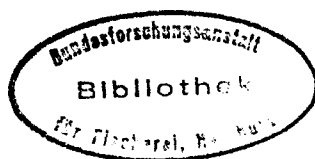


International Council for the
Exploration of the Sea



C.M. 1994/F:1
Report of Activities



MARICULTURE COMMITTEE

by

Robert H. Cook

1993

BELGIUM

by

Patrick Sorgeloos

(University of Ghent)

UNIVERSITY OF GENT, LABORATORY OF AQUACULTURE & ARTEMIA REFERENCE CENTER

Effect of culture conditions on the lipid composition of microalgae

Use of substitution and supplementation diets for live algae in bivalve hatcheries (hard clam in the USA, scallop in Chile)

Characterization of the microbiological environment in marine fish hatcheries and its relation to the larval health status of seabream, seabass and turbot; development of disinfection procedures to reduce bacterial contamination levels in live food preparations; screening for and evaluation of probiotic bacteria in rotifer cultures (in cooperation with the Laboratory of Microbiology, University of Gent; the Laboratory of Ecology and Aquaculture, Catholic University of Leuven; Cephalonian Fisheries, Greece and Tina Menor, Spain).

Development and standardisation of a challenge test with pathogenic bacteria for larval turbot; application of the bioencapsulation technique for incorporating antibiotics and vaccines in Artemia and Brachionus to treat bacterial infections in the larval stages of fish and shrimp; use of a challenge test with turbot larvae to quantify effects of prophylactic and therapeutic treatments with various compounds (in cooperation with the Lab of Medical Biochemistry and Analytical Chemistry, University of Gent; School of Biological Sciences, University of Thessaloniki, Greece).

Further developments and dietary testing of live (Brachionus and Artemia) and formulated (enrichment and substitution) diets containing high HUFA and/or various DHA/EPA ratio's and vitamin C, for use in the larviculture of freshwater and marine fish, marine shrimp and freshwater prawn, and molluscs (in cooperation with research laboratories and private hatcheries in Belgium, France, Greece, Norway, Spain, the Philippines, Thailand, Canada and the USA).

Study of lipid requirements in marine fish during weaning and first on-growing, and in post larval shrimp using a "standard" diet

Characterization study of Artemia strains from Africa, Asia and Europe (biometrics, culture characteristics, genetics, lipid metabolism, free amino acid metabolism) (in cooperation with the School of Biological Sciences, University of Wales, Swansea, UK, the School of Biological Sciences, University of Thessaloniki, Greece, the Department of Genetics, University of Milan, Italy, the Zoology Department, University of Bergen, Norway).

Study of diapause in Artemia cysts (in cooperation with the Bodega Bay Marine Laboratory, University of California at Davis, USA)

INVE AQUACULTURE NV/SA

Development (contract research with the Laboratory of Aquaculture of the University of Gent) and marketing of new diets for use in larviculture of marine fish and shrimp

CATHOLIC UNIVERSITY OF LEUVEN, LABORATORY OF ECOLOGY AND AQUACULTURE

Bacteriological and histological research on larval mortalities in marine fish: detection of infection route of fish pathogen in young larvae as well as the ontogenetic stages during which infections occur (cooperation with the University of Gent et al., see above)

Study of the physiological mechanisms that explain the skewed sex ratios in environmentally induced sex differentiation in European eel (*Anguilla anguilla*)

Development of DNA microsatellite probes for the study of population structure of European eel.

CANADA

by

Robert H. Cook

(Department of Fisheries and Oceans)

This report is a partial summary of the research and development on mariculture in Canada, based on information received from research in government, universities and private research institutions.

In 1993, the Deputy Minister of the Department of Fisheries and Oceans, the lead federal agency for aquaculture, initiated the development of a new strategy for aquaculture development in Canada. A second Canadian Aquaculture Planning Forum, involving industry and government, was convened in Campbell River, British Columbia, in October 1993 to address the various elements to be included in this new strategy. The development of this strategy, and related consultations, is continuing.

The Aquaculture Association of Canada held its Annual Conference in Prince Edward Island in 1993.

Newfoundland and Labrador:

1. Electrophoretic analyses of salmon

Preliminary sampling of salmonids in the Bay D'Espoir area has been started for electrophoretic analyses to estimate effective size of hatchery and natural populations of salmonids. One batch of salmon parr was collected from the Little River for Genetic analysis.

2. Non-maturing salmoids

Experiments are continuing at the Bay D'Espoir Salmon Hatchery on production of all-female, triploid salmon. The all-female production line of Saint John River salmon failed to mature in 1993. Half of the sex reversed stock was sacrificed in an attempt to secure homogametic sperm. As an alternative, approximately 61,000 mixed sex eggs were treated to induce triploidy.

3. Aquaculture performance of a Newfoundland salmon stock

About 180,000 Grand Codroy stock eggs were obtained from the Bay D'Espoir marine cages in 1993. These were incubated in the Bay D'Espoir hatchery with less than 10% mortality. Arrangements have been made with the Bay D'Espoir company to provide hatchery rearing of sufficient of these juvenile salmon to produce 25,000 Grand Codroy smolts in 1996.

4. Mussel spat collection failure in Notre Dame Bay

Work continued on an investigation of the causes behind widespread losses of mussel spat from collectors, experienced by many mussel farmers in Notre Dame Bay, on the northeast coast of Newfoundland. Heavy bio-fouling with a cold water species of red algae, Polysiphonia flexicaulis, coupled with unusually cold water conditions in the spring is believed to be a major cause of the problem. In 1994, work will focus on bio-toxins produced by the alga which may be toxic to bivalve spat.

5. Seasonal changes in the body proportions of cultured scallop

Samples of juvenile and adult scallops from pearl nets grown at a commercial shellfish culture site in Notre Dame Bay were collected seasonally. Analyses were carried out of size and season-related changes in the body proportions of various organs. The information was used to help scallop farmers pinpoint appropriate times to harvest scallops intended for sale as whole scallops (shell on or off), meats alone or meats with roe.

6. Identification of Mytilus trossulus and edulis distributions

A start has been made on laboratory techniques to identify trossulus and edulis mussels by electrophoretic and morphological analysis. Morphometric and morphological data has been collected on mussels from three different stock sources at a commercial mussel site. Commercially important characteristics of the two mussel types are being studied.

Nova Scotia:

(a) Halifax Fisheries Research Laboratory

At the DFO Halifax Laboratory, the mariculture research is presented under the following headings:

Salmonids

i) Nutrition

- Vitamin C and immune response

Atlantic salmon smolts were fed practical diets supplemented with 0, 100, 500 or 2,000 mg/kg of L-ascorbyl-2-polyphosphate; a stable derivative of L-ascorbic acid. The response criteria included growth, survival, feed efficiency, tissue ascorbic acid deposition, pathological signs, immune response and resistance to *Aeromonas salmonicida* and *Vibrio anguillarum*. Fish fed unsupplemented diets showed significantly low ascorbic acid levels in all tissues. Increases in the level of vitamin C caused a gradual increase in ascorbic acid deposition in both liver and kidney. Lower mortalities were experienced in fish fed the megadose concentration of ascorbic acid when challenged with *V. anguillarum*, however, no improvement in survival was observed in fish challenged with *A. salmonicida*. The complement system and macrophage activity showed variable response to experimental diets.

- Atlantic salmon fry mortalities

An extensive investigation was undertaken to determine the cause of high mortality in Atlantic salmon fry reared in DFO and some private hatcheries. Moribund fish were anaemic and showed segmented erythrocytes. Analytical results of feed and tissues show neither a deficiency nor toxicity of vitamins and trace elements. Chemical analysis of feed ingredients revealed high content of biogenic amines, particularly histamine. Results to date indicate the problem was associated with amines or an interaction during processing. Many feed manufacturers had used horse mackerel and other South American fish meals in their starter diets.

ii) **Disease and Immunology**

- A research program has been initiated on the potential use of live avirulent *Renibacterium salmoninarum* (BKD agent) as a vaccine to protect fish.
- Many salmon farms in the Bay of Fundy were affected by Hitra Disease in 1993. Work has been initiated to determine if a new stereotype of the disease agent (*Vibrio salmonicida*) is present in the Bay of Fundy which could assist in refinement of vaccines.

Marine Finfish

i) **Nutrition**

- Juvenile turbot EFA feeding study conducted at the Halifax Research Laboratory confirmed earlier results of the collaborative project with scientists at the NERC Unit of Aquatic Biochemistry, Stirling University, Scotland. In addition to the n-3 unsaturated fatty acid (HUFA) eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3), juvenile turbot have a requirement for the n-6 HUFA arachidonic acid (20:4n-6).
- Collaborative studies with the DFO St. Andrews Biological Station demonstrated that over the entire larval halibut culture period, April to June, wild plankton captured in the Bay of Fundy were rich in the n-3 HUFA (20:5n-3 and 22:6n-3), which are considered essential in the diet of larval marine fish. In addition, HUFA concentration increased during short-term (24-49 hours) storage.
- The laboratory participated in a inter-calibration project, co-ordinated by Dr. Patrick Sorgeloos, aimed at standardizing fatty acid methyl ester analysis and reporting procedures using reference *Artemia* samples. A collaborative study with Memorial University of Newfoundland demonstrated that rotifers could be more efficiently enriched with n-3 HUFA, using emulsified fish oil concentrates, than could *Artemia nauplii*. A collaborative study with Dr. Peter Coutteau, University of Ghent, using emulsified oils in juvenile scallop nutrition, was also conducted.

ii) **Disease**

- A histological assessment of abnormal jaw development in halibut larvae was carried out. Larvae were hatched from fertilized eggs received from St. Andrew's and were grown to 33 days at the Halifax Laboratory. Samples were processed for light microscopy (embedded in resin and processed for cartilage and bone straining), and transmission and scanning electron microscopy. A manuscript on normal and abnormal jaw development is in preparation.
- Extensive studies were done on broodstock halibut from St. Andrew's Biological Station, that had experienced serious mortalities. The animals had large numbers of the blood fluke, *Aporocotyle simplex*. The melanomacrophage centers in the liver were large and contained vacuolated cells, and

there were areas of vacuolated cells in the intestinal wall and brain, indicating damage from a systemic infection. Myxosporidia were also found in the gall bladder of these halibut and studies were conducted on the structure, pathological effects and taxonomy of these myxosporidia.

