une structure de concertation qui a pour but de mettre au point une technologie rentable d'ensemencement du pétoncle sur le fond. La mise au point de cette technologie permettrait d'envisager le repeuplement des fonds marins comme une solution à la diminution des stocks naturels de pétoncles.

Les principaux objectifs de ce programme de recherche/développement en partenariat sont:

- la réalisation d'une étude de faisabilité financière;
- de développement d'une source stable d'approvisionnement en juvéniles prêts pour l'ensemencement (par captage en milieu naturel ou par production artificielle);
- la détermination des paramètres biologiques essentiels: taille et densité optimale d'ensemencement, nature des fonds marins, croissance et mortalité;
- la mise au point d'une technologie transférable à l'industrie;
- la réalisation d'une étude de marché;
- la réalisation d'un projet-pilote.

REPERE assure la concertation des efforts de R/D des trois partenaires suivants: le ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec, le ministère des Pêches et des Océans du Canada et l'Association des pêcheurs de pétoncles des Iles-da-Madeleine. La plus grande partie des travaux reliés à ce programme se déroulent aux Iles-de-la-Madeleine.

Les deux premières années d'opération du programme ont permis d'atteindre les résultats suivants:

- Une étude a démontré, sous certaines conditions, la faisabilité financière de cette pratique.

- Le développement d'une source d'approvisionnement en juvéniles est en bonne voie d'être assuré. D'une part, malgré certains succès initiaux, les recherches effectuées n'ont pas encore permis la production artificielle (écloserie-nurserie) de juvéniles en quantité suffisante et surtout de façon répétitive. D'autre part, nos recherches sur le captage de larves en milieu naturel sont encourageantes et ont permis d'identifier des sites qui fournissent des rendements de captage assez près des rendements nécessaires à la réalisation d'activités commerciales.

- Les 6 ensemencements expérimentaux effectués jusqu'à présent nous amènent à faire les constats suivants:

  - les ensemencements connaissent parfois une bonne mortalité due à la prédation;

  - les pétoncles qui survivent se dispersent très rapidement après l'ensemencement;

  - le type de fond marin pourrait être un facteur important expliquant cette dispersion et serait possiblement déterminant dans la survie des ensemencements;

  - les ensemencements expérimentaux à petit échelle ne constituent probablement pas la meilleure approche pour évaluer le succès de cette pratique. Les ensemencements à plus grande échelle, d'individus marqués, seraient probablement plus appropriés.

2. Basse Côte-Nord

Le suivi biologique d'un projet-pilote d'élevage du pétoncle géant (Placopecten magellanicus) en suspension s'est terminé. Ce projet, débuté en 1988, a lieu dans une baie près de Chevery sur la Basse Côte-Nord du Golfe St-Laurent. Notre suivi visait à évaluer la croissance et la mortalité des 450 000 juvéniles de pétoncles transportés chez le producteur en 1989 et 1990.

Un projet réunissant l'entreprise privée, un groupe de consultant, et les deux paliers de gouvernements (aide technique ou financière au projet) s'est terminé en 1991. L'évaluation du succès de captage de trois baies distantes de 50 à 100 km a eu lieu; ces travaux, entrepris en 1990, avaient pour but de mettre au point une méthode de suivi larvaire afin de bien identifier la période de fixation des larves et ainsi déterminer la meilleure période de mise à l'eau des collecteurs.

MOULES

1. Mortalité estivale des moules de 2 ans aux Iles-de-la-Maeleine

Pour comprendre la mortalité estivale qui frappe les moules de 2 ans des Iles-de-la-Madeleine, nous avons utilisé des individus épargnés par la mortalité estivale apparue lors de leur première saison de croissance. Les moules expérimentales furent placées dans des cages. La moitié des cages furent remises dans la lagune de Grande-Entrée à 3 m de la surface tandis que l'autre moitié fut tranférée en mer à environ 15 m de profondeur. Aux deux sites, une première ponte survint à la fin juin, suivie par une courte période de récupération. Une seconde ponte survint chez les moules laissées dans la lagune à la fin juillet et la mortalité commença la semaine suivante pour atteindre 50% à la fin août. Il n'y eut ni seconde ponte, ni mortalité chez les moules en mer, même si elles semblaient prêtes à pondre. Probablement que seules les conditions environnementales dans la lagune peu profonde (par ex. brassage de la colonne d'eau) ont pu induire la ponte. Ces résultats semblent supporter le rôle du stress de la reproduction dans l'apparition de la mortalité estivale des moules.

2. L'utilisation d'un stock performant pour solutionner la problématique de mortalité estivale affectant la mytiliculture aux Iles-de-la-Madeleine.

Du naissain de 4 populations locales a été récolté à l'automne 1989 et transféré à 5 sites d'élevage aux Iles-de-la-Madeleine. Les moules ont été placées en cage et suivies mensuellement de juin à novembre jusqu'à l'automne 1991. À chacune des visites, les moules vivantes et mortes furent dénombrées et mesurées, puis les survivantes replacées dans des cages propres. À l'automne '90, les moules du Bassin de Havre-Aubert (BHA) et celles de la Baie de Plaisance (BP) fournirent les taux de survie les plus élevés. La mortalité estivale affecta particulièrement les moules de Havre-aux-Maisons (HAM) et de Grande-Entrée (GE). Ces résultats se traduisirent par des biomasses estimées pour les moules de BHA jusqu'à dix fois plus élevées que pour celles de GE. Les taux de survie des différentes populations au terme de ce projet sont remarquables: 82,1, 22,4, 11,2 et 12,7 respectivement pour les moules de BHA, HAM, GE, BP. L'utilisation de naissain provenant de populations plus performantes représente une solution pour contourner à court terme, la problématique de la mortalité estivale.

3. Évaluation de la biomasse de moules en élevage chez les producteurs.

Une évaluation de la biomasse de moules en élevage chez des producteurs de la Basse Côte-Nord a été réalisé. Cette activité a complété des travaux semblables exécutés en 1990 dans les deux autres régions maritimes du Québec (Gaspésie et Iles-de-la-Madeleine). Une méthode a été mise au point pour déterminer, par producteur, le nombre de lignes d'élevage, leur position, l'origine des moules en élevage, leur taille, leur poids, le rendement commercial des coudins ainsi que la production totale des mytiliculteurs.

HOMARD

Un projet visant à évaleur l'applicabilité d'une stratégie d'engraissement du homard de petite taille pêché commercialement a été entrepris en 1991. Les principaux objectifs du projet étaient l'évaluation de la quantité de produit disponible à cet effet dans les viviers des producteurs commerciaux, la mise au point d'une diète à base d'ensilage et des essais d'engraissement du homard, suite à la mue, dans des bassins approvisionnés en eau de mer à température ambiante. Selon nos calculs préliminaires, environ 5 à 10% des captures moyennes annuelles, environ 3000 tonnes, seraient susceptibles d'être sélectionnées à des fins d'engraissement. La diète élaborée a été bien acceptée par les homards adultes et a donné de bons résultats en terme d'augmentation du rendement en chair après la mue et d'acceptabilité du produit par un panel de consommateurs. Ces résultats seront affinés en 1992.

OTHER STUDIES

Researchers at the Centre océanographic de Rimouski (Québec) are continuing their studies on a number of topics in mariculture including:

- the migrating ability of charr (brook charr, arctic charr) and American cod and plaice to adapt to estuarine environments, with the goal of developing the St. Lawrence estuary water resources.

- the development of surf clam (Spisula solidissima) culture, new technologies for producing triploid scallop (mainly Placopecten magellanicus) and fundamental embryology studies.

- the kinetics of development of marine invertebrates under various culture conditions.

- the uptake of carotenes (synthetic and natural) and their influence on the pigmentation of various cultured species.

- l'optimisation de la reproduction et la définition de quelques pramètres (nutrition, densité larvaine) permettant d'accélérer la croissance larvaine du pétoncle géant.

- le développement des procédés de cultures d'algues en milieu contrôlé en vue de leur application dans les activités aquicole et dans la valorisation de la biomasse algale en agro-alimentaire.

British Columbia

The following studies by the Department of Fisheries and Oceans were carried out at (1) the Pacific Biological Station, Nanaimo, or (2) the West Vancouver Laboratory, West Vancouver, B.C., in 1991.

1.1 A pilot rearing experiment was initiated with ocean-type and stream-type chinook and their hybrids to compare their suitability for stocking in netpens as S0 and S1 smolts. A study with the feed additive FinnStim demonstrated improved growth and reduced plasma sodium concentrations in yearling chinook salmon stocked into seawater netpens. Laboratory feeding trials demonstrated that larval sablefish (Anoplopoma fimbria) fed rotifers grown on the algae Nannochloropsis had greater growth and survival than those reared on Chroomonas or Isochrysis. Multiple spawnings of two female halibut (Hippoglossus stenolepis) occurred for the first time at the Pacific Biological Station; fertilization rates of the 19 batches of eggs ranged up to 88% but most eggs developed abnormally beyond epiboly. Experiments were conducted with growth of the toxic alga Heterosigma akashiwo in the laboratory and a procedure was developed to make the algae toxic in culture.

1.2 Investigations continued to determine the filtering efficiency of the gill of very early juvenile Japanese scallops, Patinopecten yessoensis and the size of particle they are able to filter from the plankton. Studies also continued to find an adequate diet for early juvenile Japanese scallops. This included studying the effect of adding extra cellular substances to diets.

1.3 An investigation continued to determine the frequency manila clams, Tapes philippinarum, should be harvested in culture operations to cause minimum mortalities to recruit clams.

1.4 Finfish research related to fish health protection dealt mainly with the diseases of salmonids farmed in seawater and included:

(a) Studies on methods for avoiding bacterial kidney disease (BKD) on salmon farms. It was shown that properly timed broodstock injections with erythromycin were highly effective at preventing vertical transmission of the BKD agent. Using this approach in conjunction with other husbandry practices, it should be possible to avoid BKD problems on salmon farms.

(b) Studies on the etiology of marine anemia (plasmacytoid leukemia) of chinook salmon. Results strongly suggest that the etiological agent is a retrovirus. The infection is apparently not readily transmitted in seawater but there are indications that it may be egg-transmitted. Research directed at developing a diagnostic test for the condition (based on monoclonal antibodies to the neoplastic cells) yielded promising results.

(c) Studies on the infectivity of the infectious haematopoietic necrosis (IHN) virus for Atlantic salmon. The studies showed that Atlantic salmon are very susceptible to the virus. The infection was readily transmitted to Atlantic salmon in seawater using bath exposure to the virus and cohabitation with infected fish. These results are relevant to salmon farming in B.C. because of the growing popularity of the Atlantic salmon on this coast and

because the farmers wish to rear their Atlantic salmon smolts in lakes where the water temperatures favour fish growth but where infections with the virus may be acquired. Smolts raised in lakes may thus introduce IHN to sea pens.

(d) Studies on the biology of the salmon louse (Lepeophtheirus salmonis) were undertaken. The developmental stages were described; development rates, growth, and survival were investigated; and the susceptibility of a number of salmon species to the sea louse infection was compared. The nature of the host responses to the louse was examined, and the doses of the anti-louse agent Ivermectin tolerated by the various salmon species were determined.

(e) Studies on an unusual systemic infection caused by a diplomonad flagellate resembling Hexamita salmonis were conducted. The infection resulted in high losses in chinoook salmon farmed in seawater at one site in B.C., and it was transmitted to chinook salmon in both fresh and seawater by waterborne exposure to heavily infected ascites and tissue and by cohabitation with infected chinook. Atlantic salmon were refractory to the infection, suggesting that the parasite may be a new, highly invasive strain of H. salmonis or a different species.

1.5 Shellfish problems dealt largely with cultured oysters and scallops:

(a) Studies on the biology of the agent (Mikrocystos makini) causing Denman Island disease in Pacific oysters showed that the disease is only expressed during periods of cold water temperatures (the disease can be suppressed by holding the oysters at temperatures above 15°C). In another study, it appeared possible to concentrate the infectious agent from infected oyster tissues using a procedure developed for a related pathogen, Bonamia ostrea. It should therefore be possible to raise antisera against the Denman Island agent that could be used in assaying oysters for the presence of the agent.

(b) Studies to investigate the cause of mortalities and associated adductor muscle lesions in out-planted Japanese scallops were undertaken. Results to date suggest that the agent responsible for the problem is an obligate, intracellular bacterium (possibly a mycoplasma). The target host cell appears to be the hemocyte. Efforts to culture the bacterium have not been successful but it is being maintained in the laboratory by serial passage in scallops.

Studies undertaken by the Biotechnology Genetics and Nutrition Section at the West Vancouver Laboratory included:

2.1 Nutrition - Progress has been achieved in the replacement of fish meal with canola protein concentrate in salmon diets. In the winter feed efficiency has been improved in seawater cultured chinook salmon without the loss of growth performance by the appropriate application of periods of starvation and refeeding.

2.2 Sex Control - Development and commercialization of a Y-specific DNA probe for the chinook salmon. This is the first DNA sex probe to be developed for any fish and it greatly facilitates the production of monosex sperm for individual stocks of this species. In addition ethynyl estradiol has been shown to be a potent estrogen for direct feminization of salmon.

2.3 Chromosome set manipulation - Studies are underway on the optimization of triploidy induction in Atlantic salmon and chinook salmon and the induction of gynogenesis in coho and Atlantic salmon.