- Studies were completed on *Goussia gadi*, a common protozoan parasite in the swim bladder of wild cod, haddock and other gadoids. This parasite could become a problem in mariculture. In advanced infections, the swim bladder was filled with parasites, indicating that fish may die as a result of losing their buoyancy. We found more stages to the life-cycle than has been previously described. We also found intense cellular host reactions to the parasite in the swim bladder wall and much of the material in the lumen consisted of moribund host leukocytes and parasites, suggesting that many hosts probably successfully destroy the parasite.

Molluscs

- Reproductive studies of two *Mytilus* species frequently found to co-occur and which we commercially harvested on the Atlantic coast of Nova Scotia demonstrate overlapping spawning regimes and produce fertile hybrids. Examinations of fertilization success between and within these species spawned in the laboratory indicated markedly diminished fertilization when hybridizations versus pure matings are attempted. This suggests that despite interfertility, survival of each pure species in mixed populations is ensured by a biological barrier acting at the time of fertilization and limiting the extent of hybridization.
- The development of synthetic diets and techniques for their application is being conducted in experiments with bivalve molluscs. In addition, experiments were completed on the effectiveness of lipid microspheres in diets for the edible oyster, *Ostrea edulis*.
- A critical period in bivalve nutrition is the condition of the broodstock. During 1992/1993, a co-operative effort was made with other scientists and industry to develop a conditioning protocol for the edible oyster to be used in a local hatchery.
- Over the last 6 months, attempts have been made to identify research topics pertinent to the growth of the oyster industry in Nova Scotia. Plan for 1994/1995 focuses on 2 areas: broodstock conditioning for both the edible oyster and sea scallop, and culture of the American oyster, *Crassostrea virginica*, in Cape Breton.

b) Dalhousie University (Halifax) and Bedford Institute of Oceanography (Dartmouth)

A comprehensive program on scallop trophic resource studies is underway involving faculty and students from Dalhousie University, the University of New Brunswick and research staff from the Department of Fisheries and Oceans under the OPEN (Ocean Production Enhancement Network of the Natural Science and Engineering Research Council) project to measure scallop growth, mortality, ingestion, digestion and fecal matter production under laboratory and *in situ* field conditions in coastal embay-

ments in Atlantic Canada. Moored instrumentation to continuously record physical (temperature, salinity, suspended particulate matter) and biological (chlorophyll) variables has been developed to continuously monitor temporal changes over time periods extending from days to months. During 1993, a field test of a new technique to conduct feeding studies with scallops under natural conditions of varied food supply was successfully completed. These observations provide field validation of parameters in models of scallop feeding and digestion used for predicting growth under conditions of variable food supply. Results will be compared with actual scallop growth rates measured with animals held at various distances above bottom at different experimental aquaculture sites.

(c) Acadia University (Wolfville)

Research on scallop aquaculture continued with studies on the determination of spat settlement sites, the bottom survival of juveniles, techniques for handling intermediate stages and the assessment for equipment for juvenile grow-out.

New Brunswick:

(a) DFO Gulf Fisheries Centre (Moncton)

Shellfish mariculture research carried out by DFO scientists included:

Oysters

A multi-year study commenced which examines influence of genetic (origin of seed stock) and environmental (grow-out site conditions) factors on the survival, growth and production of seed oysters from different sources in New Brunswick and Prince Edward Island in collaboration with Provincial agencies (NBDFA and PEIDAF&S) and aquaculturists. The biological basis of the present commercial size regulations (76 mm) are being examined in light of understanding what effects could be encountered in wild population dynamics and production with small changes to the legal size limits. Sexual maturity and fecundity of oysters at different size and age classes are being examined at various locations in New Brunswick and Prince Edward Island by histological analysis of gonads. Field data from public fishing areas are also being modelled to examine the effects of different fishing methods and intensity on the productivity of the populations.

Scallops

DFO (Moncton) is completing a multi-year histological study examining the gonadal and sexual development of juvenile scallops in suspended culture from Port au Port, Newfoundland as part of MSc. thesis requirements at the Université de Moncton. Reciprocal transfer experiments examining seedstock performance commenced in collaboration with aquaculturists in New Brunswick and Prince Edward Island, and seasonal mortality, growth rates and production are being monitored over a 2-year period. Staff are also assisting with Provincial agencies (NBDFA and PEIDAF&F) to locate and identify the best areas for artificial spat collection in Prince Edward Island and New Brunswick.

Quahaug

DFO (Moncton) commenced a multi-year study of quahaug *Mercenaria mercenaria* in Prince Edward Island and New Brunswick to examine the environmental (biological, physical and chemical) and genetic factors influencing suspended and cage culture productivity for aquaculture site

and seedstock selection. Age and growth increments are being examined from experimental data and growth curves will be computed for each of the study sites.

Parasites and Diseases

DFO (Moncton) published a summary 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, complete with colour plates and illustrations which completes a 5-year regional survey. The bay scallop moratorium on the transfer of bay scallops among the maritime provinces for aquaculture grow-out has been lifted as a result of the negative results from inter-specific transmission experiments completed recently.

(b) DFO St. Andrews Biological Station (St. Andrews)

Atlantic Salmon

Food deprivation of post-smolts in the first winter resulted in significant reductions in the incidence of male and female grilse, and the findings have resulted in recommendations to industry on application of this technology. The use of elevated winter temperature to stimulate growth may not lead to enhanced smolt production: males are likely to mature and both males and females may remain parr. Three confirmed transgenic male salmon matured and were crossed with normal females; the progeny will be assessed for growth, maturation and smolting. Tests with production of fall smolts have been encouraging. The presence of overhead cover at first-feeding of a salmon fry provided some beneficial effects for the first 2 weeks, after which other factors appeared more important. The size of salmon fry at swim-up was positively correlated with the percentage of the hatchery tray covered with artificial substrate.

A new study was initiated, in collaboration with the Atlantic Salmon Federation, on interactions between aquaculture and wild Atlantic salmon in a Bay of Fundy river using biotelemetry.

Striped Bass

By manipulating temperature and photoperiod, striped bass broodstock were induced to spawn 2-3 weeks earlier than normal. Both temperature and salinity were found to have profound effects on the rate of yolk utilization efficiency. Growth of striped bass juveniles was assessed at three salinities and three temperatures; initial tests indicated better growth at 15‰ than at 1 or 30‰. Striped bass eggs and larvae were once again provided to the private sector for production.

Marine Fish (halibut, haddock, cod)

Facilities for the production of food organisms for halibut and haddock larvae (algae, rotifers, atremia) were expanded and resulted in the production of 50-60 each of juvenile haddock and halibut - this was the first successful production of halibut and haddock juveniles in Canada. A successful larval halibut feeding strategy yielded promising results. The use of 1100-L, submerged plastic bags proved successful for the rearing of larval halibut. Experiments were successfully completed on the contribution of batch and maternal effects and effects of light on halibut egg buoyancy. Growth studies of halibut in sea cages continued. Funding was secured to set up and operate a pilot haddock hatchery in St. Andrews and to construct a commercial hatchery on Campobello Island.

Cod and haddock egg and larval development was unsuccessful at 10 and 20‰ and at temperatures in excess of 8°C; development of first feeding was successful at 4-8°C and 30‰.

Marine Invertebrates

Experimental sites for sea scallop culture research have been established at two locations in Passamaquoddy Bay. Each has been equipped with pearl, lantern and shibetsu nets and stocked with several thousand sea scallops. One of the sites is in connection with a salmon farm and will be used to evaluate the co-culture of scallop and salmon. The availability and distribution of scallop seedstock was studied through the deployment of spat collection bags at 16 stations throughout the Fundy Isles. A trial groundline collection system was also deployed. Benthic collectors were evaluated for scallop seedstock collection and rejected in favor of a horizontal longline system that suspends spat collection bags 2-3 meters off the bottom. Several new materials were compared for efficiency in scallop spat collection; one of the new materials - Netron - outperformed traditional monofilament nylon as a settlement medium and proved far easier to harvest and sort. A project was initiated to determine the levels and variability of toxins in scallops held in suspension culture as opposed to normal residency on the bottom.

(c) University of New Brunswick (Fredericton)

Parasitology

A preliminary pilot study during the summer of 1993 indicated that the cercarial larval stage of *Cryptocotyle lingua* (Platyhelminthes: Digenea) could kill small juvenile winter flounders (*Pleuronectes americana*). A detailed study of the risk posed by this parasite, to hatchery operations using seawater from areas inhabited by large numbers of periwinkles (the first intermediate host in which the cercariae develop), has been started. Results to date indicate that smaller fish are more vulnerable than larger fish and that temperature plays a critical role in the ability of cercariae to penetrate the skin of their fish.

A second initiative started involves investigations into the transmission of the myxosporean *Kudoa* spp to captive fish in sea pens. A survey of various fishes for these parasites is underway in the north-west Atlantic and the research with respect to transmission will be coordinated by collaboration with investigations into the life cycle of these protozoans being conducted by DFO scientists at the Pacific Biological Station in Nanaimo, British Columbia.

Sea lice numbers were higher than average in 1993, in part due to other diseases (Hitra) stressing the salmon. A project on the potential of cunner to act as cleaner fish suggested that they are a poor candidate for cleaning lice from salmon. Research on the biology of sea lice larvae and on host factors important to sea lice infections, continues. It appears that stressed fish have more sea lice and that iodinated feed can help to reduce the effects of stress and lower sea lice numbers on fish.

Bacteriology

This research program involves studies of bacterial pathogens of importance to the Atlantic salmon aquaculture industry. Projects presently being carried out include: field analysis of commercially reared Atlantic salmon in New Brunswick for the presence of bacterial

kidney disease (BKD) and evaluation of diagnostic methods to detect BKD; development of PCR systems for the detection and control of BKD; investigation of asymptomatic BKD infections in Atlantic salmon; and characterization of the major soluble antigen produced by *Renibacterium salmoninarum*, the causative bacterium of BKD.

Triploidy

In collaboration with the Atlantic Salmon Federation and the New Brunswick Salmon Growers' Association, field trials of triploid Atlantic salmon are being conducted. Preliminary results indicate that survival rates are moderately reduced in triploids, but growth rates are similar to diploids. After 18 months in sea water, triploid females were indistinguishable from diploid females (no grisling was observed in either ploidy), except for lower jaw deformities in 7% of the triploids. In other studies, sex-reversed and triploid Arctic char were produced and are being evaluated for growth in competition with diploid fish, the haematology and respiratory physiology of triploid brook trout are being evaluated and the effect of dietary folic acid supplementation on erythrocyte abnormalities in triploid brook is being tested.

Scallop Trophic Resource Studies

The purpose of this research, in collaboration with Dalhousie University and DFO, as a part of the OPEN project (described earlier) is to measure scallop growth, mortality, ingestion, digestion and fecal matter production under laboratory and *in situ* field conditions in coastal embayments in Atlantic Canada. A component of this research will be conducted in New Brunswick.

Phycology

This research focuses on the ecophysiology and biochemistry of seaweeds of commercial value. In particular, the phosphorus and nitrogen metabolism of red algae, and their impact on the production of phycocolloids (carrageenans), both in controlled culture conditions and natural beds, are being studied. Carrageenophytes from developing countries are also being investigated. Nutrients and organic matter of the commercially harvested brown alga *Ascophyllum nodosum* (rockweed) are being analyzed to provide information and advice to the industry and the governments managing the resource, and to investigate the possibility of using seaweeds as nutrient biomonitors and to remove excess nutrient loading resulting from human activities in coastal zones.

(d) Université de Moncton (Moncton)

Researchers have completed a six-year oyster monitoring program which was designed to address the problems of the oyster industry attributable to adverse environmental conditions. This monitoring program was established by the Environmental Sciences Research Centre of the Université de Moncton, in close collaboration with a team of oyster growers, and in consultation with DFO and provincial biologists. A better understanding of what constituted a "good" vs a "poor" site and individual site profiles for participating operations was achieved.

Six years of data suggest that there are important differences in growth rates and indices of condition between oysters grown at different sites and that depending on the specific location and the environmental conditions that define them, either bottom and/or suspension methods may represent effective and viable culture alternatives. Recommendations based on the findings were formulated and presented to growers and government agencies. Based on the information now available in the data

bank, the province is better prepared to determine the productivity and carrying capacities of the waters where the sites are located and it is useful for growers in formulating their commercial and investment strategies.

(e) Huntsman Marine Science Centre (St. Andrews)

The HMSC has directed its future mariculture research and development studies to the culture of the small commercial Pleuronectids, specifically winter flounder (Pseudopleuronectes americanus) and yellowtail flounder. Broodstock of yellowtail flounder (Limanda ferrugineus) has been established and is being maintained on a diet to condition the fish for spawning in 1994. Eggs from an initial spawning in 1993 were successfully reared through metamorphosis and early juvenile growth is being studied. Some preliminary findings of the research to date, as organized by the life history of the fish, include:

- 1) **Eggs and sperm:** Flounder are usually found in reproductive condition from April through to late May. This year, the reproductive season was extended through to July.
- 2) **Fertilization:** The dry method of fertilization was used. Winter flounder fertilization success rate was near 100%.
- 3) **Hatching:** Hatching success was very high, upwards of 90%.
- 4) **First Feeding:** Larvae were placed into specially designed rearing bins when they were 4 days old. Green water was used throughout the rearing period (rearing bins were stocked with algae every day). As larvae grew, they were fed oyster trochophores, rotifers and atremia.
- 5) **Metamorphosis:** Winter flounder larvae reached metamorphosis in 25 days. This is almost twice as fast as reported in the literature. Survival to metamorphosis was exceptionally high at 18.5%.
6. **Juveniles:** Experiments using wild caught and lab raised juveniles are being conducted. Weaning from atremia to artificial feed was successful with very low mortality during this period. Growth of more than 100% per month in experiments on the effects of temperature and stocking density has been observed.
7. **Adults:** Both groups reared in the lab and the cages are growing much faster than wild populations. Caged fish at a marine cage site gained an average of 49% from August through to November. Adults grown in the lab and the cage are significantly heavier at length than wild stocks, indicating a much greater fillet thickness.

(f) Atlantic Salmon Federation (St. Andrews)

The Salmon Genetics Research Program (SGRP), a co-operative research activity involving a number of research agencies and institutions, performs an extensive array of research on Atlantic salmon. One of the major roles of the SGRP is to develop good genetic stock for the New Brunswick salmon growers. There are four strains of Atlantic salmon being developed: 84JC, 87JC, 89JC and 90JC. Select lines have been

established in three of the four strains. Index selection, a form of multiple objective selection, was adopted by the SGRP to improve the following traits:

- proportion of S1 smolts;
- proportion of non-grilse;
- market length; and
- disease resistance to bacterial kidney disease.

Substantial genetic gains have been realized in Strain 84JC. These genetic gains have been passed on to the Industry through multiplier growers that produce eggs for commercial hatcheries. As of 1993, select smolts are available each year to the New Brunswick aquaculture industry.

The studies carried out in the SGRP can be divided into two categories: genetic and culture. The genetic studies relate to the development of aquaculture strains. The use of triploids in aquaculture is one such study. All female triploid stocks are sterile and, therefore, are desirable for mariculture since they do not suffer the marketing problems associated with maturation, nor do they threaten the wild salmon stocks in the event of their escape. Growth and development of triploids, relative to diploids, during fresh and sea water life stages are being monitored for an evaluation of triploid Atlantic salmon in commercial scale aquaculture in the Bay of Fundy. Preliminary results from a competition study indicate that triploids grow better if reared on their own as opposed to being reared with diploids in the same tank.

Also, the occurrence of, and spawning interactions between wild and aquacultural salmon, is being studied in the Magaguadavic River, New Brunswick. It has been found that aquacultural salmon enter the river later than wild salmon. Blood samples are being examined by DNA finger-printing to distinguish hatchery stocks from each other and from the wild population. Also, chemical analysis is being used to determine the percentage of wild and aquacultural eggs in the spawning beds.

Other genetic studies at the SGRP include projects involved in:

- disease resistance; and
- the study of domestication and selection effects through DNA finger-printing and electrophoretic techniques, and comparative studies with wild stocks.

Given good husbandry techniques and good genetic stock go hand in hand, some of the ongoing culture studies within the SGRP are summarized below:

1. The relative performance of diploid and triploid sac-fry reared with and without biomat substrate was studied. Results indicated that all fish, whether diploid or triploid, responded positively to being reared with biomat substrate.
2. The effects of luteinizing hormone-releasing hormone (LHRH) and gonadotropin hormone (GnRH) analogues on the synchronization of spawning and on fertilization and progeny survival is being evaluated.

3. Post-smolts were used in an experiment to study sexual maturity response to various strategies of feed deprivation during winter-spring. Results from the study clearly indicated that reduced rations in winter-spring can reduce the incidence of grilse the following autumn.
4. The pathophysiological effects of formalin, a primary drug of choice in the aquaculture industry for the treatment and prevention of parasitic infestation of Atlantic salmon, was examined. Preliminary results suggest that low level formalin treatment may have some potential use as a prophylactic treatment of salmon smolts with little apparent long-term physiological effects on fish and positive effects on growth.
5. The use of live (brine shrimp) versus dry feed at first feeding is currently being evaluated.

Prince Edward Island:

Prince Edward Island Fisheries and Aquaculture Division

Shellfish Culture

Mussel (*Mytilus edulis*):

Studies were carried out to examine the degree of starfish predation on mussel spat collectors in several of the Island's prominent spat collection areas and several methods to remove starfish from spat collectors were examined. Technology to mechanically strip mussel seed from collectors and to clean collector ropes with high pressure steam was examined.

Oyster (*Crassostrea virginica*):

Efforts continued to enhance public oyster beds in co-operation with the federal government and a local shellfish association by spat collection, desilting of oyster shell beds and relays of oysters from crowded areas to better bottom. Lease holders carried out evaluation of spat collection materials and grow out techniques to increase quantity and quality of cultured oysters.

Quahaug (*Mercenaria mercenaria*):

The development of quahaug culture technology, in conjunction with private lease holders, continued. As well, techniques to enhance public quahaug beds were evaluated.

Soft-Shell Clam (*Mya Arenaria*):

The growth and survival of soft shelled clam seed transplanted from contaminated areas to leases was evaluated. Several methods to collect clam seed on the leases were also examined.

Bar Clam (*Spisula solidissima*):

Experiments with hatchery spawning of bar clams and early rearing of seed in upwellers vs other nursery systems were conducted.

Sea Scallop (*Placopecten magellanicus*):

Developmental studies to evaluate sea scallop spat collection in close proximity to wild scallop beds and grow-out on leases in estuaries were carried out. Efforts were undertaken to examine the shelf life of fresh product and value added product options.

Bay Scallop (*Argopecten irradians*):

Bay scallop seed was produced at the Ellerslie Hatchery. Small numbers were cultured by several aquaculturists. Efforts were undertaken to examine shelf life and value added products.

Finfish Culture:

Cultured finfish species include: Rainbow trout (*Onchorhynchus mykiss*); Arctic char (*Salvelinus alpinus*); Speckled trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*).

Studies were carried out to evaluate the quality of pond water feeding into several fish farms to assist farmers to predict changes in oxygen levels associated with algal blooms.

Characterization of the impact of effluent water leaving fish farms on receiving waters was undertaken.

Technology, including triploidy induction of finfish eggs, low head oxygenation and hydrotech filtration, was evaluated.

Striped Bass (*Morone saxatilis*):

Efforts continued to capture, spawn and raise juvenile striped bass in captivity. Fresh water holding and sea water holding were evaluated.

Quebec:

Centre Aquicole Marin - Direction de la Recherche Scientifique et Technique (Grand Rivière)

i) Homard

Un projet visent à évaluer l'applicabilité d'une stratégie d'engraissement du homard, *Homarus americanus*, de petite taille pêché commercialement s'est poursuivi pour une troisième année en 1993. Le principal objectif était de raffiner la composition d'une diète semi-humide afin que la dureté et l'apparence de la carapace des homards engraisés ainsi que leurs caractéristiques organoleptiques se rapprochent le plus possible de celles des homards pêchés dans le milieu naturel. Les résultats ont montré, sur une base qualitative, qu'un supplément en phosphore visant à modifier le taux d'incorporation du calcium dans la carapace n'avait pas eu l'effet escompté puisque la texture et la composition chimique de la cuticule des pinces était voisine pour les deux groupes de homards expérimentaux. Cependant, la durée de la période de conditionnement (4 mois à température de l'eau ambiante) n'a pas été suffisante pour permettre aux homards d'atteindre une condition semblable au produit pêché (en pré-mue) bien que tous les essais organoleptiques ont montré

que le produit était très acceptable aux yeux des évaluateurs. En 1994, l'emphase sera placée sur l'analyse des résultats obtenus jusqu'à présent et sur le transfert des connaissances acquises.

ii) **Saumon Atlantique**

Un projet de production de saumons de l'Atlantique adultes par la combinaison des techniques de ruisseau-pépinère et de sea-ranching s'est poursuivi en 1993 dans la Baie des Chaleurs, au Québec. La production des saumoneaux se fait en milieu naturel, dans des incubateurs à courant ascendant, dans une petite rivière sans population naturelle des saumons. Les taux de survie ont été largement supérieurs aux taux naturels en rivière. Les retours des saumons adultes sont suivis depuis 1992. En 1993, les taux de retour ont été relativement fiables comme dans la majorité des rivières du Québec. Une analyse bioéconomique sur la faisabilité économique du sea-ranching au Québec a aussi été réalisée en 1993.

iii) **Moules Bleues**

Lors de la deuxième année du projet, nous avons principalement évalué les rendements des boudins et suivi, pour une deuxième année consécutive, le succès de captage de collecteurs disposés à cinq sites dans la baie et le rendement en chair de moules semi-sauvages. L'évaluation s'est faite en mettant à l'eau du printemps 1993 des collecteurs, en les échantillonnant à trois reprises pour évaluer les cinq sites et en échantillonnant à quatre périodes différentes les boudins fabriqués en septembre et octobre 1992. Pour une seconde année, le rendement en chair des moules semi-sauvages était supérieur à 40% tout au long de la saison. De plus, avec le succès de captage obtenu et les rendements commerciaux des boudins de 40-50% à la fin octobre, il semblait très prometteur d'établir une activité mytilicole dans la baie de Gaspé dans un proche avenir. La récolte pour la commercialisation des boudins en hiver sous la glace correspondrait à un temps de l'année en dehors des périodes de contamination bactérienne importante et des biotoxines par les algues.