2.4 Transgenics - Success has been achieved in the production of coho salmon which are transgenic for the chinook salmon growth hormone gene. These transgenic coho are growing much faster and smolting sooner than normal coho.

2.5 DNA Fingerprinting - Success has been achieved in the development of fingerprinting techniques for chinook salmon utilizing DNA probes.

2.6 Selective Breeding of Coho Salmon - Selection over two generations has resulted in improvements in smolting and growth. Transfer of the resultant stocks to the private sector has been initiated.

2.7 Canada/Japan Workshop - A Canada/Japan workshop on Aquaculture Biotechnology was held at the West Vancouver Laboratory in March, 1991. Thirty Canadian and ten Japanese researchers representing government, academia and the private sector met to discuss areas for collaboration.

Mariculture research at the University of Victoria, Biology Department, included research on the trophic dynamics of periphyton/microhaptobenthic communities in both marine and freshwater systems; part of a program in in-field experimental ecological manipulations of microhaptobenthos in split-mesocosm raceways. Present focus is upon the influence, upon production and biochemical (proximate) composition of periphyton biomass, of several parameters including water movement and N/P ratios. Applied objectives include the employment of microhaptobenthos to recover excess energy, (in form of nutrients), from waste water streams by incorporation into biomass of composition appropriate for use as supplementary feedstocks in a variety of feeds for the aquaculture industry. Such feedstocks, generated in aquatic systems, bring to formulated feeds some of the nutritional components integral to the natural trophic system. Of particular interest is the influence upon broodstock condition and egg production as well as upon health and disease resistance.

The research program carried out at the University of British Columbia, Animal Science Department, included a number of collaborative projects with funding support from several agencies. A summary of this comprehensive mariculture research activity includes:

Stress Protein Expression: Its Role as an Indicator of the General Stress Response with Special Reference to BKD and Immune Functions in Fish

SDS-PAGE and Western and Dot immunoblotting using polyclonal and monoclonal anti-stress protein antibodies are being used to evaluate the expression of stress proteins (SP). Correlation between SP expression in fish exposed to various stressors and the conventional indicators of stress (e.g. plasma cortisol, glucose) will be determined. SP expression in BKD fish and in Renibacterium salmoninarum, the relationship between p57 and SP, and whether or not BKD has an autoimmune component, will be examined. Also, immune functions in normal and SP-administered fish will be compared.

Development of Simple Tools to Detect Stress in Fish

The goal of this project is to develop simple methods of assessing stress and general condition of fish in the field. This research involves testing portable instruments to measure physiological parameters such as blood glucose, haemoglobin and erythrocytes.

The Influence of Calcium on Nitrogen Excretion in Salmonids: Physiological Effects and Cellular Mechanisms

One factor affecting fish growth and survival is the ionic content of the water, especially calcium. For example, there is evidence that calcium ions (Ca^{++}) can ameliorate the detrimental physiological effects of extreme pH exposures. The objective is to test the hypothesis that the ability of trout to survive alkaline conditions and maintain nitrogen excretion is related to gill processes that are influenced by Ca^{++} concentration. One aspect is to examine the effect of Ca^{++} dependent mechanisms and the effects of calcium mediating hormones such as calmodulin, staniocalcin and prolactin. Understanding the action of Ca^{++} in normal and extreme environments would serve to refine the use of calcium as a management tool in fish culture.

The Role of Natural Defense Factors on Disease Resistance in Coho Salmon (Oncorhynchus kisutch)

There is increasing evidence that genetically based differences in disease resistance exist in salmonids. The mechanism(s) responsible for the observed disease resistance have not yet been identified. The aim of this project is to examine the role of the natural immune system on disease resistance. Some of the natural immune factors under examination are lysozyme, C-reactive protein, complement and macrophage activity. Heritability estimates will be calculated for some of these factors, to determine whether they can be used as selection criteria for a future breeding program designed to develop disease resistant salmon for the aquaculture industry.

Development of the Specific Immune System of Pacific Salmon with Regard to Early Life-Stage Infections of BKD

With the dramatic growth of the aquaculture industry in B.C. has come the increase in the incidence of disease outbreak among cultured salmon. In terms of economic losses, Bacterial Kidney Disease (BKD) is the most important infectious disease. Salmonid eggs and embryos can be infected with Renibacterium salmoninarum (Rs, the causing agent for BKD), while the immune system is in developmental stages and the disease can be carried until later in the life cycle before losses occur. Studies are examining the effect of early life stage infection with Rs on the development of the immune system. Suppression of the immune response by the pathogen may lead to increased susceptibility later in life. In investigating the effect of the bacteria on the maturing immune system, this study may aid in the development of a vaccine against BKD.

The Energetic Costs of Ionic and Osmotic Regulation in the Eggs and Larvae of Various Commercially Important Fish Species

For fish to maintain an internal ion and water balance they must expend energy to actively regulate their internal ionic and osmostic environment. The objectives of this research are to determine the energetic costs of ionic and osmotic regulation and relate these costs to the probable regulatory mechanisms involved. The species used in the study include Pacific halibut, sablefish (black cod), lingcod, English sole, herring and rainbow trout as well as chinook, coho, chum, and Atlantic salmon. A better understanding of the regulatory processes may lead to the modification of fish rearing practices which could reduce the whole-animal energetic costs associated with ion regulation. The bioenergetic savings should translate into enhanced growth and health, and possible reductions in feed intake.

Precocious Sexual Maturation in Chinook Salmon: An Analysis of the Genetic Contribution

Jacking or precocious sexual maturation is a serious financial problem within the BC aquaculture industry. A mature salmon has a much reduced market value as a result of the onset of maturity. Although it is widely believed to be heritable, the situation is complicated by strong evidence that environmental cues play a large part in the regulation of jacking rates. The main purpose of the research is to partition the observed variance in jacking rates into genetic and environmental components. This is being done through two approaches: a breeding program (quantitative genetics) and DNA fingerprinting (molecular genetics). The breeding program is examining maternal, parental and environmental effects on growth, stress response, hormonal changes and rate of precocious maturation. The molecular genetics aspect of the research includes using DNA fingerprinting to determine relatedness of jacking and non-jacking fish.

The Effects of Stress on Immune Function in Oysters

The Pacific Oyster has a wide distribution and is of commercial importance in British Columbia. The coastal waters of B.C. are becoming more contaminated by anthropogenic pollutants such as heavy metals, petrochemicals and organochlorines. The principle objective of this study is to describe the effects of stress on immune function in oysters. The pollutant to be applied as a stressor in this investigation is dioxin, which due to its persistent presence in some locations, has forced fisheries closures. The development of cannulation techniques for oysters, quantification of cellular and humoral immunological parameters of resting and stressed oysters and the response to simultaneous challenge of biotic and abiotic stressors is being investigated.

Interaction Between Cellular Stress Response and the Whole Animal Immune System

This study investigates the possible interactions between the cellular stress response by producing a family of proteins collectively called stress proteins while stressed animals have been shown to be immune compromised and vulnerable to infection. The goal is to elucidate the cellular stress response of select tissues and organs in heat-shocked and toxicant-exposed fish and ascertain the effect which heat shock proteins may have on the specific and non-specific immune response of fish challenged with Bacterial Kidney Disease (BKD).

Characterization of the Primary and Secondary Circulation in Rainbow Trout During Resting and Stressful Conditions

While the cardiovascular or primary circulatory system of fish has been extensively studied, secondary circulation (similar to the mammalian lymphatic system) and its role in transport and immune function has not. The fluid of this system is normally low in red blood cell content and is derived from extracellular fluid and also from small anastromoses which shunt fluid from the primary circulatory vessels. The research is focusing on haematology and selected immune characteristics of the secondary system in rainbow trout. Investigations should lead to increased understanding of the secondary circulation system in teleosts and may provide an avenue for future disease control research.

Swim Bladder Stress Syndrome in Arctic Charr

Swim bladder stress syndrome is a condition which has been found to occur in Arctic charr as well as some other cultured species. It is characterized by an over-inflation of the swim bladder that results in the fish losing its ability to maintain position in the water column. The final outcome of this condition is death by exhaustion and starvation. The objective of the research was to induce this condition and explore the link between stress and the disease using stocking density as the stressor.

CANADIAN MARICULTURE PRODUCTION STATISTICS

(1991 Estimates)

ATLANTIC COAST

		mt	Can$ (000's) value
Newfoundland and Labrador:			
Blue mussel		1,350.3	521.7
Rainbow trout		9.1	22.7
Arctic charr		0.1	5.2
Cod		17.6	5.2
Scallop		4.4	8.0
	Subtotal	1,381.5	557.8
Nova Scotia:			
Atlantic salmon		284.1	2,457.4
Steelhead trout		366.3	2,000.5
Trout		66.5	301.5
Blue mussel		348.3	501.5
American oysters		121.6	154.5
European oysters		5.5	8.9
Bay scallops		5.9	8.3
	Subtotal	1,198.2	5,432.7
Prince Edward Island:			
Blue mussel		3,404.0	3,745.0
Oysters		1,310.0	1,689.0
Rainbow trout		37.0	394.7
	Subtotal	4,751.0	6,008.7
New Brunswick:			
Atlantic salmon		9,000.0	79,912.0
Rainbow trout		272.0	1,700.0
Oyster		19.0	50.0
Blue mussel		41.0	45.1
	Subtotal	9,332.0	81,707.1
Quebec:			
Mussels		79.5	166.5
Atlantic salmon		130.0	836.9
	Subtotal	209.5	1,003.4

PACIFIC COAST

	mt	Can$ (000's) value
British Columbia:		
Marine salmonids (Chinook, Coho, Atlantic salmon, Steelhead trout)	16,500.0	100,000.0
Pacific oysters	4,500.0	3,500.0
Subtotal	21,000.0	103,500.0
Total estimated Canadian Mariculture Production (1991)	37,872.2	$198,209.7

Denmark

by

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Rainbow trout

The production of rainbow trout in sea water has stabilized around 6.000 tons per year during the last 3-4 years. Strict environmental regulations have stopped further development . The production in 1991 is estimated to be around 6.300 tons. Only little research is going on in this field – mainly development of better feed products carried out by the dry pellet compagnies and some experiments with disease problems (see below)

Turbot.

Two commercial turbot hatcheries and two to three smaller ones have been established during the last 3-4 years. In 1991 around 500.000 turbot with a size of 5 – 6 g have been produced. Most of these (70 - 80 %) were exported to the Mediterranean area, the rest have been used for stocking purposes in Denmark (see below). The production systems are based on the extensive rearing technology where the larvae are hatched and reared in large outdoor tanks and fed with natural plankton grown in the tanks. After a few weeks the small turbot are moved to indoor tanks and fed with dry pellets.

Cod

The interest for rearing cod has increased and two smaller rearing plants have been established. The production systems are more or less extensive. The larvae are hatched in tanks supplied with marine water contaning natural plankton. The small cod are all used for stocking purposes.

Stocking programmes

The number of marine stock enhangement programmes with marine species apart from salmonids have increased during the last years. In 1991 a total of 100.000 **turbot** have been released in a semi closed fjord (Limfjord) and 10.000 were released in the southern Kattegat. Out of the total approximately 40.000 turbot were tagged. The size of the fish were 30 – 75 g. A total of 7.000 small **cod** (mean length 15 cm) were released in the Limfjord. All fish were tagged. In 1992 a large hatchery will be established in the Baltic area on the island Bornholm and a stocking programme with small cod for the Western Baltic will be started.

Diseases

For rainbow trout *VHS* (Viral Haemorrhagic Septicaemia) seems to be a recurring problem in Danish marine farms. In 1991, VHS was diagnosed in 7 of 42 farms. The mortality varied from 20 to 50 %. Most of the outbreaks were observed in early summer.

Approximately 90% of the raimbow trout transferred to the sea water were vaccinated against *Vibriosis* and *Furunculosis* (triple vaccine). Disease monitoring was carried out at five farms throughout the production season. Outbreaks of both furunculosis and vibriosis were observed. Furunculosis outbreaks were seen in both vaccinated and unvaccinated stocks while vibriosis was only observed in unvaccinated fish. No resistance to any of the antibiotics applied was observed but isolated strains of *Aeromonas salmonicida* showed resistence to *trimethoprim.*

In cod and turbot cultivation units smaller outbreaks of vibriosis were observed but no serious mortalities were registrated.

Finland

by

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(This report is partly based on Heikinheimo-Schmid et al. 1992)

I Introduction

The rectilinear length of Finland's coastline is about 1 100 km, but its actual length is 39 000 km including the mainland and 73 000 islands and islets (Granö & Roto 1986). The water depth of 20 m is usually reached at a distant of 5-15 km from the shore line. There are over 60 000 lakes, 17 of which have a surface area of more than 200 km^2. The total length of the rivers exceeds 20 000 km. The main problem with exploiting these resources for aquaculture are the environmental impacts. To conserve the Baltic Sea very strict rules have been established to limit the nutrient load.

Government responsibility for both inland and marine fisheries and their management and the promotion of aquaculture in Finland is vested in the Ministry of Agriculture and Forestry.

In 1988 the Finnish Game and Fisheries Research Institute was partly re-organized. A new division, the Aquaculture Division, which takes care of the State fish culture, was separated from the Fisheries Division.