Reproduction of blue mussels in the Amherst Basin (Magdalene Islands, Canada):

Mussels from the Amherst Basin are known to be resistant to the summer mortality which hits other stocks regularly. Moreover, spawning is earlier in this small lagoon than elsewhere. This results in an earlier spat fixation on collectors. It is possible to proceed to stocking in early fall (better weather conditions) or to get bigger spat relative to other areas. These mussels are also known to have higher growth rates than other stocks. Therefore, these mussels are of great interest for mussel growers. The Amherst Basin was dedicated to spat collection since June 1993. The small area (approx. 37 ha) available for spat collection must be optimized in order to satisfy the mussel grower's needs. In 1993, we began to gather information on the possibility of placing high densities of spat collectors on this limited area: no more than 7 m between longlines, more than 250 collectors per long line. The objective of the study is to verify if it is possible to get uniform spat

collection all over the site despite a possible "wall effect" created by the high density of collectors. Ultimately, operation rules will be proposed to mussel growers in order to get maximal spat collection.

Summer mortality of cultured blue mussels in the Magdalene Islands (Quebec, Canada):

In 1993, the multidisciplinary study continued on mussel's summer mortality based on the comparison of two stocks: a fragile stock regularly decimated by this phenomenon and a resistant stock which has always showed high survival. There was no summer mortality in 1993 (less than 5%) and in 1992. We hypothesize that the cool weather observed during those two years played a major role in the inhibition of this phenomenon. For example, we observed delayed spawnings compared to the previous years. Moreover, there were single, instead of double spawnings during these two summers. These changes in the reproductive pattern associated with a cooler water temperature (lower metabolism) were probably the main factors involved. Despite this absence of mortality, partial results show that the resistant mussels have a lower metabolism than the fragile mussels when held in the same conditions. Resistant mussels are also much more active than fragile mussels when kept in raceways. Therefore, the resistant mussels showed, for a second year, that they were in better "shape" than fragile mussels, although the environmental conditions were favourable.

iv) Pétoncle Géant

Pré-élevage de Pétoncle géant (*Placopecten magellanicus*) aux Iles-de-la Madeleine:

Dans le cadre du programme REPERE (Recherche sur le Pétoncle à des fins d'élevage et de repeuplement), des travaux sont réalisés en vue de définir les meilleures stratégies de pré-élevage dans le contexte des Iles-de-la-Madeleine. Deux sites sont en cours d'évaluation soit la lagune de Havre-aux-Maisons (milieu abrité) et la baie de Plaisance (milieu ouvert). Les principaux facteurs étudiés sont la densité, le type de panier et la position dans la masse d'eau. Les travaux de 1993 ont permis l'obtention de juvéniles de 30 mm et plus en trois mois de pré-élevage, et ce, à partir d'une taille initiale de 11 mm. Les taux de survie se sont avérés très élevés soit de 95% et plus.

Captage de juvéniles de pétoncles géants en milieu naturel:

Les travaux commencés en 1991 se sont poursuivis en 1993. Les principaux objectifs sont de déterminer les meilleurs sites de captage en milieu naturel aux Iles-de-la-Madeleine, d'optimiser le captage en comparant l'efficacité de divers types de substrat, d'évaluer la croissance et la rétention des jeunes pétoncles laissés sur les collecteurs pendant un an. De plus, en 1993, des essais de transfert de pétoncles adultes en milieu lagunaire ont été réalisés afin de vérifier la possibilité de créer des concentrations de larves pour la collecte dans ce milieu abrité. Le succès de collecte de 1993 a été le meilleur obtenu depuis 1991. Dans les meilleurs secteurs, le nombre de pétoncles/collecteur dépassait 2,000 individus. Les essais sur les substrats ont

permis de déterminer celui qui, au niveau efficacité, facilité de manipulation et de nettoyage répond le mieux aux exigences d'opérations de captage à l'échelle commerciale. Le transfert de pétoncles adultes en milieu lagunaire, milieu où l'on ne retrouve pas le pétoncle géant à l'état naturel, ont donné des résultats intéressants. Des larves de pétoncle ont survécu et il a été possible d'obtenir un faible succès de collecte à l'intérieur des lagunes.

Dans le cadre d'un projet-pilote réalisé par une association locale de pêcheurs de pétoncle, 10,000 collecteurs ont été mis à l'eau à l'automne 1993 afin de réaliser des ensemencements sur le fond à partir de l'automne 1994. On évalue que 10 millions de pétoncles se sont fixés sur ces collecteurs.

Évaluation de l'abondance des prédateurs du pétoncle géant aux Iles-de-la-Madleine:

Afin de diminuer l'impact des prédateurs sur les ensemencements de pétoncles qui seront réalisés à partir de 1994, des données d'inventaire récoltées depuis 1986 ont été analysées afin de déterminer l'abondance des principaux prédateurs du pétoncle géant (crabe commun et étoile de mer) sur les sites visés pour les ensemencements. Cette analyse a permis d'identifier des secteurs où ces espèces sont moins abondantes et il sera possible de privilégier ces secteurs pour les ensemencements. Afin de vérifier la possibilité de diminuer l'abondance des prédateurs par un dragage intensif, un essai a été réalisé sur un site expérimental en 1993. Les résultats indiquent que le pourcentage de prédateurs capturés est inférieur à 5%.

Dispersion des pétoncles ensemencés:

A partir de 1993, l'approche qui est privilégiée pour évaluer le taux de dispersion des pétoncles après l'ensemencement est la marquage à grande échelle. 30,000 pétoncles ont donc été marqué et remis sur le fond à l'automne 1993. Pour vérifier l'efficacité du marquage et son effet sur les pétoncles, des spécimens ont été gardés en cage sur le site d'ensemencement et seront suivis en 1994.

British Columbia:

(a) DFO Pacific Biological Station (Nanaimo)

(i) Fish culture research:

A new study was initiated with the lingcod (*Ophiodon elongatus*). Eggs collected from the wild were incubated and after hatch, larvae were induced to feed on Artemia enriched with SuperSelco. It was also found that feeding larvae will grow well at temperatures as high as 15°C. Larvae were able to tolerate a wide range of salinities from 30‰ down to 20‰ or less. Reduced light intensity was found to promote survival of newly hatched larvae. Two dozen metamorphosed juveniles were produced.

Spawning and incubation of Pacific halibut commenced in February. Three female halibut matured and produced a total of several hundred thousand eggs. The eggs and larvae were held in upwelling incubators at 6°C. No feeding trials were conducted.

An experiment to determine the effect of size and season on survival of escaped farmed chinook salmon was initiated; 55,000 eggs were purchased from a commercial supplier and placed into incubation. Releases of tagged fish from a seawater netpen will commence in mid 1994.

An experiment was set up in a production hatchery to determine the efficacy of ozone treatment in the prevention of infection with the myxosporean which causes proliferative kidney disease. A control system was developed and tested. Once it was functioning effectively, juvenile chinook salmon in an ozone treated raceway were found to be free of proliferative kidney disease.

In the Toxic Algae Program, a significant variation was demonstrated in levels of domoic acid in cells of *Pseudonitzschia pungens* f. *multiseries* cultured in 20 L carboys, 250 L columns and 500 L bags. Using bag cultured *P. pungens* f. *multiseries*, the rate of accumulation of domoic acid in the mussel, *M. Californianus* fed the alga and the subsequent rate of toxin loss when depurated unfiltered seawater was assessed. The data provided a measure of the efficacy of this species as a sentinel for monitoring domoic acid.

(ii) Fish health and parasitology research:

Research on the survival of *Aeromonas salmonicida* and *Renibacterium salmoninarum* in frozen fish tissue samples was carried out preparatory to a study to investigate wildfish/farmed fish interactions with respect to these organisms. Results indicate that freezing of samples is contradicted if the goal is to detect the pathogens by culture. Following a single freeze (-20°C)/thaw cycle, the former was virtually 100% killed and the latter was approximately 70% killed.

Research to determine the feasibility of vaccinating fish against the kidney disease bacterium continued but results to date have not been particularly promising. We have succeeded in producing protection but it could only be measured in terms of a marked delay in the onset of mortalities following challenge.

Results continue to support the hypothesis that microcystin LR is the cause of netpen liver disease of Atlantic salmon.

Loma salona caused significant gill disease in seawater pen-reared chinook in 1993. In two laboratory studies, we transmitted the parasite in sea water, indicating that fish to fish transmission can occur in netpens.

We are continuing to evaluate a monoclonal antibody test for plasmacytoid leukemia (PL) of pen-reared chinook. The disease is common in pen-reared chinook salmon in British Columbia and we have detected PL in a few wild-caught fish.

The North American form of the viral hemorrhagic septicemia virus was detected in British Columbia Pacific herring for the first time in 1993 and is now known to be widespread in this species in the Pacific Northwest. Pacific salmon, which may have evolved in the presence of the virus, are apparently refractory to the virus. We are not testing Atlantic salmon, which are exotic to the Region, to determine their susceptibility to the virus.

A protozoan (referred to as SPX) of unknown taxonomic affinities occurs sporadically in cultured Japanese scallops. Sufficient material was obtained to confirm the presence of flagellated stage in its life cycle.