1.1. Fish farms and the production

Production of fish for human consumption increased rapidly in the 1980s and has reached 18,593 million kg (98 % rainbow trout) in 1990, of which only 5 400 tons was reared in fresh water. This was a little less than in 1989 which was the turning point of the production, for the first time in ten years the production decreased. 70 % of the fish is reared in brackish water in net cages. The value of the food fish production in 1990, calculated as the producer price, was 89 million USD (Appendix 1).

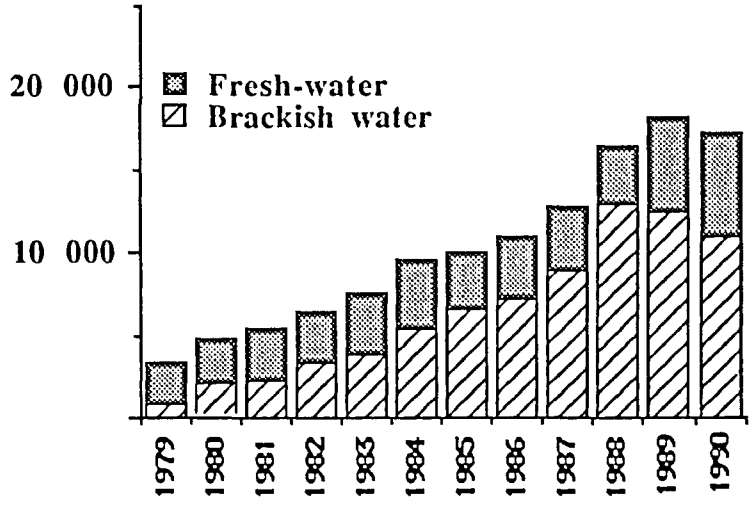

Figure 1. The production amount of rainbow trout in Finland in 1979-1990

The amount of rainbow trout exported has increased since mid 1980's and has been approximately 3000 tons/a in last two years (Table 1). Less gutted fish is exported nowadays than in the beginning; in 1990 already half of the amount consisted of filets.

Table 1. The export of rainbow trout in Finland in 1986 - 1990

Year	Export t/a
1986	236
1987	782
1988	3830
1989	3073
1990	3021

In 1990 the total number of fish farms in Finland was 351 (about one half in inland water) and in addition natural rearing ponds were used with a total area of c. 9 000 hectares. The rainbow trout is practically the only fish species farmed for food in Finland, although a few attempts have been made to develop the farming of Baltic salmon, whitefish and arctic char in net cages in brackish and fresh water. There is also growing interest in crayfish farming.

Fish for stocking are produced either intensively in land-based fish farms (mostly salmonids) or extensively in large ponds with a natural food supply (mostly whitefish, grayling, pike and pike-perch and some cyprinid species). Many farms producing rainbow trout also rear other salmonids for stocking. In 1990, the number of salmonids produced for stocking and on-growing purposes, excluding newly hatched larvae, was 14 million. The natural freshwater rearing ponds produced about 54 million mostly one-summer old juveniles (Appendix 1). In 1990, the value of juvenile production for stocking was about 25 million USD.

1.2. State fish culture

The Finnish Game and Fisheries Institute and its Aguaculture Division takes care of the State fish culture. The State has 14 fish culture stations already in operation or under construction and plans also exist for three further stations. The fish culture stations produce high-quality eggs and fry to conserve and increase the stocks of valuable fish species. The stations also produce fish for research and for stocking carried out by the State. An important task is the conservation of threatened fish species and stocks and the selective breeding of rainbow trout for food fish farming.

19 fish species, 64 different fish stocks and two crayfish species are cultivated in the State fish farms. The stations annually produce ca. 90 million eggs and fry of whitefish, ca. 24 million eggs and fry of salmon, trout and char and ca. 32 million eggs of pike-perch, grayling and other fish for stocking. Since it has become more and more difficult to obtain eggs from natural waters, due to weakening of the fish stocks, the State fish culture has attempted to ensure the supply of eggs and fry by cultivating brood fish at the stations. The use of the eggs can then be controlled in such a way that only the most suitable fish species and stocks are released in each river or lake.

1.3. Stocking

According to the nationwide fish stocking register, the number of salmonids (Salmo and Salvelinus sp.) released to the wild at the age of one summer or more was about 7 million. The corresponding number for whitefish species was 25 million, for other fish 8.6 million (grayling, pike, pike-perch, cyprinidae and burbot) and for crayfish 82 000. The value of the input was about 18 million USD, which is 70-80 % of the amount produced for stocking (Appendix 1).

1.3.2. Introductions

During 1990 and 1991 the animal health authorities permitted the import of eels (60 000 and 118 000, respectively) from Swedish quarantine for stocking purposes of some small lakes in southern Finland. Eggs of rainbow trout were imported from Sweden in 1990 for breeding purposes. Fry of Atlantic cod were imported from Sweden in 1991 for stocking purposes in the sea. Signal crayfish were also imported from Sweden in 1990 to be reared in closed ponds but during 1991 the animal health authorities permitted only imports of eggs of signal crayfish.

II FISH DISEASES

2.1. Fish

The official Fish Health Control system conducted by National Veterinary Institute will be replaced by a new program during 1992.

At the beginning of 1980's vibriosis was the most important fish disease in Finland. Vaccination against vibriosis has been fairly effective and thus other bacterial diseases have now become more important.

Furunculosis occurs not only in coastal regions but also in some freshwater hatcheries. Furunculosis was diagnosed in 48 and 85 different farms during 1990 and 1991, respectively. Most of the farms are situated in the archipelago and the coastal area of the Baltic Sea, where most of the rainbow trout production takes place. 14 cases have been detected at freshwater farms (land-based and netcages). Effective vaccines against furunculosis are not yet available and thus therapeutic antibiotics are commonly used with results in residues and bacterial resistance.

Bacterial kidney disease (BKD) has been diagnosed in one far per year during 1989-1991, all of which are on the island of Ahvenanmaa. The mainland is still free of BKD. Transport of eggs and live fish from Ahvenanmaa to the continent is prohibited.

IPN virus has been isolated only once during 1991 in comparison to 7 isolations from different farms during 1990. The main serotype has been Ab. There has not been clinical signs of IPN.

Research on fish diseases increased considerably in Finland in the late 1980s. Beside the official Health Control System, for example, the distribution of viral and bacterial diseases and the monogenean Gyrodactylus salaris has been studied in some research projects (42). The occurrence of bacterial and parasitic diseases has been monitored and studied intensively at four fish farms in NE Finland since 1984 (84). Research projects on the influence of water quality on fish diseases are in progress in the coastal area adjoining the Gulfs of Finland and Bothnia and in four lakes differing in water quality (including parasites) in Central Finland (41, 111, 113). Attempts have been made to improve fish disease diagnostics (23) and to find new drugs against bacterial diseases (4, 5, 6). The immunological response has been investigated in both farmed and wild fish. A study has been started with the aim of improving disinfection methods for the roe of the main fish species cultivated in Finland. New disinfectant chemicals for fish farms have been tested against the most common bacteria.

2.2. Crayfish

Some new cases of crayfish plague appeared in 1990-1991. Research has continued on the role played by plague-resistant signal crayfish as plague spreaders. If stressed under culture conditions, juvenile signal crayfish have shown rather high plague mortality. Haemolymph studies on Aphanomyces -infected crayfish and signal crayfish have continued.

The number of finds of the parasite Psorospermium haeckeli has risen to 70 (25 in 1989) in southern Finland. The haemolymph values of infected crayfish are under study. In certain conditions P. haeckeli can cause mortality in both natural crayfish populations and aquaculture stocks.

III RESEARCH

3.1. Fish and fish farm effluents

The main factor limiting the growth of the fish farming industry in Finland is the problem of fish farm effluents. In fresh waters, the main nuisance is eutrophication caused by phosphorus; organic loading and direct oxygen uptake are of less importance. Net cage farming on the Baltic coast can cause changes in the primary production because of nitrogen loading.

Fish farming is mainly increasing in the sea. In fresh waters the production actually decreased in the late 1980s if measured by mass. The new low phosphorus feeds, effective feeding techniques and new methods of removing suspended solids from the outlet waters decreased the total phosphorus load in inland fish farming by 37 % in the last decade, though the total production in fresh waters increased by about 56 % in the same period.

A new project aimed promoting the use of herring as raw material for the feed used in Baltic aquaculture was started in 1990. This was done in order to reduce the nutrient loading coming to

the Baltic Sea from outside the region. Because there is no manufacturer of fish meal based on the Baltic herring fishery the use of herring is based on the direct use of the fresh fish. For this reason , as a first step, the effect of the herring content in the feed on the growth and the consequent nutrient load in fish farming was studied.

One commercial dry feed was compared with five different herring based semi-moist feeds. The herring content of the feeds were (water contents in parentheses): 49% (22.6%), 49% (42,1%), 70 (56.8%), 84% (66.8%) and 100% (78.2%). The growth of the fish getting dry feed was remarkably better. Those fish getting the two most humid feeds were growing about 70% of that of the dry feed groups' growth during the 100 days experiment. The other three groups were growing at about 85% compared with the dry feed group. The feeding coefficient calculated in terms of dry weights were the same in all groups excluding the group getting the pure sliced herring. The fish were compensating the lower energy and dry matter in the feed by eating more. With the two of the most humid feeds this compensation was not complete which was estimated to be the most probable reason for lower growth and feed utilization efficiency.

The nutrient load (only the nutrients coming from outside the Baltic Sea included) decreased with increasing herring content in the feed. If only chopped herring were used for farming, 29 kg phosphorus and 280 kg nitrogen were removed from the Baltic Sea for every tonne of production. The local nutrient load inreased with the increasing herring content of the feed. With the lower water content the nutrient load was not very much different compared with the dry feed. The higher nitrogen load was probable a consequence of different protein-energy-ratio in the feeds; the higher phosphorus load probably a consequence of higher phosphorus content in the herring used compared with the low-phosphorus fish meal.

The project is still going on and will strive to examine how the compensation provided by the low energy feeds could be improved and the growth of the fish increased, how the local loading could be decreased and how the use of herring as feed would effect the economy of the farming. If the herring were used as a basis for feeds in Baltic fish farming, it should be possible to double the recent production. The decision to reduce nutrient load before 1995 to half of the level of 1987 would still be attainable (Ruohonen & Mäkinen 1991).

A new outflow water treatment technology came into operation on a productive scale at one State fish culture station in northern Finland in 1989. Testing of the procedure is still incomplete, but it appears that the phosphorus loading from fish farms can be reduced to the lowest level generally attainable in flow-through systems, but the costs of the effluent treatment will make the application of the high technology used at this State owned fish culture station impossible for a private farm.

3.2. Research on fish physiology

Research has been continued on improving techniques for rearing high-quality smolts. In examining the fish in the stocking groups, not only the general smolt characteristics have been studied - minimum size, body silvering and condition factor - but also several physiological properties, including the oxygen carrying and osmoregulatory capacities, and energy stores. Attention has also been paid to the hormonal control of smoltification. By connecting the physiological studies with tagging experiments a clear correlation between the physiological smolt status and the tag return of adults was shown. A project to slow down the amount of grilse has been started in some fish farms producing smolts for stocking purposes.

The research on brood stocks and roe quality has been continued. It includes experimental work on the effects of the annual light rhythm on the hormonal control of reproduction. Promising progress in regulating of the spawning time has been gathered on salmon and trout brood stocks, in addition to rainbow trout.

3.3. Research on fish nutrition

The farmed fish in Finland mainly receive dry feed. Low-value fish (mainly smelt) and Baltic herring are used to some extent mainly as a raw material for semimoist feeds. Recently, utilization of Baltic fish as raw material has received increasing attention as an alternative protein source for imported fish meal originated outside the Baltic. The idea is to recirculate nutrients in the Baltic and thus decrease nutrient loading from net cage farms.

The nutrition research in Finland can be classified according to the main goals of the on-going work. These are reduction of the environmental impact of aquaculture, reduction of the production costs, increasing the use of domestic raw material for fish feeds, increasing the quality of aquaculture products and widening the range of farmed fish species from salmonids fish to non-salmonid fish and invertebrates. In order to achieve these, recent studies have dealt with such subjects as salmonid brood stock nutrition, larval nutrition (especially whitefish and pike-perch), growth and nutrition at very low temperatures (< 5 °C), protein-to-energy rations in feed, use of semimoist and moist feed and feeding, feed intake and growth relationships in the rainbow trout.

3.4. Development of aquaculture technology

Most modern fish farms in Finland have adopted microprocessor-controlled systems to optimize automatic feeding, and to control water flow, illumination and temperature.

A new aquaculture technology development unit came into use at one State fish culture station in central Finland in 1989. In this unit it is possible to regulate temperatures and other cultivation conditions with a computer based system.

In intensive aquaculture systems new species need new technical developments. For example, production of live feeds for crayfish and pike-perch is receiving attention.

The development of aquaculture technology includes examination of the physiology of fish for stocking reared under different conditions. A considerable and increasing part of the stocking material in Finland is produced using heated effluents to stimulate growth, which requires a whole series of new technological steps.

Appendix 1.

Fish Culture in Finland 1990

Food fish production[1]

	Brackish water	Fresh Water	Total	Value (M$$[2])
Production, 1000 kg				
Rainbow trout	13 024	5 297	18 303	87
Salmon	157	61	218	1.8
Other species (Brown trout and whitefish)	0	72	72	0.5
Total	13 181	5 430	18 593	89
Farms	164	187	351	

1) In ungutted fish
2) Exchange rate used 1$ = 4 FIM

Production capacity

	Brackish water	Fresh Water	Total
Net cages, 1000 m^3	782	256	1 038
Ponds and tanks, 1000 m^3	46	1 471	1 517
Natural food rearing ponds, ha	1	9 061	9 062

Output of juveniles[1]

Species/group and size class		Output for stocking and on-growing 1 000 individuals	Amounts in the hatcheries at the end of the year 1 000 individuals
Rainbow trout	under 20 g	11 766	2 876
	20 - 200 g	5 098	6 924
	over 200 g	2 323	8 926
Atlantic salmon	under 20 g	2 411	3 204
	20 - 200 g	2 116	2 502
	over 200 g	1	68
Sea trout	under 50 g	2 474	2 291
	over 50 g	1 497	1 264
Brown trout	under 50 g	2 678	4 484
	over 50 g	2 614	2 700
Char and brook trout	under 50 g	40	345
	over 50 g	246	160
Coregonids	under 20 g	37 322	441
	over 20 g	716	57
Grayling[2]	all sizes	2 656	66
Pike-perch[2]	all sizes	7 379	3
Pike[2]	all sizes	5 617	2
Cyprinids[2]	all sizes	681	17
Crayfish species[2]	all sizes	66	16
Others[3]	all sizes	63	6

1) Output of newly hatched larvae excluded
2) Usually one summer old fingerlings under 10 g in size
3) Burbot

Value of juvenile production:

Rainbow trout	12.5 M$$
Other species	25 M$$ (70-80% of which for stocking)

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Les principales recherches se rapportent à cinq grands thèmes d'activités finalisés : la maîtrise de la reproduction en écloserie, la gestion des bassins, l'amélioration des techniques et des zootechnies, l'amélioration génétique des espèces et la protection des cheptels.

1 - MAITRISE DE LA REPRODUCTION EN ECLOSERIE

L'espèce modèle de cette étude est la coquille St-Jacques, *Pecten maximus*. Les recherches portent sur les mécanismes de maturation et de déclenchement de la ponte, sur le rôle de la nourriture pour obtenir des ovules et des larves de bonne qualité et sur la définition de critères simples de qualité des ovules.

Des premiers résultats ont montré l'importance des acides gras polyinsaturés nécessaires au bon développement des phases de reproduction. La densité.des ovules s'est révélée être un bon descripteur de leur qualité.

2 - GESTION DES BASSINS

Des modèles complexes, incluant la courantologie, l'effet de la marée, des paramètres intervenant dans la production primaire, la chlorophylle, et la répartition des biomasses au sein du bassin de Marennes-Oléron, sont au point. Des travaux complémentaires, en cours, visent à mieux définir certaines lois notamment des lois de respiration, de filtration en fonction de la taille des particules et d'assimilation. Un modèle similaire est à l'étude pour le bassin de Thau, en Méditerranée, où l'effet du vent est primordial.

3 - AMELIORATION DES TECHNIQUES ET DES ZOOTECHNIES

Ces recherches ont concerné à Bouin, la valorisation des eaux de forage qui permettent d'obtenir la production importante d'une espèce phytoplanctonique, *Skeletonema costatum*. La définition des conditions d'élevage (densité, volume d'eau, aération, distribution du phytoplancton) a été défini afin d'obtenir des performances de croissance et d'engraissement des palourdes et de l'huître *C. gigas*.

Des essais d'amélioration des performances de croissance sont également en cours en milieu ouvert, en travaillant avec des cages mobiles et sur des lignes en suspension.

Enfin, des recherches sont entreprises sur l'éthologie des prédateurs comme l'étoile de Mer, *Asteria rubens*, et le bigorneau perceur, *Ocenebra erinacea,* afin de contrôler et de réduire leur action. Une méthode de lutte biologique est tenté dans le premier cas, des moyens de capture (drague et piège) sont testés dans le deuxième cas.

4 - AMELIORATION GENETIQUE DES ESPECES

Ces études comportent trois volets :

- L'obtention d'une lignée d'huîtres plates résistantes à *Bonamia ostreae*. Les performances d'une F_2 testée expérimentalement par inoculation de *B. ostreae* a révélé, après six mois, des différences de survie du simple au double par rapport au témoin. L'étude suit son cours.

- Les techniques de polyploïdisation sont au point pour plusieurs espèces de mollusques (*C. gigas*, *O. edulis*, *R. philippinarum* et *R. decussatus*). Des lots de mollusques diploïdes et triploïdes sont en cours d'élevage. Une méthode simple par analyse d'image permet de corréler les performances de croissance et de qualité avec la ploïdie. De nouvelles molécules, non toxiques pour les larves, sont en cours de testage.

- La définition de méthodologies d'introduction de sondes génomiques ou d'oligonucléotides dans le noyau d'ovules de mollusques. Plusieurs méthodes, telles la microinjection, l'électroporation, la lipofection ont été testées.

5 - PROTECTION DES CHEPTELS

La situation épidémiologique de *Marteilia refringens* et *Bonamia ostreae* n'a pas évolué. Par contre, l'action du vibrio P_1 a régressé, notamment suite à l'application du contrôle des lots ensemencés et à l'observation des règles zootechniques. La production de *R. philippinarum* a retrouvé son niveau (600t) antérieur à la maladie.

Les recherches ont surtout porté sur l'immunologie des mollusques, en particulier sur les mécanismes de défense oxygène dépendant étudiés en chimioluminescence, sur la caractérisation des hémocytes de *C. gigas* et de *M. edulis* pour lesquels des anticorps monoclonaux ont été produits. Par ailleurs, des études sont en cours pour tenter d'obtenir des cellules transformées par carcinogénèse et oncogénèse.

Iceland

by

(Jónas Jónasson & Björn Björnsson)
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PRODUCTION IN AQUACULTURE IN 1991.

Atlantic salmon.

In 1991 8,6 million salmon smolts were produced and 6 million of those were released in ocean ranching. 2,6 million were used for ongrowing in landbased farms and netpens.

3.030 tons of salmon were produsedd, whereat 1.195 tons were in landbased units, 1.490 tons in net pens and 345 tons from ocean ranching.

Production for 1992 is estimated around 4000 tons.

Other salmonids.

Porduction fo Arctic char, Rainbow trout and Brown trout was 307 tons. Most of the production is Arctic char or 217 tons. About 1 million smolts were produced of these three species.

RESEARCH ACTIVITIES.

ATLANTIC SALMON

Ocean ranching.

Selective breeding in Ocean ranching. A nordic project started in 1987. The main purpose is to estimate the genetic parameters for homing and growth in freshwater and in the sea, by releasing families of salmon. The genetic parameters will be used to estimate the possibilities for selective breeding in ocean ranching. Until now 3 yearclasses have been released in all 400 families. Results are promising.

A large scale research program ti determine the optimum size of smolts, release methods and time of release is under-way in cooperation with companies in commercial ranching.

Land based units.

Selective breeding program for land based culture of Atlantic salmon is under way with breeding goals including growth rate, late maturity and disease resistance. 100 families are being used each year. Research is also under way to estimate most practical ways to run land based units, where different units as well as different environmental conditions are compared.

ARCTIC CHAR

Research is under way for rearing of arctic char. Comparison of different stocks and selective breeding in land based units, feeding experiments, rearing at different light regimes and temperatures.

DISEASE CONTROL

Research is under way to find ways to control bacterial kidney disease in aquaculture. Furunculoses caused by Aeromonas salmonicidia subsp. achromogenes is a problem in ongrowing of salmonids. Research is under way to produce vaccines. Disease control is also under way for marine species.

MARINE SPECIES

Halibut.

The Mariculture Research Institute carried out some breeding trials for the second season at its Mariculture Laboratory (ML) near Grindavik SW-Iceland. No fry survived. A private firm Fiskeldi Eyjafjardar (FE) N-Iceland managed during its third larval season to produce 5000 metamorphosed fry.

ML completed a 3-year long experiment studying the effects of different stocking densities on growth rate of young halibut weighing 2-12 kg. The results indicate that young halibut can tolerate high stocking densities (40-80 kg/m²) without much reduction in growth rate. In a temperature experiment ML found that the optimal temperature of young halibut ranged from 7-12 °C, in a feeding frequency experiment ML found no reduction in growth rate of young halibut fed 2x and 3x per week relative to those fed 6x per week. Growth rate experiments with halibut fry from FE were started at ML to study the effects of temperature and different dry feeds on growth rate. First results indicate that optimal temperature of fry is above 13°C.

Catfish

A growth rate study of young spotted catfish (Anarchichas minor) at different temperatures was started at ML.

Cod

Several adult cod were collected and brought to ML for breeding trials.

Abalone

Experimental breeding trials were carried out with red abalone(Haliotis rufescens) at ML. There was good success with spawning, fertilization, hatchin and larval settlement. At the end of the year there were a few hundred 3-6 mm animals allive and a few thousand 0,5 mm animals.

Ireland

by

(David Jackson)
Fisheries Research Centre, Dublin

Introduction

Production figures for 1991 are not yet complete but estimates to date predict a slight increase on the 1990 figures given below.

FINFISH (1990)	tonnes
Salmon	6300
Seafarmed Trout	320
Freshwater Trout	710

MOLLUSCS (1990)	
Mussels (rope culture)	3500
Mussels (bottom culture)	15000
Oysters (*O. edulis*)	400
Oysters (*C. gigas*)	200
Clams	70

SALMONIDS

The development of offshore sites using large flexible cages continues. New farm sites being considered and those which have recently gone into production are in exposed locations and in some cases are some distance offshore.

Disease - The incidense of pancreas disease was much reduced compared to 1990. Several outbreaks of furunculosis occurred at a number of sea sites. The increasing multi-drug resistance patterns observed in the isolates of *A. salmonicida* is becoming an increasingly serious problem. Effective sea lice treatments has led to a trend of reduced mortalities. Mortalities due to UV irradiation lesions were reported from a number of farms.

MOLLUSCS

Oysters - A moderate settlement of oysters was recorded. Bonamia is still the main disease of wild and farmed flat oysters. No new areas positive for this disease were detected but significant spread within one infected area, Galway Bay, was observed.

Scallops - A moderate settlement of scallops occurred in Mulroy Bay, Co. Donegal. Experimental longline culture was undertaken in a number of locations in the southwest on a pilot scale.

Mussels - The expansion of the rope culture industry in the southwest continues. The occurrence of DSP toxins in the mussels during a large portion of the summer, with various areas closed to harvesting between June and November, caused difficulties with the maintenance of continuity of supply to markets. *Dinophysis acuta* and *D. acuminata* were the species responsible for the toxicity.

RESEARCH

There are ten organisations involved in ongoing research in aquaculture related projects. The main research programs are summarised below.

1) Fisheries Research Centre

- Research on disease diagnosis and control.
- Monitoring of the incidence of algal blooms and investigations of their impact on aquaculture activities.
- Algal toxins; their occurrence and impact.
- Environmental effects of salmonid farming.
- Epidemiology of sea lice on farmed fish.
- Mollusc culture techniques.

2) Taighde Mara Teo, Galway

- Development of mollusc hatchery techniques.
- Culture of *P. lividus*.

3) Shellfish Research Laboratory, Carna, Co. Galway

- Abalone ongoing research on all aspects of the culture cycle of *Haliotus tuberculata* and *H. discus hannai*.
- Cultivation of the sea urchin *Paracentrotus lividus*.
- Nutritional studies i) the development of low cost feeding systems for bivalve nurseries ii) determination of optimal diet for abalone and urchin post-larvae and juveniles.

4) University College Galway (UCG)

Zoology Dept
- Genetic studies on salmonids.

Microbiology Dept
- Development of methods to detect antibiotics in marine sediments.
- Studies of the fate of tetracycline following its use on a marine fish farm.
- Studies on the use of ivermectin to control lice infestations in farmed fish.
- Development of the use of Flumisol baths to eliminate stress induced furunculosis.
- Cooperative work with BRI on the use of attenuated *A. salmonicida* strain as a possible immunogen.
- ECLAIR programme to develope oral delivery vaccines for fish.
- Development of a DNA probe for *A. salmonicida*.
- Studies on the transmission of pancreas disease in laboratory held fish.

Oceanography Dept
- Oceanographic studies of site suitability for aquaculture.

5) Trinity College Dublin

Environmental Science Unit
- Studies on the use of wrasse as cleaner fish for sea lice control on salmon farms.
- Studies on the fate and sinks of malachite green.

Microbiology Dept
- Development of a furunculosis vaccine

Zoology Dept
- Biology of parasitic copepods of farmed salmon.
- Crayfish (*Ausropotamobius pallipes*) aquaculture.

6) University College Cork (UCC)

Zoology Dept
- Investigations into PKD, PKX and a possible vaccine.
- Development of a vaccine against sea lice.
- Investigations into *Bonamia* and possible resistance in oysters.
- Study of *Myxobolus* induced lesions in flatfish.
- Various studies on the population genetics of wild and farmed salmonids.
- Evaluation of the feasability of turbot farming in Ireland.

7) Salmon Research Agency, Newport, Co Mayo

- Salmon ranching studies.
- Studies on the decline of seatrout populations in the west of Ireland.

8) Electricity Supply Board

- R&D of salmon farming.

9) Regional Technical College Galway

- Algal culture collection.

10) Regional Technical College Cork

- Studies on algal toxins.

EDUCATION AND TRAINING

A number of specialised training courses are offered in aquaculture from industrial training courses to postgraduate courses. A short cummary of available courses is given below.