The microcell protozoan (*Mikrocytos mackini* that causes Denman Island disease) was shown to be more infectious and lethal to other species of oysters (*Crassostrea virginica*, *Ostrea edulis*, *Ostreola conchaphila*) than to the usual host, the Pacific oyster *Crassostrea gigas*. Progress was made on the eventual production of monoclonal antibodies that will be incorporated into a specific and sensitive diagnostic technique for this parasite. DNA from the ITS 1 region of *M. mackini* was sequenced and found to be different to that from other *Bonamia* spp. (this work was done in collaboration with the University of Queensland, Australia).

204 F1 flat oysters (*Ostrea edulis*, progeny of broodstock imported into quarantine in the summer of 1990 and grown at two localities in British Columbia) were screened and found free of *Bonamia ostreae*.

Experiments were conducted to determine the toxicity of hydrogen peroxide to chinook and Atlantic salmon over a range of temperatures and to evaluate its efficacy against the salmon louse *Lepeophtheirus salmonis*. Atlantic salmon were less sensitive to hydrogen peroxide than chinook salmon. The toxicity to both salmon species increased with increasing water temperatures, concentration and exposure time. Histological sections of gills revealed extensive epithelial lifting and necrosis in those chinook and Atlantic salmon that experienced acute toxicity. Twenty minute bath treatments of 1.5 g l^{-1} hydrogen peroxide at 11°C effectively dislodged approximately 80% of the preadult and adult stages of *L. salmonis*, but had no significant effect on the intensity of infection with the attached chalimus stages.

The efficacy of orally administered ivermectin against *Lepeophtheirus salmonis* on Atlantic salmon was investigated under laboratory conditions at a targeted dose of 0.05 mg kg^{-1} fish administered in the feed every third day arrested the development and reduced the intensity of infection by *L. salmonis*.

(b) DFO West Vancouver Laboratory (Vancouver)

(i) Biotechnology:

An important breakthrough was achieved in the production of monosex female coho salmon. Two families of coho salmon fingerlings (among ten progenies tested), produced by fertilization of normal ova with the sperm of sex reversed

(masculinized) gynogens, were found to be all-female. This is the first successful generation of monosex progenies in coho salmon achieved by the use of monosex coho salmon sperm generated by the masculinization of genotypic females produced by gynogenesis. Additional sex reversed coho gynogens are expected to mature in the fall of 1994. The plan is to conduct further progeny testing or use a Y-chromosomal DNA probe to identify genotypic masculinized gynogens. The final objective is to generate monosex sperm for all-female coho salmon production for mariculture. Mitotic gynogenetic coho were also produced at the West Vancouver Laboratory. The ploidy and sex of these fish will be determined in the summer of 1994.

An experiment on the performance of groups of diploid and triploid all-female (sterile) chinook salmon reared separately and communally is underway. Differences in specific growth rates in weight and length, feed efficiencies, conversion factors and feed intakes expressed as percentages of body weight are being monitored. Gonadal samples are also being collected periodically to determine GSI changes during the grow-out period.

Transgenic Pacific salmonids are being produced with enhanced growth characteristics and altered reproductive potential. The purpose of this research is to (1) produce genetically engineered strains of salmon for use in the aquaculture industry; and (2) provide information to allow the development of a regulatory framework in which transgenic fish can best be implemented. Current research is focused on the mechanisms of transgene introduction and transmission of subsequent generations. Associated research includes modelling potential interactions of transgenic fish with natural populations to allow risk assessments to be made for future introductions of genetically engineered fish into aquaculture.

Research is also under way to isolate and characterize Y-chromosomal DNA probes from commercially important salmonid species. Such probes are useful to the aquaculture industry to improve the efficiency of monosex (all-female) stock synthesis and thus control losses arising from precocious male maturation. To date, the ability to determine genetic sex (independent of phenotype) has been developed for chinook, coho, pink and chum salmon. Current research is focusing on similar probes for Atlantic salmon and rainbow trout.

Two recombinant DNA expression systems (baculovirus and bacteria) are being used to produce sockeye salmon type 2 growth hormone (GH2). This protein has potential application in the areas of growth enhancement and smoltification of salmon for aquaculture and will provide important material necessary to determine whether salmon GH is bio-active in mammalian systems. This will facilitate evaluation of the potential risk from transgenic fish containing elevated levels of this protein.

Development is under way of a simple and rapid Polymerase chain Reaction assay for the induction of P450LA1, the gene encoding EROD activity. This gene is induced in response to environmental pollution and various stress-inducing stimuli.

The assay developed is approximately 3 orders of magnitude more sensitive than EROD enzyme assays and may provide an additional tool to allow evaluation of environmental contamination of wild or farmed fish.

(ii) Genetics:

Data acquired for chinook, chum, coho and sockeye salmon with multiple nuclear DNA probes of salmonid origin have shown strong patterns of area and stock-specific variation. The use of this genetic variation in determining stock compositions of mixed stock fishery samples is now being examined. In chinook salmon, the DNA profiles of two farmed strains using the B2-2 probe indicate that the domesticated strains closely resemble the Big Qualicum chinook salmon from which they were most probably derived. Thus, use of the B2-2 probe may enable us to identify escaped farm fish, and their offspring, in west coast Vancouver Island spawning streams. An examination of the DNA from 30 Atlantic salmon caught in British Columbia waters with the Ssa-1 probe has revealed considerable genetic diversity and an indication that these fish have originated from multiple strains with different allele frequencies.

(iii) Nutrition:

Dephytinized rapeseed/canola protein concentrate can entirely replace high quality fish meal in trout diets without compromising any aspect of fish performance, provided that the diet is simultaneously supplemented with FinnstimTM (diet palatability enhancer). This finding should lead to a significant reduction in the present production costs of salmonid farming operations.

A form of the red yeast *Phaffia rhodozyma* was shown to be just as efficacious as synthetic astaxanthin for flesh colouration of cultured Atlantic and chinook salmon. It is expected that *Phaffia* will be cost competitive with synthetic carotenoid pigments. The addition of synthetic carotenoid pigments now accounts for 10-15% of the cost of salmon diets and in British Columbia alone, this represents an annual expenditure of over 6 million dollars.

CANADIAN MARICULTURE STATISTICS
(1993 ESTIMATES)

ATLANTIC COAST:

<u>Newfoundland and Labrador:</u>	<u>mt</u>	<u>CDN \$(000's)</u>
Atlantic salmon	100.0	713.0
Steelhead trout	113.0	753.0
Arctic char	12.0	35.0
Cod	5.3	6.0
Mussels	209.0	147.0
Scallop	2.5	28.0
	<u>441.8</u>	<u>1,682.0</u>

Nova Scotia:

Atlantic salmon	850.0	5,800.0
Steelhead trout	285.0	1,600.0
Arctic char	*	-
Mussels	200.0	330.0
American oyster	80.0	200.0
European oyster	*	-
Scallop	*	-
Chondrus crispus	*	-
	<u>1,415.0</u>	<u>7,930.0</u>

Prince Edward Island:

Mussel	4,540.0	4,994.0
American oyster	1,078.0	1,973.0
Rainbow trout	32.0	207.0
Arctic char	14.5	166.0
Atlantic salmon	-	33.0
Speckled trout	2.3	33.0
Bay scallop	0.5	3.0
	<u>5,667.0</u>	<u>7,409.0</u>

New Brunswick:

Atlantic salmon	10,145.0	89,280.0
Rainbow trout	380	2,400.0
Shellfish (mussel, oyster)	270	600.0
	<u>10,795.0</u>	<u>92,280.0</u>

Quebec:

Atlantic salmon	20	154.0
Mussel	34	75.0
	<u>54</u>	<u>229.0</u>

PACIFIC COAST:

	<u>mt</u>	<u>CDN \$(000's)</u>
Marine salmonids (Chinook, Coho, Atlantics, Steelhead)	24,027.0	115,000.0
Rainbow trout	115.0	715.0
Arctic char	4.0	30.0
Pacific oysters	5,000.0	4,200.0
Manila clam	200.0	700.0
Scallops	*	*
	<u>29,346.0</u>	<u>120,645.0</u>
 Total Estimated Canadian Mariculture Production (1993)	 47,718.8	 230,175.0

* Denotes less than three farms reporting and to maintain producer confidentiality, these numbers cannot be reported.

DENMARK

by

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(Danish Institute for Fisheries and Marine Research)

Rainbow trout (*Salmo gairdneri*)

The production of rainbow trout in seawater during 1993 is estimated to be 7000 tons and is similar to the previous 4-5 years, since strict environmental protection regulations prevent the further development of this industry. Research is primarily related to development of dry feed products and disease control. During 1993 new projects have been initiated concerning pigments in dry feed, genetics and environmental impact from net cage cultures.

Turbot (*Scophthalmus maximus*)

Two commercial turbot hatcheries and 2-3 smaller hatchers have been established over the past 3-4 years. In 1992 the production of turbot of 5-10 g was around 810,000. Most of these (around 60%) were exported to the Mediterranean area, the rest were used for on-growing or for stock enhancement projects in Danish waters (see below). The production systems are based on extensive rearing technology, using wild or extensively reared copepods as food during the larval phase. After metamorphoses, the turbot are transferred to indoor tanks and weaned onto dry food pellets.

In one intensive, land-based production unit, 27.5 tons market sized turbot were produced during 1993.

Cod (*Gadus morhua*)

Cod have been produced since 1991 for stock enhancement purposes. A cod-rearing unit has been established on the west coast, based on extensive rearing technology. Around 11,000 cod juveniles (3 cm) were produced during 1993.

Plaice (*Pleuronectes platessa*)

The production of plaice is also associated with the Danish restocking program. During 1992, 240,000 juvenile plaice (2-5 cm) were produced and a further 8,000 plaice were grown to a size of 10-15 cm during 1993. The majority of these fish were produced in intensive rearing systems using enriched rotifers and *Artemia nauplii* as live feed during the larval stage. Around 10,000 juvenile plaice (3-5 cm) were produced in an extensive system.

Flounder (*Pleuronectes flesus*)

Flounder are produced for the Danish Stock Enhancement program. During 1993, 7,000 juveniles measuring 3-5 cm were produced.

Gilthead seabream (*Sparus auratus*) and sea bass (*Dicentrarchus labrax*)

These species are reared using intensive rearing techniques and recirculation systems. Around 250 tons, 300 g fish were produced in one commercial hatchery. The fish are exported to the Mediterranean area.