M.Sc. in Aquaculture	U.C. Cork and U.C. Galway
Higher Diploma in Aquaculture	U.C.G.
B.Sc. in Aquaculture	R.T.C. Galway
Diploma in Aquatic Biology	R.T.C. Galway
National Certificate in Aquaculture	R.T.C. Galway
Certificate in Technology (fish farming)	RTC Tralee & RTC Letterkenny
Industrial Training Courses	BIM
Industrial and Community Education	Udaras na Gaeltachta

The Netherlands

by

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Mollusc culture

For a report of molluscan mariculture, see the report of activities of the Shellfish Committee.

Fish culture

Eel culture

Commercial eel farming in the Netherlands is coming off the ground, as appears from the fact that the production of a growing number of farms now matches the design capacity of the systems. This considerably improves their commercial results. Most of the eel farms use fresh water, but also brackish ground water is used.

A number of research projects into cultivation of eels in the laboratory of the Netherlands Institute for Fishery Research (RIVO-DLO) in IJmuiden were carried out, among which an analysis of the performance of different on-growing systems for eels. A study of first feeding of elvers was carried out, testing different commercial starter feeds and cod-roe. A comparative study into growth and survival of elvers, caught on various locations in Europe did not show significant differences between locations and transport distances. Small-scale experiments with on-growing of eels in the laboratory appeared to be representative for commercial-scale situations.

At the Agricultural University of Wageningen, different aspects of recirculation systems were studied. Research is carried out there into factors influencing sexual development and maturation of eels, as well as studies of kinetics of therapeutants (e.g. flumequin) in eels.

Turbot culture

Fundamental research was carried out to make a deterministic model for growth of turbot in cooperation with the Agricultural University of Wageningen. Experiments by the RIVO-DLO in a recirculating rearing unit for turbot, completed with a study tour to commercial projects in Europe, provided basical information for an appraisal of the commercial feasibility of turbot cultivation. The first results suggest that, provided growth performance is good, possibilities exist for commercial rearing of turbot in closed seawater systems in the Netherlands.

Mariculture of salmonids remained limited to one firm in the Oosterschelde, producing about 20 tons of rainbow trout. Experiments are done with culture of sea bass (*Dicentrarchus labrax*).

Norway

by

(Snorre Tilseth)
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The report summarizes the mariculture research activities contributed by the main aquaculture research institutions in Norway.

INSTITUTE OF MARINE RESEARCH

ATLANTIC SALMON (*Salmo salar*)

Genetics and biotechnology.

Comparison of trypsin sequence of Atlantic salmon to mammalian trypsins of bovine, mouse and rats showed a high degree of identity. About 57% of the amino acid residues in the mature proteins are conserved in all species. The salmon trypsin is respectively identical to 72 %, 69 % and 77 % of the residues in bovine, mouse and rat trypsins. Only 37 residues (17 %) are unique in salmon trypsin as compared to the mammalian trypsins. All the 12 cysteins forming 6 disulphide bridges in the mammalian trypsins are conserved in salmon. The amino acids in mammalian trypsin know to participate in the active site and the residues forming a pocket region around it, are all conserved in salmon. A plot of hydrophobicity and charge of the amino acid residues in the salmon trypsin sequence showed a similar pattern when compared to that of bovine trypsin.

The DNA from Atlantic salmon was analyzed by Southern blotting and hybridized to a salmon trypsin cDNA probe. The hybridization patterns are complex indicating the existence of several trypsin genes in Atlantic salmon.

As revealed by Northern blotting, the salmon trypsin transcript has approximately 950 nucleotides which is in agreement with the expected transcript length of 940 nucleotides in rat. The unusual strength after hybridization (only a few minutes exposure) implied that the trypsin transcript represented a large fraction, probably more than 1 % of the RNA.

New cDNA clones were isolated and sequenced. All clones were relatively short varying from 100 to 500 nucleotides. Two of the clones were identical to previously sequence (Salmon TRP-1). However, the other three contained sequences from a transcript significantly different from Salmon TRP-1 and were designated Salmon TRP-2. The Salmon TRP-2 amino acid sequence is 66 % identical to Salmon TRP-1. Amino acids known to participate in the active site of the enzyme and residues determining the tertiary structure of the protein by forming covalent bonds or salt bridges are all conserved between the two trypsins. Alignment of the trypsin sequences with chymotrypsin and pancreatic elastase reveals diagnostic gaps identifying both sequences as trypsin. The alignment of the sequences reveals that trypsin from salmon is well conserved as compared to mammalian sequences. The pronounced differences between the two trypsin cDNA sequences we have determined is surprisingly large. The Salmon TRP-2 sequence is only partial, however, it may be concluded that the genes coding for the two trypsins must have diverged from each other early in the history of salmon ancestor.

NUTRITION

Protein digestibility and food conversion were determined in groups of Atlantic salmon with the presence or absence of the trypsin-like isozyme TRP-2(92). Determinations were made at different salinities, temperatures and fish size. The overall digestibility of protein using chromoxide as a marker, was unaffected by the presence of the isozyme or the other variables, but the feed conversion of Atlantic salmon possessing the variant of interest was observed to be significantly lower than in the fish without this isozyme.

Atlantic salmon (*Salmo salar*) have been fed different pigment sources, synthetic astaxanthin (Carophyll pink), krill meal, the yeast *Phaffia rhodozyma* and the algae *Heamatococcus pluvialis*. The astaxanthin deposition in the flesh have been measured analytically by colorimetric measurements.

Dose-response effects of dietary astaxanthin supplementation on flesh pigmentation have been studied in relation to feeding time.

Biological function of astaxanthin has been studied in different stages of Atlantic salmon. Effects of astaxanthin on survival and development of eggs and yolksac fry, growth promotion, immune response, and anticarcinogenic effects have been investigated.

Different fish meal qualities have been compared as protein sources for Atlantic salmon fry, and a test diet based on casein-gelatin has been developed.

Physiology

The effect of photoperiod and current velocity on growth and incidence of early maturation in Atlantic salmon were studied. The experiments were done in illuminated sea cages and in floating enclosures, respectively.

Earlier experiments studying the effects of photoperiod on timing of ovulation have revealed possible interactions with temperature. Last year the timing of ovulation was studied under three different temperature regimes.

The effect of photoperiod on the development of the desmoltification process and the development of total immunoglobulin and the specific antibody after vaccination against *Vibrio salmonicidae* at different times during the smoltification process were studied.

ARCTIC CHAR (*Salvelinus alpinus*)

Nutrition

Protein digestibility and food conversion were studied in two strains of Arctic char, an anadromous fast growing with trypsin-like isozyme TRP-2(92) and a nonanadromous slow growing without the allelic isozyme. The variation in fish strains, fish sizes, temperatures and salinities had no apparent effect on the apparent digestibility coefficient of protein using chromic oxide as a marker, but the fast growing strain with the isozyme of interest seemed to be able to utilize the feed better as their food conversion was better than the slow growing strain without this isozyme. At temperature below 6°C, the slow growing "Skogseid" strain did not consume as much feed as the fast growing "Hammerfest" strain, since very little faeces were obtained. At temperature higher than 6°C, faeces were easily collected from both strains. These results show that food consumption patterns between these two strains is different at low temperature.

SEA RANCHING PROGRAMME

The programme is part of a large scale national programme for investigating the potential of sea ranching of cod, lobster, arctic char and Atlantic salmon as additional livelihood for coastal areas where a considerable part of the fishing income was lost when drift net fishing for salmon was closed in 1969.

Atlantic salmon

Within the frame of the programme 55 000 smolts originating from three regional rivers were released by the Institute of Marine Research at Sotra island (SW-Norway) in 1991. Another cooperating project at Helgeland (mid-Norway) released 10 000 smolts originating from a regional river at Vega island. The aim is to study possible ecological consequences of large scale releases, and returns in the spring/summer of 1992.

Cod

In 1991 a total of 317 000 cod fry, the largest number ever produced, were recaptured from the semi intensive fry production unit at Øygarden, near Bergen. These fry were tagged and released in the Masfjorden and Øygarden, west of the Bergen area.

Lobster

The fry production unit at Kyrksæterøra produced 71 000 lobster seedlings. 30 000 of these were used in large scale stocking experiments at Kvitsøy (SW-Norway). The rest were released at Øygarden and in the south of the country. All the released lobsters were tagged with micro-tags.

MARINE SPECIES

Cod

1. Effects of broodstock management on egg quality.

In this program several different broodstock feeds have been applied and a subsequent investigation on broodstock growth and maturation. The main objective have been to carry out analyses on egg quality from the different parental groups. So far broodstock diets containing different C-vitamin levels, carbohydrate levels and HUFA types have been dealt with. Effects of vitamin C on egg buoyancy, egg strength and content of free amino acids were detected.

2. The impact of feeding on growth and sexual maturation in cod.

Growth rates in cod under different feeding regimes have been examined in order to decrease energy spent on liver growth and sexual maturation. Comparisons studies between cod and Atlantic salmon in terms of the sexual maturation process were carried out. Length and weight were measured on individual cod before and after the feeding experiment. Also growth of gonads and liver size were examined with an ultrasonic scanner.

HALIBUT

1. Production line for halibut fry production.

Experiments on carrying capacities for the production units of halibut fry have been carried out. During the yolksac stage the larvae were kept in large 13 m^3 silos at densities ranging from 5 to 30 individuals pr. liter. No effects of stocking density on mortality rates were found. After the yolksac period the larvae were transferred to outdoor startfeeding units where they were stocked at different densities and offered mixed diets of natural zooplankton and artemia. For stocking densities up to 30 individuals pr. liter, no density dependent morality was registered.

2. Mesocosm as partial production line for halibut fry.

Experiments on optimal start feeding regimes for halibut larvae have been carried out. Halibut larvae were offered various diets consisting of natural zooplankton and artemia under different environmental conditions. The experiments clearly revealed that green water technique enhanced the start feeding success. Artemia enriched with marine oils as sole food for halibut larvae beyond metamorphosis resulted in reduced growth and increased frequency of malpigmentation among the fry compared to natural zooplankton.

3. Optimal environments for marine fish larvae in culture.

Larval stages of halibut display simple fixed behaviour patterns, with little adaption to different environmental changes.

The investigations have concentrated on finding the optimal environmental factors for the development of a functional production line for halibut fry. Effects of light on growth and behaviour on the larval stages have been studied. In addition effects of bacterial infections on behaviour and buoyancy of halibut yolksac larvae have been investigated.

4. Bacterial infection and methods for disinfection of eggs

Bacterial infections on fish eggs and larvae have for years been a recognized problem in

aquaculture. In halibut culture major mortalities on both eggs and larvae have been observed after infections by *Flexibacter ovolyticus*. In controlled experiments up to 80 % mortality have been detected after infection with this bacteria. Halibut eggs seems to have a low tolerance limit against disinfection drugs compared to other fish species. Investigations on finding an adequate treatment against bacterial infection have been carried out, and from these experiments Buffodine seems to be the most potent.

5. Ongrowth of juvenile halibut

The ongrowth phase of halibut from metamorphosis to consume size have received little attention due to practical reasons. During the last years the number of farmed halibut have increased to the amount where such experiments are now feasible. Experiments on finding the natural diurnal feeding rhythms and optimal light regimes for feeding have been carried out. These experiments are in progress, and the results so far indicate extremely good food conversion rates at low light, and at high stocking densities.

6. Effects of daylength on sexual maturation of halibut

Juvenile halibut have since 1987 been kept under different light regimes with respect to photoperiod. In november 1991 one female matured and spawned, thus indicating that alteration of spawning time by changes in photoperiod is feasible.

SHELLFISH AND CRUSTACEA

1. *Pecten maximus*

Experiments were undertaken in April to investigate the effect of surface water (3 m) on growth and survival of young king scallop spat after metamorphosis. The experiment was designed to separate the effect of phytoplankton and the effect of dissolved organic materials (DOM) in the surface water. Cultured food consisted of at least two algal species, and was added in specific concentrations. The results showed that phytoplankton in surface water enhances the growth of scallop spat.

2. *Cancer pagurus*

I nature the quality of crabs displays large variations. These variations is mainly due to seasonal variations in food, but also in connection to molting. During such periods the crabs are not suited for human consumption, and the customers experience large differences in crab quality. No good criterion for evaluation of crab quality have been put forward, although several attempts have been made. To resolve this problem experiments on improvement of crab quality by feeding in captivity have been carried out. The project aimed at finding strategies for culture of wild-caught crabs for improved quality.

ENVIRONMENTAL IMPACT FROM MARICULTURE.

The research activity in 1991 was continued from 1990 on environmental effects of antibiotics and mineralication of organic matter.

The results show that commonly used antibiotics like oxolinic acid and oxytetracycline remains in the sediment in high concentrations for months after medication.The decrease in concentration is a result of washing out rather than of decomposition. The drugs retain their antimicrobial activity in the sediments and a decrease in the number of bacteria and in the rate in sulfate reduction are observed. The sulfate reduction activity was regained two months after end of medication. The number of bacteria recovered more slowly.
In addition, the number of resistant bacteria in a sediment containing antibiotics is in average tenfold than in a sediment without antibiotics.

Wild fauna in the vicinity of medicated fish farms contains residues of the antibiotics used. The highest concentration was found in the muscle of coalfish. However, the interindividual variance was high.

The organic load beneath a farming site is normally local. It may vary from undetectable to heavy pollution. The decomposition rate as a function of accumulated organic matter was more than twice as high in sediment with macrofauna compared to sediment without.

DISEASES.

Salmon lice.

Experiments on alternative treatment have developed a new administrative principle for oil-soluble chemotherapeutics. A natural extract from flower heads of chrysanthemum (*Chrysanthemum cinerariaefolium*) called Pyrethrum, has been found to be effective. When applied to the salmon surface for four to six seconds, a delousing efficiency of 90% or more was achieved. Tests carried out show an increased effect of the chemotherapeutic on smaller stages of the lice compared to the organo-phosphorous compounds used today.

Furunculosis.

Through infectivity studies and observations from field trials it has been shown that cod, halibut and wrasse are susceptible to furunculosis. However, these species are more resistant than Atlantic salmon. In addition, no carrier state was demonstrated in marine fish surviving a challenge experiment.

Cohabitant experiments do not reveal transmittance of *Aeromonas salmonicidae* from infected cod, halibut and wrasse to Atlantic salmon. However, such transmittance can not be excluded.

Vibriosis.

So far, vibriosis has been the most serious bacterial disease on farmed marine fish, causing yearly losses up to 50% of the total production of cod and turbot fry. Biochemical, serological and immunochemical properties of the pathogenic *Vibrio anguillarum* isolated from different farms revealed species specificity. These analysis form the basis for development of vaccines. Results of immersion vaccination of cod in a field trial with a vaccine based on two isolates of *V. anguillarum* are promising. Also vaccination of turbot fry in laboratory scale followed by an artificial challenge resulted in high relative percent protection. However, further work on vaccine optimalization and adjustment to the production line of marine fish are in progress.

Infectious Salmon Anaemia (ISA).

Infectious Salmon Anaemia (ISA) is spreading and has caused great losses in Norwegian fish farming in 1991. The disease can be transmitted by injection of blood cells (erythrocytes and leukocytes) and plasma from diseased fish. By fractionation of plasma from diseased fish on sucrose- and CsCl gradients the infectious agent was recovered in a narrow band in the gradient. ISA is primarily affecting Atlantic salmon, even though the susceptibility varies among families of the species. Wrasse and turbot seems to be resistant. Attempts to cultivate the causative agent have so far failed.

Infectious Pancreatic Necrosis (IPN).

Infectious Pancreatic Necrosis Virus (IPNV) has in 1989, 1990 and 1991 been isolated from moribund farmed Norwegian turbot and halibut. In 1991 samples were collected from halibut eggs, larvae and fry for virus detection. The virus was detected only on metamorphosed fry. Simultaneuouly, an increased mortality in the population was observed. These results indicate that mortality due to IPNV infections occur in the weaning period. However, the virus may be introduced to the population previously without causing any disease outbreak. All isolates are serotyped to N1. Histological examinations revealed pancreatic necrosis indicating that IPNV was the probable causative agent of the mortalities. The virus was also isolated from blue mussel sampled near by the halibut farm. Experiments are also carried out to investigate the fate of IPNV in scallops and the possibility of scallops acting as virus reservoir and vector organisms.

Shellfish.

A screening program is continued to control the health and parasite status of bivalve molluscs used in commercial production. Broodstock populations of oysters and clams are the primary subjects of investigation. Histological examinations of Norwegian oyster and clam has not yet revealed any serious pathogen. Additional samples are collected from stocks of indigenous clams and scallops which are or will be used in commercial production.

Institute of Nutrition,
Directorate of Fisheries, Bergen

Experiments which were either finished, initiated or published in 1991 are listed in the following:

SALMONIDS - NUTRITION

- dietary requirement and metabolism for the vitamins E, D, C and B_6
- interactions between vitamin E and polyunsaturated fatty acids
- dietary requirement and metabolism of Se, Zn, Mn and Fe
- utilization and metabolism of hydrolyzed proteins in the diet
- utilization and metabolism of dietary carbohydrates
- possible factors influencing irregular flesh pigmentation in salmon (cooperation with the Institute of Marine Research)
- digestion physiology in salmonids
- growth and utilization of processed protein sources with determination of protein synthesis in muscle tissue

MARINE SPECIES - NUTRITION

- vitamin C requirement for cod broodstock with respect to hatching success of eggs and fry survival
- dietary carbohydrates in cod broodstock diets, health and energy metabolic aspects
- energy metabolism in starving cod
- metabolism of n-3 fatty acids in cod
- metabolism of micronutrients (vitamins, trace elements, fat and fatty acids) and variations in haematological parameters during maturation in turbot
- weaning diets for cod and halibut larvae
- dietary protein quality and growth in wolffish
- dietary vitamin C for young turbot, growth and disease resistance
- growth and dietary protein quality in cod
- protein and amino acid requirements in cod
- modelling growth, protein and energy retentions in cod
- effects of starving and refeeding on restitution of growth, on protein synthesis in muscle tissue and on energy and protein metabolism in cod
- effects of the protein/fat ratio in the feed on protein metabolism and turnover in cod muscle
- determination of nutrient digestibility, methodology

University of Bergen
Institute of Fisheries and Marine Biology

SALMONIDS

Atlantic salmon

Studies on the parr-smolt transformation have been carried out in cooperation with the Inst. of Marine Research. The effects of photoperiod and temperature on the initiation of smolting and the appearance of smolt characteristics have confirmed the synergistic effects of the two stimuli.

A method has been developed for the production of 0+ smolts of Atlantic salmon using a combination of photoperiod and temperature manipulation.

It has been shown that long photoperiod during winter stimulates growth and may reduce sexual maturation of Atlantic salmon. It is also possible to accelerate or postpone ovulation by upto several months through the use of photoperiod.

MARINE SPECIES

Halibut

The early life stages (egg and larvae) are being examined to determine normal growth and development patterns, in cooperation with the Inst. of Marine Research. The two most important variables are temperature and light. Halibut eggs and early larvae have best growth and normal development around 6°C, and exogenous feeding should start at about 50% yolk absorption.

The effects of light intensity and wavelength on the early life stages include changing the density of the eggs, postponing the timing of hatching or synchronising hatching, increasing the activity of larvae, accelerating optic cell differentation and possibly other effects. The history of the developing halibut eye is now being studied to determine normal patterns and the effects of light intensity and wavelength on differentiation.

The growth rates of individually tagged juvenile halibut (initially 10 - 60 gm), held in the wet labs of the High Technology Center, show best growth at 13°C. There is as yet no clear effect of photoperiod. The fish will be followed throughout their life in captivity (in cooperation with Sea Farm A/S) to show male and female growth rates and times of maturation.

Cod

There are various experiments being run on cod in the wet labs of the Dept. of Fisheries and Marine Biology. Juveniles over 1 gram weight are being used in an experiment on the effects of temperature on density dependent growth and mortality. There was an effect of density on rates of cannibalism. Best growth was 4% per day at 14°C for fish between 1-2 grams. These fish are also being measured for oxygen consumption and ammonia excretion.

Another experiment, in cooperation with the Inst. of Marine Research, is looking at the effect of size distribution on cannibalism, growth and survival. There was no effect of the size distribution of fish over 10 grams on cannibalism, in opposition to previously obtained results. Better growth was found on moist feed.

No significant differences have been found in the activity rate of wild and farmed cod juveniles with regard to prey fish (gobies).

The types of haemoglobins in cod reared at different temperatures have been studied - cod with Hg-I(2/2) showed the highest mean growth rate regardless of environmental temperature.

Turbot

Juvenile turbot are kept in the Aqua hall of the High Technology Center. The effect of photoperiod and temperature on growth and survival of juvenile turbot >5 gm. As expected, growth was best (3% per day) for fish around 5 grams fed commercial dry feed at the warmest temperature (19°C). Survival is about 96% after four months. Further growth studies will be carried on individually tagged fish around 20 grams.

National Veterinary Institute, Oslo

RESEARCH ON FISH DISEASES

1: Furunculosis

A. Studies of pathogenesis and immune response after infection with *Aeromonas salmonicida* subsp. *salmonicida*, and after immunization with antigens from the bacteria. The aim of the studies is to obtain knowledge as a fundament for the work on improving vaccines against furunculosis.

B. Improving diagnostic methods for the detection of *A. salmonicida.* This work is necessary in order to diagnose latent carriers of the bacteria. A sensitive and specific diagnostic method is of great significance for the prophylactic work against the disease.

C. Trails of vaccines against furunculosis. Controlled field-trails have shown that losses are reduced significantly if vaccines are used in a correct way. Based on epidemiological studies, information about the positive and negative effects of vaccinations are achieved.

2. Infectious Salmon Anaemia (ISA)

A. Infectious Salmon Anaemia (ISA) is a new disease. The causative agens is not described, and a clinical description of the disease is therefore necessary. Studies of haematological conditions associated with ISA have been given priority.

B. Pathological aspects of ISA have been described, based on light microscopical and electron microscopical studies. The aim of the electron microscopical investigations has been to identify and describe the causative agens of ISA, and also to describe ultrastructural changes in liver morphology at early and terminal stages of disease.

C. The official authorities have needs for informations on disease transmission to be able to make administrative directives. Much effort has been made to investigate the resistance of the causative agens.

D. A precise diagnosis of ISA is dependent upon a causative agens (probably a virus) which might be cultured. It has not been possible to propagate an agens in cell-culture. The work is now concentrated on finding fish cell cultures which are susceptible to virus growth.

E. Efforts have been made to purify antiserum from chronically diseased fish to aid in search for the causative agent.

F. Factors which might be important for the ISA infection are quantified in an epidemiological survey.

3. Vibrio-infections

1) Non luminescent, psychrophilic strains of commercial and wild opportunistic strains of *Vibrio splendidus* isolated from anadromous and marine fish species have been characterized genotypically and phenotypically.

2) Two previously undescribed psychrophilic vibrios have systematically been isolated from kidneys and dermal ulcerations of Atlantic salmon suffering from "winter ulcers". One of these vibrios seems to play a particular significant part in of the pathogenesis of the conditions. The isolates are currently been described as novel genospecies.

* *Vibrio viscosus* spes. nov.
* *Vibrio wodanis* spes. nov.

Experiments with vaccines based on *Vibrio viscosus* are now carried out.

3) Strains of *Vibrio salmonicida*, the causative agent of cold water vibriosis ("Hitra disease") isolated from diseased fish from different geographical regions (North European and Canadian Coastal Areas) of the Atlantic Ocean have been compared on genotypic and phenotypic level. A large degree of homology has been revealed.

4) Strains of *Vibrio anguillarum* isolated from salmonid fish species and from several marine fish species have been characterized biochemically, serologically and by numerical taxonomy. The strains originated from Norway and from other parts of the world. The work is important in order to have the right composition of vibriosis vaccines.

5) Parasite-infections

The work has been concentrated on studies of *Gyrodactylus salaris*. Taxonomical aspects are studied in particular. The spreading of the parasite in norwegian rivers and fish farms has been mapped. A study on unspecific skin reactions of *Salmo salar* against *G. salaris* is in progress. The parasitological studies carried out at National Veterinary Institute have also as an aim to study aspects and infestations of other *Gyrodactylids* on different fish species. Disease problems with systemic hexamitosis in fish farms located in Northern Norway are also studied.

6) Virus-infections

In addition to Infections Salmon Anaemia (ISA), IPN-virus has been further studied. The main aims have been a serological characterization of different isolates, and a clarification of the primary and secondary effects of infections in farmed fish. Experimental infections of Atlantic salmon with a Sp. type of IPN-virus has been carried out.

4. Immunology and immune prophylaxis

A. There is limited information about immune system of salmonid fish species. It has been necessary to establish a number of laboratory tests. These have been used in studies of the specific humoral and cellular immune response in salmonids against different antigens. A work on mechanisms involved in the transfer of maternal immunity has started. Knowledge about transfer of immunity to fry may be applied in immunprophylaxis in order to protect the off-spring from infections.

B. In fish farming, several factors influence the protective immune response after vaccination. Temperature is one important factor. However, the vaccination method and use of booster vaccination are other important factors.

C. Immune histochemistry is an important field both for research and diagnostic work. Immune histochemical methods have been established and are now used in pathomorphological studies of different fish diseases.

Norwegian Institute of Fisheries and Aquaculture
(FISKERIFORSKNING), Tromsø

DISEASES

Fish immunology/diagnostic methods/vaccines.

- Studies of the immune system of fish in order to produce effective vaccines against fish diseases;
- Studies of viral diseases of farmed fish;
- Monitoring changes in levels of specific serum components as function of bacterial infections;
- Development of monoclonal antibodies against bacterial antigens;
- Recombinant DNA technology in vaccine design.

MARINE SPECIES

Fish juveniles

- Studies of digestive enzymes in fish larvae;
- Assay techniques for monitoring of digestive capacity of marine larvae;
- Formulated dry feed;
- Weaning feed.

Spotted wolffish (*Anarhichas minor O.*)

Stock Assessment

- Reproduction; - behaviour and artificial fertilization;
- Growth optima versus temperature, density and nutrition;
- Products and marketing; - utilization of fish skin for leather production.

Cod (*Gadus morhua L.*)

- Formulated dry feed for startfeeding the larvae;
- Developing criterias and techniques for sorting "Danish-seine" - caught cod for aquaculture purpose;
- Monitoring mixture between Coastal Cod and North-Arctic Cod in Vestfjorden (main spawning area) during the spawning period and describing development in condition;
- Monitoring skin-coloration on netpen-kept cod.