Stock enhancement

The Marine Stock Enhancement program was established in 1989 with the primary aim to enhance stocks in Danish waters. The program comprises 3 main activities;

- site-assessment for release and restocking purposes
- evaluation of the effect of the releases
- administration.

To enable an evaluation of the effect of the releases, fish are tagged prior to release. Different tagging methods are used including external Floy tags and chemical markers.

During 1993 the following species, numbers and sizes have been released in the Limfjord, southern Kattegat or the western Baltic area. The majority of the fish were tagged as part of research projects.

Species	Size (cm)	Number	Tag percentage
Cod	3	11,300	100
Plaice	11-13	8,000	100
Turbot	3-12	262,000	34
Flounder	4	7,000	100

A hatchery was established in the Baltic area on the island of Bornholm in association with plans for a restocking project for Baltic cod.

Diseases

Trout: No serious disease outbreaks were registered during 1993, probably due to the cold summer. Enteric redmouth disease was registered in 2 cases in association with transfer to saltwater. Furunculosis is still the dominant disease, although over 90% of the released fish had been vaccinated with Aquavac/Aqua Health triple vaccines.

Salmon: An outbreak of furunculosis was registered among imported Swedish salmon in association with release to marine net-cage culture.

Research is directed towards development of vaccines and of identification and detection techniques for fish pathogens.

FINLAND

by

KARI RUOHONEN and TIMO MÄKINEN

I Production

1.1. Fish farms and the production

Production of fish for human consumption decreased from 1991 output to 17,909 tons (99% rainbow trout) in 1992. Only 3,236 tons of this was reared in fresh water and 82% of the fish was produced in net cages in brackish water. The value of the food fish output in 1992 (calculated as the producer price) was 68 million USD (1 USD = 5.5 FIM).

The amount of rainbow trout exported were increasing since mid 1980's and was approximately 3,000 tons/a ungutted fish till beginning of 1990's (Table 1). Less gutted fish is exported nowadays than in the beginning; in 1990, already half of the amount consisted of filets. Because of the devaluation of the Finnish currency, a new increase of export is waited to take place in coming years.

Table 1. The export of rainbow trout in Finland in 1986 - 1992, gutted weight:

Year	Export t/a
1986	236
1987	782
1988	3830
1989	3073
1990	3057
1991	1179
1992	1709

In 1992, the total number of fish farms in Finland reduced somewhat and it was 360 (44% in inland water) and, in addition, natural rearing ponds were used with a total area of 9,110 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 a growing branch of 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 1992, the number of salmonids produced for stocking purposes, excluding newly hatched larvae, was 13.5 million. The natural freshwater rearing ponds produced about 49 million mostly one-summer old juveniles. In 1992, the value of juvenile production of rainbow trout was about 13 million USD and that of other species produced for stocking purposes in natural waters about 19 million USD.

1.2 Introductions

During 1992 and 1993, eel juveniles were imported (114,000 and 122,000, respectively) from Swedish quarantine for stocking purposes of some small lakes in southern Finland.

II FISH DISEASES

No new dangerous fish diseases were observed in 1993. 23% of Finnish fish farms have voluntarily joined the Fish Health Control System conducted by National Veterinary Institute.

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 43 and 40 different farms during 1992 and 1993, respectively. Most of the farms are situated in the archipelago and the coastal area of the Baltic Sea, where also most of the rainbow trout production takes place. Effective vaccines against furunculosis are not yet available and, thus, therapeutic antibiotics are commonly used with results in residues and eventual bacterial resistance.

Bacterial kidney disease (BKD) was diagnosed on one farm in 1992 and on two farms 1993, 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 was isolated seven times during 1992 in comparison to 7 isolations from different farms during 1990 and one in 1991. No isolations was detected in 1993. There has not been clinical signs of IPN.

III RESEARCH

3.1. Mariculture

Mariculture research station was founded in the beginning of 1993 under the government of Finnish Game and Fisheries Research Institute. It is located in the south-western archipelago of Finland about 40 km west from the city of Turku.

The project on the use of Baltic herring in rainbow trout feeds continued. Experiments were undertaken to clarify the role of dietary water on the digestion and gastric adaptation of rainbow trout, to compare the excretion of phosphates and ammonium of rainbow trout fed on chopped herring or artificial dry food, and to give recommendations on the use of binding agents in moist pellets. In collaboration with National Health Institute and National Food Administration, the accumulation of environmental toxins from the diet to the rainbow trout was studied. A primer on the formulation and use of moist pellets in rainbow trout farming has been published by Finnish Game and Fisheries Research Institute. The primer is intended to Finnish fish farmers.

A project on feeding techniques in cage farming has been going on during 1993.

3.2. Environmental changes threatening fish farming

Increased mortality of eggs and newly hatched larvae has been observed in salmon egg batches supplied from natural spawning fish. In Finland, culturing of brood fish for egg production at fish farms is a common practice and only some eggs are taken from natural spawners. In cultured brood, fish eggs or newly hatched larvae no increased mortality has been observed.

The reasons of increased mortality, called M 74 at Swedish side of the Baltic Sea, will be a main focusing point of the research activities in the near future.

Appendix 1

Fish Culture in Finland 1992

Food fish production¹

	Brackish water	Fresh Water	Total
Production, 1000 kg			
Rainbow trout	14 588	3 200	17 788
Salmon	85	0	85
Other species (Brown trout and whitefish)	0	36	36
Total	15 198	4 073	19 271
Farms	200	170	370

1) In ungutted fish

Production capacity

	Brackish water	Fresh Water	Total
Net cages, 1000 m ³	1057	233	1 290
Ponds and tanks, 1000 m ³	54	1 244	1 298
Natural food rearing ponds, ha	3	9 110	9 113

Output of juveniles¹

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	18 225	3 272
	20 - 200 g	4 265	7 493
	over 200 g	2 895	7 021
Atlantic salmon	under 20 g	2 766	4 002
	20 - 200 g	2 661	2 362
	over 200 g	35	101
Sea trout	under 50 g	1 024	2 030
	over 50 g	1 509	1 625
Brown trout	under 50 g	2 545	3 979
	over 50 g	2 498	2 129
Char and brook trout	under 50 g	207	976
	over 50 g	209	263
Coregonids	under 20 g	36 294	468
	over 20 g	211	85
Grayling ²	all sizes	1 779	44
Pike-perch ²	all sizes	8 109	19
Pike ²	all sizes	1 941	0
Cyprinids ²	all sizes	704	40
Crayfish species ²	all sizes	229	68
Others ³	all sizes	71	20

1) Output of newly hatched larvae excluded

2) Usually one summer old fingerlings under 10 g in size

3) Perch and vendace

Value of juvenile production:

Rainbow trout 13 Million USD

Other species 19 Million USD (70-80% of which for stocking)

FRANCE

by

H. Grizel

(IFREMER)

En 1993, la production française de mollusques a été de 130,000 tonnes pour l'huître creuse, Crassostrea gigas, de 3,000 tonnes pour l'huître plate, Ostrea edulis, de 80,000 tonnes pour les moules, Mytilus edulis et M. Gallo-provincialis et 600 tonnes pour la palourde, Ruditapes philippinarum.

Les points forts concernant les recherches en conchyliculture ont été:

- (a) L'extension, au sud-ouest de la France, du réseau de contrôle des maladies de mollusques, fonctionnel depuis de nombreuses années en Bretagne et un Méditerranée.
- (b) La création d'un réseau de mollusques visant à suivre chaque année les performances de croissance des huîtres et les mortalités dans les sites majeurs d'élevage français.
- (c) La continuation des recherches en génétique avec la mise au point de techniques performantes de production de triploïdes, de contrôle de la palourde par individu et de tests de croissance comparée de tri et diploïdes dans plusieurs sites d'élevage. Les performances de croissance des triploïdes seraient meilleures dans les sites performants alors qu'elles seraient, au moins la première année, comparables ou moindres à celles des diploïdes dans les sites présentant des biomasses élevées. Par ailleurs, un plan de croisement et de rétrocroisement a été mis au point pour l'huître plate afin de vérifier la résistance de certaines «souches» à la bonamoïse. Enfin, des premiers résultats ont été obtenus sur le mode de transmission de la couleur et des ornements des coquilles de palourdes.
- (d) La progression des recherches sur la reproduction des mollusques avec la mise au point de protocoles d'évaluation de la qualité des gamètes, une meilleure compréhension du rôle de l'alimentation sur la maturation et la vie larvaire et, enfin, sur les techniques de production de microalgues.
- (e) L'approfondissement des connaissances en écophysiologie, en particulier, sur les taux de respiration et de filtration liés aux conditions environnementales et sur l'amélioration des modèles existants sur les relations entre la biomasse de filtreurs, les sources de nutriments, leur dynamique et leur utilisation. Un modèle global d'aménagement devrait être prochainement mis à l'étude.
- (f) L'orientation des recherches sur les maladies de mollusques avec en particulier une orientation sur la mise au point de méthodes de diagnostics, sur l'épidémiologie analytique pour mieux comprendre les cycles d'évolution et le rôle de porteurs de mollusques, sur la préparation d'un atlas d'histologie et sur la compréhension et le rôle de nouveaux agents pathogènes.

- (g) L'amélioration des zootechnies avec en particulier la mise au point de procédés de nursage d'huîtres en utilisant des eaux de forage enrichies en phytoplancton, le développement du télécaptage pour l'huître plate, l'étude de circuit fermé en utilisant des filtres biologiques et le fonctionnement des claires (enrichissement en vue de la production de blooms phytoplanctoniques).
- (h) La poursuite de travaux de recherches d'accompagnement de la conchyliculture notamment ceux visant à la meilleure gestion des cheptels (évaluation des biomasses, performance de croissance) et à la meilleure gestion des sites (impact des rejets agricoles et industriels).

ICELAND

by

Stefan E. Stefànsson

(Institute of Freshwater Fisheries)

and

Björn Björnsson

(Marine Research Institute)

PRODUCTION IN AQUACULTURE IN 1993

Atlantic salmon (Salmo salar)

In 1993 around 6.0 million salmon smolts were produced and over 3.65 million of those were released in ocean ranching. 2.35 million were used for on-growing in land based farms and net pens.

2.850 tonnes of salmon were produced, whereof 1.648 tonnes were in land based units, 700 tonnes in net pens and 502 tonnes from ocean ranching.

Production in 1994 is estimated around 3.050 tonnes.