ANADROMOUS SPECIES

Atlantic salmon (*Salmo salar L.*)

- Sea ranching with Atlantic salmon, including:
  - studies on smoltification
  - vaccination and its impact on smoltification;
- Effects on growth and food intake in Atlantic salmon, feed diets supplemented with gustatory feeding stimulants, studied by X-Radiography;
- Growth, chemical composition, product quality and health in Atlantic salmon fed moist diets based on fish protein concentrate and other marine raw materials, compared to fish fed a commercial dry diet.

Arctic char (*Salvelinus alpinus*)

- Seasonal variations in seawater growth- and osmoregalatory performance;
- Effect of salinity on growth, feed intake and osmoregulation;
- Smoltification characters in wild anadromous Arctic char.

ENVIRONMENT

- Inactivation of bacteria (*Aeromonas salmonicida* subsp. *salmonicida*) and viruses (*Infectious pancreatic necrosis virus*) in water from aquacultural activities;
- Fish pathogenetic microbes in marine ecosystems;
- Marine antibiotics in fish disease control.

Poland

by

(Józef Wiktor)
Sea Fisheries Institute, Gdynia

The rearing of salmon (*Salmo salar*) spawning stock in sea cages was continuated to obtain eggs necessary for reintroduction of this species into Polish rivers.
Also the observations on effectiveness of delayed releasing of sea trout (*S. trutta*) smolts in brackish water were conducted.
Growth rate and behaviour of artificial hybrids sea trout x rainbow trout in the brackish water was observed.

Spain

by

(I. Arnal & J. Iglesias)
Instituto Español de Oceanografía, Madrid & Centro Oceanográfico, Vigo

This report gives a summarized overview on the research activities concerning mariculture in Spain.

The Institutions included in this annual report can be grouped in four main Organizations.

1. Instituto Español de Oceanografía (I.E.O.) Ministery of Agriculture and Fisheries.
2. Consejo Superior de Investigaciones Científicas (C.S.I.C.) Ministery of Science and Education.
3. Universities.
4. Local research Centers of autonomic goverments.

1. INSTITUTO ESPAÑOL DE OCEANOGRAFIA (I.E.O.)

Centro Oceanográfico de Santander

- Hatchery and ongrowing techniques on turbot (Scophthalmus maximus) and Pagellus bogaraveo.
- Biological research and production (indoor and outdoor) of macroalgae: Gelidium sesquipodale, Gracilaria verrucosa and Gracilaria folifera.

Centro Oceanográfico de La Coruña

- Pectinids culture.
- Nutritional studies on bivalve Molluscs: Ostrea edulis, Venerupis decussata and V. semidecussata.
- Biochemical composition of Cianoficea, Diatomea and Dinoflagelade.
- Studies on "red tides" and their effects on mussel culture in the Galician rias.

Centro Oceanográfico de Vigo

- Hatchery research on turbot (Scophthalmus maximus): Reproduction, larval nutrition, oxygen comsumption and restocking.
- Studies on "red tides" and their effects on mussel culture.

Centro Oceanográfico del Mar Menor, Murcia

- Hatchery and ongrowing of Sea bass (Dicentrarchus labrax), sea bream (Sparus aurata) and Seriola (Seriola dumerilii).
- Natural stock assesment on Ostrea edulis in Mar Menor.

Centro Oceanográfico de Tenerife

- Hatchery and ongrowing of Sea bream (Sparus aurata) and other Sparidae.

2. CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS (C.S.I.C.)

Instituto de Acuicultura de Torre de la Sal. Castellón

- Research activities on sea bass (Dicentrarchus labrax): oxygen comsumption on eggs and larvae, reproduction and sex control, ongrowing diets and pathology.
- Reproduction of sole (Solea senegalensis).
- Quality control of Artemia salina from different sources.
- Culture of Penaeus kerathurus and P. japonicus.
- Biochemical composition of Tetraselmis suecica, Thalassiosira minima, Pecten jacobaens and Ostrea edulis.

Instituto de Ciencias Marinas de Andalucia. Puerto Real. Cádiz

- Ecofisiology of clams (Venerupis decussata and V. semidecussata)
- Culture of sea bream (Sparus aurata)
- Metabolism and physiology of microalgae.

Instituto de Investigaciones marinas de Vigo

- Larval nutrition in bivalve Molluscs: Biochemical composition of ostrea edulis and Mytilus galloprovincialis larvae.
- Nutrition of turbot (Scophthalmus maximus) larvae.
- Biology and pathology of bivalve Molluscs: Ostrea edulis and Mytilus galloprovincialis.

Centro de Documentación en Acuicultura. Madrid.

- National bank os aquaculture data.
- Spanish directory of Aquaculture activities.

3. UNIVERSITIES

University of Santiago de Compostela

- Microbiology Department: Facultad de Farmacia
  .Culture of marine microalgae. Biochemical variability.
  .Culture of Artemia with microalgae and inert diets.
  .Utilization of the pigments in fishes.
- Biochemistry Department: Facultad de Biología.
  .Biochemical composistion of molluscs larvae.
- Microbiology Department: Facultad de Biología
  .Pathology of molluscs and fishes.
- Genetics Department. Facultad de Biología.
  .Genetics of Molluscs.

University of Barcelona

- Animal Physiology Department. Facultad de Biologia.
  .Fish Nutrition.
- Zoology Department. Facultad de Biología.
  .Fish culture.
- Botanic Laboratory. Department of natural products, biology and edaphology. Facultad de Farmacia.
  .Biological potential of macroalgae and their application in aquaculture.
  .Structural and biochemical characteristics of microalgae.

Autonomic University of Barcelona

- Cellular biology and physiology department.
  .Natural feeding of sole (Solea vulgaris)
  .Aerobic metabolism of mussel
  .Stress in marine fishes.

Politechnic University of Cataluña. High-School of Aquaculture

- Zoothecnic Department.
  .Physiology and fish nutrition.

University of Granada

- Department of animal biology, ecology and genetics. Facultad de Ciencias.
  .Chromosomic manipulation, sexual maturing and hibrids in Salmonidae, Sea Bass and Sea Bream.
  .Nutrition of freshwater and marine fishes.
- Department of Biochemistry and Mollecular Biology.
  .Metabolism of proteins in anguilla.

University of Murcia

- Animal Physiology Department. Facultad de Biologia.
  .Nutrition of Sea Bream (Sparus aurata) and Sea bass (Dicentrarchus labrax).
  .Nutrition and metabolism of rainbow trout (Salmo gairdneri irideus).
- Cellular Biology Department. Facultad de Biologia.
  .Sea bass, sea bream and Seriola.
  .Gastric-entero-pancreatic system and liver
  -Gonadal-hipophisis effect in the sexual cicle.

University of Las Palmas

- Facultad de Ciencias del Mar.
  .Macroalgae culture.

4. LOCAL RESEARCH CENTERS

Centro de Cultivos Marinos. Ribadeo. Xunta de Galicia.

- Culture of bivalve Molluscs: Ostrea edulis, Venerupis decussata, V. pullastra and Donax trunculus.

Centro Experimental de Villajuán. Villagarcía. Xunta de Galicia.

- Natural stock assesment on bivalve molluscs.

Centro de Cultivos marinos de Couso. Xunta de Galicia.

- Turbot, clams, and oyster culture.

Centro Experimentación Pesquera. Principado de Asturias.

- Biology and culture of clams: Ruditapes decussata and R. philippinarum.
- Hatchery research on bivalve molluscs: Ostrea edulis, Crasostrea gigas and Ruditapes philippinarum.

Planta de Experimentación de Cultivos Marinos. Murcia. Consejo Murciano.

- Hatchery research on Sea bass (Dicentrarchus labrax) and Sea bream (Sparus aurata).

Estación de Acuicultura del Port d'Andratx. Palma de Mallorca. Gobern Balear

- Hatchery production and ongrowing in sea cages os sea bream (Sparus aurata), sea bass (Dicentrarchus labrax).
- Diplodus puntazzo, Dentex dentex and Seriola dumerilii.
- Desing of different structures for sea cages and their effects on the natural environment.

Centro de Tecnología Pesquera. Taliarte. Cabildo Insular. Gran Canaria.

-Culture of Sea bream and Shrimp.

5. PRODUCTION

The Ministery of Agriculture and Fisheries still has not published the 1991 official production data; but we include the 1990 data.

1990 MARICULTURE PRODUCTION IN SPAIN

SPECIES	PRODUCTION METRIC TONNES
Marine finfish	
Turbot *(Scophthalmus maximus)*	640.3
Sea bass *(Dicentrarchus labrax)*	30.7
Sea bream *(Sparus aurata)*	564.6
Mugilidae *(Mugil Sps.)*	118.1
Seriola *(Seriola dumerilii)*	20.8
Sole *(Solea sp.)*	7.1
Thunnidae	357.7
Anguila *(Anguilla anguilla)*	124.8
Salmon *(Salmo salar)*	355.0
TOTAL:	2219.1
Crustaceans	
Shrimp *(Penaeus japonicus)*	40.6
Prawn *(Palaemon serratus)*	160.0
TOTAL:	200.6
Molluscs	
Clams *(Ruditapes / Venerupis)*	4157.2
Oysters *(Ostrea / Crasostrea)*	2857.4
Mussels *(Mytilus)*	173300.0
Venus verrucosa	10.0
Pecten maximus	120.0
TOTAL:	180444.6

UNITED KINGDOM

England and Wales

(S.D. Utting)
Ministry of Agriculture, Fisheries and Food, Conwy

FISH

Commercial production

Ten tonnes of trout were reared in sea water on a trout farm in Pembroke, South Wales.

Approximately 250,000 turbot juveniles were reared in a hatchery on the Isle of Man. The majority were exported to Galicia, Spain.

Research

1. Ministry of Agriculture, Fisheries & Food (MAFF), Fisheries Laboratory, Conwy, Wales - techniques for the cultivation of Dover sole in the context of stock enhancement programmes. Includes collaborative studies with School of Ocean Sciences, University College of North Wales, Bangor, on feeding and digestion in sole.

SHELLFISH

Commercial production

The commercial production of bivalves was as follows:
200 tonnes *Ostrea edulis*, 600 tonnes *Crassostrea gigas*, 50 tonnes *Tapes philippinarum* and 4,000-5,000 tonnes *Mytilus edulis*.
Several million seed oysters and clams were produced by two commercial hatcheries (one in England and one in Guernsey) for on-growing in the UK and for export.

Research

1. MAFF, Conwy - a study into the hatchery culture of the King scallop (*Pecten maximus*) was started. The main emphasis of the work will be to determine the factors required for the successful hatchery conditioning of scallop broodstock. Preliminary results have been promising.

2. MAFF, Conwy - research to assess the environmental impact of clam farming. Changes to the substrate and its benthos are being assessed in relation to the farming, on a semi-commercial scale, of *Tapes philippinarum, T. decussatus* and *Mercenaria mercenaria*. Triploid *T. philippinarum* are included in the study.

3. Recaptures from MAFF's lobster stock enhancement trial were 117 in 1991. (50,000 juvenile *Homarus gammarus* were released off the coast of north-eastern England from 1983 to 1989) . A total of 5,000 lobsters were tested for microtags. Recaptured lobsters were from the 1984-1987 releases and the positions of recapture were as in previous years. Monitoring will continue through 1992.

Scotland

by

(A.L.S. Munro)
Marine Laboratory, Aberdeen

Salmon and Trout

Atlantic salmon production in Scotland in 1991 was 40,593 tonnes (25.5% increase from 1990) but egg and smolt input data indicate that future production will probably remain static at around 40,000 tonnes until at least 1994. As in previous years the major biological problems facing salmon farming are concerned with disease. Trout production in sea water was 178 tonnes compared to 3,334 in fresh water.

Sea Farm Salmon Survival

The decline continues in the survival at Atlantic salmon in the sea phase of salmon farming in Scotland with 57.9% of the 1989 smolt input surviving to harvest compared to 63.4 for the 1988 input. The combination of furunculosis and lice infestation are the major causes of the losses but storm damage, particularly in January 1991, also contributed. There is now evidence of improving survival in 1991 with 41.4% grilse and pre-salmon recovered from the 1990 smolt input compared to 32.3% for the 1989 input in 1990. This may be attributed to a general move in the industry towards decreasing stocking densities and towards the implementation of strategic health management agreements. The full effect of these agreements which involve synchronised fallowing of shared waters and subsequent stocking with smolts of good health status must await some years for full evaluation. However, preliminary reports suggest beneficial results in reducing infestations of lice and outbreaks of furunculosis and a decline in the resistance patterns of lice to dichlorvos and of *Aeromonas salmonicida* to antibiotics.

Furunculosis continues to pose the greatest disease problem necessitating the extensive use of antibiotics. Of cases submitted for sensitivity analysis 14% showed resistance to four drugs, 16% to three, 24% to two and 42% to one. Only 3% of isolates were fully sensitive to all five drugs tested and these were mainly from wild caught fish. A vaccine being developed in Scotland against furunculosis is currently undergoing ATC trials in the salmon farming industry. Where furunculosis outbreaks occurred on sites, fish vaccinated by a single intraperitoneal injection always suffered lower mortalities with mean RPS values between 60 and 70%. Experimental trials have shown that protection persists for about nine months but thereafter it declines. Presently the vaccine contains no adjuvant and work in 1992 will test a variety of adjuvants in attempts to prolong the duration of protection. As indicated management methods are also showing encouraging results in reducing the severity and occurrence of furunculosis.

Lepeophtheirus salmonis ranks as the second most important disease in Scottish salmon farming. Resistance to dichlorvos continues to develop in some sites but some alternative treatment compounds currently being investigated are showing considerable promise. An *L. salmonis* DNA library has been established and has been used to produce monoclonal antibodies which are being screened using immunohistochemistry to identify putative protective antigens. Specific binding to louse gut has been shown for some monoclonals and these are currently being assessed with respect to developing immunity in salmon. It has been shown that infection on farms is often derived from reinfection by larvae from the lice population on that farm and other farms sharing the same water. Maintenance of clean nets reduces reinfection but fallowing of the area is proving to be highly effective in managing the problem.

IPN virus, a notifiable disease in Scotland, showed significant increase in occurrence in 1991.

Most of the isolations of virus were from sea water sites. As reported previously there is a continued trend towards an association between IPN and increasing post smolt problems but the occurrence of other concurrent problems such as Pancreas Disease and fading smolts makes it difficult to determine the precise role being played by IPN. The strict statutory control of the disease status of individual broodfish used to supply eggs to the salmon farming industry is considered to be effective in preventing IPN becoming widespread in fresh water farms.

Pancreas Disease showed a variable severity during 1991 with some farms being seriously affected but with the industry as a whole showing relatively mild outbreaks. It has been shown to be possible to induce resistance to infection which can persist from the pre-smolt through to the post smolt stage, giving encouragement in research towards vaccine development. There has been a possible successful *in vitro* culture of an agent which is currently being evaluated. It has been shown that starvation of salmon at the time of infection will prevent destruction of the exocrine pancreas so enabling rapid recovery but still permitting resistance to develop. Fish farmers are now advised to stop feeding immediately PD is suspected in a farm stock and to return gradually to noral rations.

Other conditions recorded in diagnostic cases included *Exophiala, Vibrosis*, unidentified protozoan infections and toxic plankton blooms.

Halibut

Rearing trials continue under direction of the SFIA at Ardtoe. In 1991 several thousand juveniles were reared reflecting the gr eatest survival success so far. These stocks will be the basis for ongrowing trials.

Wrasse

A variety of trials and studies are ongoing ranging from studies of the effects on wild wrasse populations of fishing, the nature of diseases they carry and susceptibility to salmon diseases and methods of culture of wrasse to supply to salmon farms for lice control.

Shellfish

Mussel production doubled to 1,024 tonnes reflecting a significant increase in production in a small number of farms. Pacific oysters harvested were 2.3 million, native oysters 120,000, scallop 316,000 and queen scallops 1.5 million. These figures represent significant increases over previous years nevertheless shellfish remains a small (in commercial terms) industry in Scotland. Factors limiting production other than the cooler waters of Scotland tend to be economic eg scale of production and remoteness from markets. No significant disease problems have been reported.

United States of America

by

(John B. Pearce)
National Marine Fisheries Service, Woods Hole, Massachusetts 02543

The culture of salmonids and various activities associated with the culture, biology, and ecology of bivalves, especially mussels and oysters, continue to be major mariculture issues on the east (Atlantic and Gulf) coastline of the USA. Highlights of these endeavors from both the management and research point-of-view follow.

GULF OF MAINE (GOM)

Mussel bottom culture developed in Maine in the early 1980's, growing to a production of 1,000 tons of mussels/year by 1987. The growth of this industry has been hindered by a lack of knowledge of site-specific factors relating to mussel growth and yield; two-thirds of the sites leased were suboptimal due to low tidal currents, lack of quantity or quality of sestonic food, soft bottom type, or excessive predation by ducks and starfish. As mussel seed transplantation grew and became mechanized, a lack of understanding of the sensitivity of mussel shell growth and meat yield led to density-dependent growth rates on both individual mussel patch (e.g., 1-10 meter) scales and on the mussel lease section (e.g. hectare) scale. To address such issues, a model has been developed which considers tidal current speed, water depth, mussel seed size, time of year seeded, the annual food curve including phytoplankton and detrital carbon, seeding density, boundary layer mixing, mussel food ingestion, and basic physiological parameters (pumping rate, respiration, assimilation) to give an output of mussel final meat size, shell size, and shucked meat yield (e.g., pounds of meat/bushel). This will allow farmers to optimize yield and predict site production based on controllable parameters such as size of mussel seeded, seeding density, density distribution and time of year seeded.

To support the model, a variety of experiments have been performed to address estuary-scale (horizontal) and vertical scale (cm) distribution of food particles available to mussels. Tidal transport of high-quality food from outer to inner estuarine areas, and settling of this forage during high water and on the ebb tide, were identified as important mechanisms for the vertical flux of food to mussels. Time-series measurements during spring and fall with underwater video showed tidal rhythms of mussel shell gape. Vertical particle profiles in the benthic boundary layer showed the importance of settled pelagic and resuspended benthic diatoms, as well as enriched organic carbon in the 5-10 cm above the bed region

on the edge of the lease sites. Measurements of scope-for-growth in the field and investigations of mussel feeding selectivity using a flow cytometer illustrated the sensitivity of mussel feeding to natural ranges in total particles, silt, and phytoplankton in relatively clear Maine waters. Finally, a particle depletion model was tested to predict seston depletion over a 1-km lease site, and different seeding strategies were investigated to improve mussel growth in inner-lease site locations.

Areas needing further investigation are:

- The role of water stratification in limiting the effective water depth over the mussel beds from which food particles are obtained;
- the role of the production of particle flocs in increasing the settling rate of particles which become available to the mussel bed (observed settling rates are about ten times greater than would be expected from the density of phytoplankton cells alone);
- the importance of spawning in the reduction of mussel growth, and triggers which cause spawning; and
- the role of resuspension in recycling near-bottom organic matter, increasing the food supply to mussels (for additional information contact C. Newell, 207-372-6317).

Other shellfisheries/aquaculture activities in the GOM include the participation of several companies in model programs for seafood inspection and increased testing of products to encourage consumer confidence. The American oyster industry in the Damariscotta River area, Maine, using a combination of suspended tray culture of hatchery-reared seed, followed by one to two years on the bottom, has grown. One company is transplanting market-sized oysters to colder, high-salinity sites to improve flavor and bacterial quality; products are commanding high prices for the half-shell market in the Northeast, and may rise to five million oysters/year by 1997.

Hard clam mariculture continues as a project on Cape Cod, with 80% survival in grow-out bottom cages achieved by much of the industry. Specific companies are also now producing seed bivalves for a growing "cottage industry". The NE Regional Aquaculture Center (USDA) shellfish group has a project aimed at improving reliability of a cultch-oyster industry to revive the Chesapeake Bay, Delaware Bay, and other areas and will be implementing it shortly. Research continues on surf clam aquaculture (hatchery reared) similar to that prosecuted for hard clams. United States and Canadianinvestigators are forging ahead on sea scallop aquaculture but there is need to develop cost effective methods of intermediate nursery and bottom culture in boreal waters.

Net-pen salmon culture has reached near record levels for production per unit area. There is some concern that production may now exceed the present market, resulting in depressed prices and profits. In spite of this the business continues to expand. The industry is the number two producer of revenue, on a dockside basis, of Maine fisheries.

MIDDLE ATLANTIC BIGHT

The more important cultured species in the region (New York - Virginia) are bivalve mollusks and blue crabs (Callinectes sapidus) culture of finfish such as the striped bass (Morone americanus) continues to be of relatively minor importance. Culture of Crassostrea virginica continues to be hampered by the incidence of MSX and "Dermo" (Perkinsus marinus) in the Chesapeake and Delaware Bay areas. High mortality of juvenile (25 mm) C. virginica at a Long Island, New York hatchery during the last year appears to have resulted from some as yet unidentified agent, probably microbial. Declining productivity of beds has fueled further a debate over introductions of Crassostrea gigas in Chesapeake Bay. Laboratory research continues to explore C. virginica x C. gigas crosses, and the efficacy of triploid C. gigas production. There is some concern whether the approach will be fruitful.

Hard clam (Mercenaria mercenaria) culture has expanded in New York and New Jersey. Towns on Long Island have constructed, or are planning, clam hatcheries, the major purpose of which is to augment public fisheries in town waters several of these hatcheries also are working with C. virginica and bay scallops, Argopecten irradians irradians. The major purpose of private hard clam mariculture is the production of littlenecks for half-shell trade seed are sold as well. Private clam culture is prevalent in New Jersey, where leasing of intertidal areas is allowed (Gregg Rivara, Cornell Cooperative Extension, Riverhead, NY). Relaying of clams from uncertified waters to certified areas, with subsequent harvest after a depuration period, has also expanded. This practice is increasing in importance due to further closures of shellfish producing areas because of poor water quality and extensive unharvested clam resources in uncertified waters. Clam relaying also helped employ local baymen who have suffered from the decline of other traditionally important fisheries (e.g., bay scallops and striped bass).

Extensive reseeding of Long Island waters with hatchery-reared A. i. irradians has been practiced since 1986 by a baymen's organization, the L.I. Green Seal Committee, as well as by local towns, in an attempt to repopulate waters from which bay scallops virtually disappeared following blooms of the chrysophyte Aureococcus anophagefferens. These programs have met with some success, as demonstrated by electrophoretic analysis of hatchery and wild brook stocks and field-collected seed (Maureen Krause, SUNY-Stony Brook). The seed used for transplants has ultimately

come from a hatchery in Maine, with most being cultured through intermediate growout at New York facilities prior to planting. Some experimental growout of scallop and Mytilus edulis seed has also been conducted in Long Island marinas. (For information contact S. Tettelbach, Long Island University, Southampton, New York.)

Two projects are underway in Delaware Bay which involve the use of exotic species held under quarantine conditions in closed systems following ICES guidelines. One is, again, a study on interspecific hybridization between C. virginica (American oyster - native sp.) and C. gigas (Pacific oyster). A second is work to characterize the byssal adhesive of zebra mussels, Dreissena polymorpha (for more information contact P. Gaffney and H. Waite, respectively, at University of Delaware, Lewes, Delaware.)

Two other laboratories in the region are working with Pacific oysters (The Haskin Shellfish Research Laboratory, Port Norris, New Jersey, and the Virginia Institute of Marine Science, Gloucester Point, Virginia.) Both labs follow strictly the ICES guidelines on introductions. There is considerable concern within the resource management and scientific community regarding the introduction of C. gigas as a means of reviving the oyster industry in the region. There is growing concern about the "invasion" of zebra mussels into this area and effects on industry, including culturing. The Mid-Atlantic Sea Grant Programs are gearing up to develop a regional effort to educate the public on this topic and similar issues.

CHESAPEAKE BAY

Two major pathogens, MSX and Dermo are recognized as causative agents of massive oyster kills in Chesapeake Bay "Dermo", Perkinsus marinus, which was first reported in the Virginia portion of Chesapeake Bay in the late 1940's and "MSX", Haplosporidium nelsoni, first reported in the mid 1950's, continue to seriously affect oyster populations. We have identified the parasites taxonomically, but know little about their life cycles the method of transmission of MSX to the oyster has not been determined, nor has the parasite been transmitted in the laboratory. Both parasites are more active in higher salinity areas of the Bay and caused significant mortalities during the drought periods of the 1960's, 80's, and 1990's. "Dermo" has spread to most oyster producing areas in the Maryland portion of Chesapeake Bay only recently has it been reported to affect seriously most populations in the New Jersey portion of Delaware Bay. There is evidence, at least with MSX infections, that a form of natural resistance can develop in the oyster we know little of the genetic components of such resistance of any particular stock of oysters. Only limited information on resistance of oysters to the "Dermo" parasite has come from recent research.

Current research activities on MSX and "Dermo" at the Oxford (MD) Cooperative Laboratory are:

- Annual oyster survey to determine the level and prevalence of oyster diseases
- development of rapid diagnostic methods for studying prevalence and distribution of Perkinsus marinus and Haplosporidium nelsoni
- study of in vivo osmotic effects on "MSX" as a consequence of rapid salinity change and
- determination of whether non-indigenous species of oysters, as the Pacific oyster (Crassostrea gigas), are more resistant to MSX and "DERMO" than the American oyster.

SOUTH ATLANTIC

Mariculture companies have recently built extensive facilities (among the largest in the world) to culture hard clams in the Carolinas, Georgia, and Florida.

GULF COAST

Louisiana is the nation's leading producer of oysters (Crassostrea virginica). Most production is from private leases to oystermen from the state. The Louisiana Department of Wildlife and Fisheries (LDWF) manages public grounds and seed beds. Seed beds are public water bottoms upon which cultch is planted to encourage the attachment of spat. Typically, as spat grow to seed, seed oysters are transplanted to private leases and grown to commercial size.

The LDWF is the primary management agency for the resource most oyster research is conducted by universities. Recent research includes:

- Alternatives to clamshell as cultch for oysters,
- parasitological surveys,
- hatchery and depuration technology,
- remote setting of larvae,
- genetics and breeding,
- bioenergetics
- bioeconomic models, and
- new indicators of sewage pollution.

A major project, freshwater diversion of water from the Mississippi River to estuaries, will be attempted to restore historical salinities and stimulate oyster production in areas experiencing salt water intrusions. (For further information contact T. Soniat, Nicholls State University, Thibodaux, LA.)