Other salmonids

Production of Arctic char (Salvelinus alpinus), Rainbow trout (Oncorhynchus mylis) and Brown trout (Salmo trutta) was 566 tonnes. Most of the production is Arctic char or 340 tonnes, then Rainbow trout (Oncorhynchus mylis) production 221 tonnes. About 1.3 million smolts were produced of these three species.

RESEARCH ACTIVITIES OF 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 5 year classes have been released in all 650 families. Results are promising.

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

Fish farming

Selective breeding program for fish farming 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 the most critical ways to run land based units where different units, as well as different environmental conditions, are compared. The aim is to improve the performance of salmon in rearing and ranching operations, using Icelandic and Norwegian stocks. The development of year-round Atlantic salmon egg production was included in the breeding programme by using artificial photoperiod. The programme can already offer salmon ova all year around in Iceland and for salmon farming on a world wide basis in 1994.

ARCTIC CHAR (Salvelinus alpinus)

Research is under way for rearing of arctic char. The most important projects are: comparisons 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 salmonicida subsp. achromogenes is a problem in on-growing of salmonids. Vaccines are being developed. Disease control is also under way for marine species.

MARINE SPECIES

Halibut

Breeding trials with halibut were only carried out by one private firm in Iceland. About 200 fry survived to the end of the year.

Marine Research Institute completed a series of experiments at its Mariculture Laboratory (ML) studying optimal temperature of juvenile halibut. The results suggest that optimal temperature of halibut decreases with size.

Cod

Early life history studies of cod were carried out at ML to investigate the effects of size of female on the size and survival of eggs and larvae.

Growth experiments were initiated at ML to study optimal temperature of juvenile cod and the influence of energy content of diet on feed conversion.

IRELAND

by

Jacqueline Doyle

1. Production Trends (tonnes)

Finfish	1992	1993
Atlantic salmon	9,231	12,366
Rainbow trout sea cage	600	677
Rainbow trout freshwater	700	906
Shellfish		
Pacific oyster	1,750	N/A
<u>C. gigas</u>		
Native oyster	334	N/A
<u>O. edulis</u>		
Mussel suspended	5,090	N/A
<u>M. edulis</u>		
Mussels bottom	8,730	

- 1.1 There has been a significant increase in the production of farmed salmon despite losses due to novel disease processes during the year. Once case involved the isolation of an, as yet, unidentified bacterium associated with mortalities of up to 100% of large salmon at sea. A second study resulted in the recurrence of an encephalitis in salmon smolt shortly after they were put to sea, with 100% mortalities of approximately half a million fish over a period of 6 weeks.

Other economically important notifiable diseases reported include Yersinia ruckeri, IPN and furunculosis.

- 1.2 Shellfish sales were disrupted by the annual occurrence of Diarrheic Shellfish toxicity DSP associated with Dinophysis species on the south-west and west coasts.

Serious concerns have been expressed at the accidental import of pest species with the continued importation of half grown C. gigas from France, some of which have spread to existing populations.

- 1.3 The further expansion of salmon farming is being curtailed by the collapse of wild sea trout fisheries lice associated with heavy burdens of juvenile in the west coast and declines of catches in southwest and northwest areas. Analyses indicated that variations in lice infestation levels on sea trout demonstrated their maximum range in the vicinity of salmon cages, whereas at distances, remote from cages, the overall infestation levels were always at the lower end of the observed range.

During 1993, the level of monitoring of sea lice infestations on farmed salmonids was increased. All farms were inspected in April, May and June, and again in the autumn and winter.

Monitoring at selected sites was continued throughout the summer. As a precaution, a control area of the west coast has been identified as an area for the protection of wild salmonids in which salmon aquaculture is prohibited for the time being.

2. Administrative Measures

- 2.1 Other issues of environmental concerns are the persistence of antibiotics in sediments and biota adjacent to fish farm sites. Routine environmental monitoring of water quality parameters is continuing as part of the licence conditions. The monitoring program is under review. Because of major changes in farm management practices in the past two years, it now seems more appropriate to move towards annual site audits to assess the impact on benthos and sediments.
- 2.2 Fallowing strategies augmented by harrowing practices have been introduced to try and break disease cycles with some success. Single bay management strategies are being encouraged where there are multiple farms located.

3. Studies related to Environmental Aspects to Mariculture in Ireland include:

- Study on the status of Marine TBT antifouling contamination in Aquaculture areas
- Introductions of exotic species associated with Pacific oyster transfers from France to Ireland
- Pollution control of freshwater fish farm effluents
- Cleaner fish technology as an alternative to pesticides
- The developing of a vaccine for furunculosis caused by A. Salmonicida in Salmonid fish
- Fate and sinks of malachite green in the natural environment
- Study of the rates of recovery in shallow embayments following intensive aquaculture activities over a 10-year period
- Research into the fate of antibiotic residues in the Marine Environment
- Research into the residency time of certain pathogens under hypoxic and oxic sediment conditions in marine fish farms
- The role of bioturbating animals in the fate of antibiotic residues in the marine environment
- A study of temporal changes in the genetic composition of juvenile salmon populations from selected rivers adjacent to fish farms
- Vaccination trials
- Phytoplankton species associated with imports of the Pacific Oyster, Crassostrea gigas, from France to Ireland
- Studies on Sea Trout and interactions with salmon farms

4. New Species

Two pilot turbot farms are being developed in the southwest coast and growth rates are reported to be very satisfactory. Experimental trials on rearing of brown trout, Arctic charr and gullspang salmon are currently being evaluated as possible alternatives to Atlantic salmon.

5. Introduction

- 5.1 The Japanese scallop Pantinopecten yezoensis cultivation in Ireland has been terminated as a result of the mortalities of broodstock.
- 5.2 A proposal to introduce striped bass Morone saxatilis and the white bass Morone chrysops and their hybrids to a land-based contained culture system is currently being evaluated by the ICES Working Group on the Introductions and Transfers of marine organisms.

NETHERLANDS

by

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Mariculture production figures for season 1993/1994 (partly estimates):

Molluscs

Metric Tonnes

Mussels (Mytilus edulis): Consumption: $\pm 39,520$ (provisional)
Seed mussels: 37,200

Oysters: Ostrea edulis ± 250
Crassostrea gigas $\pm 2,000$

Finfish

Rainbow trout (Oncorhynchus gairdneri) 20
Sea bass (Dicentrarchus labrax) <1

Developments

After a period of 3 years with poor mussel and cockle spatfall, a good year class of mussel seed in 1991 provided sufficient prime material for the industry. However, mussel recruitment in 1992 and 1993 has been poor again. Mussel production in 1993 was somewhat lower than in 1992.

The molluscan industry in 1993 had to deal with new national legislation, mainly aimed at protecting natural values in the coastal area. The two main production areas, the Wadden Sea and the Oosterschelde, had earlier been declared natural reserves. Additionally, in order to safeguard the undisturbed development of eelgrass fields, mussel and cockle banks, and also food supply for birds, a part of the intertidal fishing areas for mussel seed and cockles were closed, and a part of the cockle stock will have to be spared in years of low cockle availability for birds, mainly eiderducks (Somateria mollissima) and oystercatchers (Haematopus ostralegus). This had led to restrictions for the fishery for seed mussels and cockle fishing in the Wadden Sea. Based on yearly stock assessments, fishing plans are made very year by the industry, which have to be agreed upon by the government.

Stricter regulations concerning the sanitary pureness of shellfish production waters were implemented, following new EC legislation. The existing monitoring programs for bacteriological water quality and for the occurrence of (potentially) toxic phytoplankton and shellfish biotoxins in the coastal water were intensified. The number of production areas covered were increased, as was the sampling frequency.

A pilot plant for turbot production is being constructed. Plans for another project, aimed at production at commercial scale, is in preparation.

New Research Activities

The Netherlands Institute for Fisheries Research is responsible for the new-style national monitoring programs for bacteriological water quality, toxic phyto-plankton and biotoxins. The program is financed by both the government and the shellfish industry.

A study of the relation between eutrophication of the Wadden Sea and growth and condition of mussels, was undertaken and will be completed in 1994. Landing statistics of mussels make valuable time-series possible of mussel condition and growth rate in a number of production areas since the 1950's. This time-span covers the periods of increase and, by some experts, supposed decrease of the eutrophication in the coastal water.

Ongoing Research Programs

Monitoring programs for stocks of cockles and mussel seed are carried out yearly to provide information on the amount of cockles and mussel seed available to the fishery, mussel culture and to wild birds.

Research into effluent characteristics of intensive fish farms (mainly recirculating eel and catfish farms) at the RIVO-DLO in IJmuiden is being continued.

Development research into the culture of turbot (Scophthalmus maximus) is carried out at the RIVO-DLO in IJmuiden and will be concluded in 1994. A pilot plant for commercial production of turbot, using power plant cooling water, was built and will be started in 1994.

NORWAY

by

Snorre Tilseth

(Institute of Marine Research)

This report is a summary of the main research activity, results and progress within aquaculture in Norwegian governmental institutions and universities. Included is also a summary of the finfish diseases in Norwegian fish farming in 1993, given by The National Veterinary Institute, in Oslo.

In table 1 is presented the production statistics of salmonids and marine species in Norway in 1993. Atlantic halibut was for the first time commercially produced and presented to the market in 1993. The volume will increase in the years to come due to progress in fry production. Priority in research and development is still focused on halibut larval rearing and fry production to achieve better methods and reduce production costs. Atlantic cod is still cultivated by a few companies, mainly by feeding small size fish in net pens, captured alive in the commercial fishery or fry produced in seawater ponds.

Atlantic cod, European lobster, Atlantic salmon, Arctic char and scallops are produced for sea ranching and/or stock enhancement purposes. Several Norwegian institutions and private companies are involved in this national program.

Table 1. Production statistics of salmonids and marine species in Norway in 1993.

1993	Tonnes produced
Salmon	170,000
Trout	7,000
Arctic char	< 1,000
Halibut	8.5
Cod	500 kg

ATLANTIC SALMON

Physiology

Salmon reared under different photoperiods were subjected to seawater challenge tests for evaluation of their hypoosmoregulatory ability during their parr/smolt transformation. Different salinities and different time of exposure were tested.

Nutrition

Biological functions of astaxanthin has been studied in different stages of Atlantic salmon. No effect of astaxanthin concentration in eggs were found on survival and development of the eggs and yolk sac fry. High mortality and reduced growth rate occurred in groups of Atlantic salmon fed diets without astaxanthin. Large variations exists between the different products, but good pigment retention can be achieved.

Discoloration and variation in salmon pigmentation have been studied. The problem seems to be related to the spring and summer time, or during phases with high growth rates.

Ongrowth technology

The vertical distribution of cultured Atlantic salmon larger than 1 kg was monitored by hydroacoustics in both a shallow (6m) and a deep (20m) cage. Surface light levels and fish distribution were registered for three periods throughout the year. The two fish groups were fed calculated rations twice a day. During the winter and spring (including vernal equinox), the fish were distributed at around 5 m depth in both cages when not feeding. Around summer solstice, the fish preferred deeper water when not feeding. The light dependency of the vertical migration was pronounced, and indicates clearly that even a 20 m deep cage is not deep enough to meet the depth requirements of large Atlantic salmon during summer.

MARINE SPECIES

Cod, *Gadus morhua*

Photoperiodic control of reproduction in cod

The effect of photoperiod on growth, sexual maturation and spawning in cod are studied. Continuous light from mid-summer delay maturation and spawning.

King scallop, *Pecten maximus*

A small-scale production line was established at IMR Austevoll Aquaculture Research Station in 1993. From a total of four spawning sessions in April-May a total of 47.6 mill eggs were incubated, which provided 25.7 mill. D3-larvae. Experiments on acclimatization prior to transfer to ongrowth boxes have been carried out.

Crab, *Cancer pagurus*

Traditionally, customers experience large differences in crab quality. These variations are mainly due to seasonal variations in food and molt stage. In a joint programme where several Norwegian research organisations participate, a method to sort out well filled crabs are developed. Fattening partially filled crabs are subject for further research. Water temperature must be at least 8°C, and a lower limit of 10°C is recommended to obtain high quality crabs. Required oxygen content in 12°C water was found to be at least 85% saturation in outlet. Less than 80% saturation gave high mortality during the feeding period, but no decrease in crab quality.

Cod, *Gadus morhua***Control of reproduction in cod.**

The effect of photoperiod manipulation on sexual maturation and spawning in cod are studied. A condensed cycle, with normal annual variation in day length occurring in six months gave an advancement in maturation and spawning by two months the first year of treatment. Correspondingly, an eighteen month-cycle resulted in maturation.

In two starvation experiments, fecundity in first-time spawners has been analysed. Adolescent body weight was most important for fecundity followed by growth rate in the autumn, while growth rate in the spring contributed insignificantly. High individual variability in both fecundity and oocyte development suggests genetic influences.

Larval rearing.

The genetic effect on growth and survival potential for coastal cod (CC) and Northeast Arctic cod (NAC) has been investigated. Due to a genetic marker in the CC stock, it was possible to identify stock origin of both CC and NAC larvae reared together on natural plankton in 5.2 m³ plastic bag enclosures. Thus, growth and survival were compared for larvae of the two different stocks reared under similar feeding and environmental conditions. No trend in stock-specific survival was observed, but the CC larvae had significant better growth than the NAC larvae.

In a mate choice experiment, 12 groups of defined spawners were followed daily. Eggs from all batches were incubated and hatched. Offspring as well as parents are now analyzed by DNA fingerprinting.

Ongrowth and quality in cod.

Three groups of cod with different relative liver size (estimated by sampling and ultrasonography) were followed in a 12 week study. In all groups a decrease in relative liver size was found during fasting, however, largest decrease in liver lipid stores were measured in the groups with the initially lowest liver index and lipid levels. There was an increase in fillet water content in those fish with initial low liver index after 4 weeks of fasting, and after 8 weeks in medium liver group. Liver glycogen was utilized as energy during fasting. However, this energy store was not depleted, neither in fillet nor in liver. The reduction in glycogen was observed during the first part of the starvation period.

Halibut, *Hippoglossus hippoglossus***Control of reproduction in halibut.**

Photoperiod manipulation of sexual maturation in halibut resulted in spawning male and female fish in August to October, six months out of season, both in 1991, 1992 and 1993. Fertilized eggs were incubated at 5°C and hatched normally.

The endocrine regulation of sexual maturation and ovulation in halibut are being studied.

Egg production and larval rearing.

Effects of long term light exposure on eggs from the Atlantic halibut (*Hippoglossus hippoglossus*) was investigated. After a certain age, the halibut eggs respond to light exposure by increased density. Increased egg density is found to be caused by a loss of water from the embryonic compartment measured as an increase of the perivitelline space, and also an increase in yolk osmolality. The ecological and practical significance of the findings are discussed.

Two experiments with halibut yolk sac larvae have been conducted in 3000 l silos. One with different flow rate and one with two different light regime in the period from hatching to startfeeding. Mortality, dry weight of larvae and yolk sac were measured. In addition the total numbers of bacteria in incubator water were recorded. Mortality increased with increasing flow rate. Bacterial numbers decreased with increased flow rate. Dry weight of larval body and yolk sac decreased with increasing flow rate. The survival after transfer to startfeeding units was highest in the groups kept in light.

Halibut eggs were treated with the disinfectant glutaric dialdehyde in two regimes, 400 ppm for 10 min and 800 ppm for 2.5 min. No significant differences in survival during the yolk sac period or percentage of deformed larvae were found. Differences in survival appeared during start feeding where eggs exposed to 400 ppm glutaric dialdehyde showed significantly higher survival than did the 800 ppm and control (untreated) group. The 400 ppm group also showed higher growth, which was most pronounced when fed wild zooplankton compared to *Artemia*.

Experiments analysing the effect of light (specter and intensity) upon activity, growth and eye development have been performed. Preliminary analysis indicates that light intensity through the yolk sac period do affect growth of halibut larvae.

The work on larval bioenergetics has been continued. To complete the energy model for first feeding larvae, metabolism and excretion has been measured at different temperatures. Experiments to determine daily feed consumption by gut evacuation models have been carried out.

It has been verified that *Artemia* provides growth and survival of first feeding halibut, but leads to a high incidence of malpigmented juveniles. Experiments has been conducted to evaluate the level of vit A in live feeds and the potential of dietary supplement of this vitamin. First feeding halibut larvae fed vit A enriched *Artemia* showed no improved pigmentation.

An investigation in seven Norwegian pond systems used in aquaculture revealed that copepod resting eggs in the sediments is a common feature in such locations. Large amounts of copepod resting eggs have been produced in large scale outdoor cultures.

Live prey are so far essential for successful rearing of halibut larvae. As the larvae grow there are an increasing demand for amount of prey. Therefore it is important to start as early as possible with formulated diets. An experiment was conducted to investigate at what size and how the halibut should be weaned to formulated diets by using survival and growth as evaluation. The survival rate was increasing with increasing size. Feeding the halibut with live prey and dry feed in combination during the 14 first days of the weaning period also increased the survival.

Feeding and ongrowth of halibut.

Feeds with varying size, moisture and specific gravity have been tested in growth experiments, in order to develop feeds that are well suited to the nutritional and behavioural need of halibut. A new method for examining potential for growth and for food utilization of fish is being developed. A floating, closed cage for halibut ongrowth is developed. A similar growth as observed in traditional tanks, as well as no wounds on the blind side when using specific bottom substrate are verified.

SEA RANCHING

The programme is part of a large scale national programme for investigation the potential of sea ranching of Atlantic cod, lobster, Arctic char and Atlantic salmon. In 1993 cultivation of scallops (sea bed) was also incorporated.

Atlantic salmon, *Salmo salar*

Within the frame of the programme 42,000 smolts originating from three regional rivers were released by the Institute of Marine Research at Sotra island (SW-Norway) in 1993. A cooperating project at Helgeland (mid-Norway) released 130,000 smolts at Vega island originating from Vefsna river. The aim is to study possible ecological consequences of large scale releases. The recaptures of the 1992 releases were of 1.9 and 0.9 percent respectively for Sotra and Helgeland.

Atlantic cod, *Gadus morhua*

In the period from 1988 to 1990 the yearly releases of reared cod in Masfjorden, north of Bergen, were 30-83,000. The released cod contributed significantly to their year-classes in the release area. Density-dependent mortality on 0- and 1-group stages reduced the abundance, and at recruitment to the fishery as 2-group, the abundances of cod in the release area were not significantly different from the control area. The experiment in Masfjorden was terminated in 1993. The aim of this experiment was to investigate if it is possible to increase the production in the fjord by releases of artificially reared cod, and to study the physical and biological factors controlling the carrying capacity of cod. The results from Masfjorden suggested that the potential for cod production are higher in open coastal areas, and from 1991 more than 100,000 tagged reared cod have been released in an open coastal area at Øygarden NW of Bergen. The first results from this area support the hypothesis of higher potential for cod production at open coastal areas.

Scallop, *Pecten maximus*

As part of a national program on scallop cultivation a cooperative project at Fosen, Sør-Trøndelag (mid-Norway) set out scallops on the sea bed, both 1200 scallops collected from local beds and 5000 spat produced in hatchery (near Bergen, SW-Norway). The aim is to study survival at different scallops size, distribution and migration of seeded scallops and to develop methods for predator control. First results five months after release indicate oriented migration from release area towards shallow waters. Data on growth are collected from wild populations and from sea bed cultivation.

Lobster, *Homarus gammarus*

From 1990, more than 100,000 tagged lobster juveniles have been released at Kvitsøy (SW-Norway). Only a small part of lobsters have yet recruited to the fishery (>25 cm TL), but the contribution of released lobster in the catches is already 12%. We have estimated the contribution of released lobster in the pre-recruit group (<25 cm) to be around 40%.

DISEASES

Salmon lice

In the project "Preventive and integrated treatment of salmon lice" methods for delousing and operational procedures preventing or decreasing the salmon lice attack are developed. The study focus upon the free swimming and infective stages of salmon lice. An indirect method for estimating the amount of copepodites in sea has been developed and the vertical migrating pattern of the free swimming stages has been mapped.

Furunculosis

Infectivity studies and observations from field trials has confirmed previous results showing that Aeromonas salmonicida can be transmitted to cod, halibut, turbot and wrasse. The susceptibility to furunculosis of adult stages of these species are low compared to the susceptibility of Atlantic salmon. However, challenges to halibut and turbot larvae caused mortality indicating that these stages are more susceptible than the adult stages.

A new vaccine concept based on a double adjuvant system has been developed. Intraperitoneal injection of the vaccine consisting of formalin killed bacteria mixed with an oil and glucan resulted in a high protection against furunculosis more rapid than vaccines with oil as single immunostimulant.

Vibriosis

Vibriosis is still the most serious bacterial disease on farmed marine fish species causing losses in the production of cod and halibut. In 1993 serological, biochemical and immunological properties of Vibrio anguillarum isolated from halibut has been studied. Based on these studies two serotypes of the bacterium are chosen for development of a vaccine. Vaccination of halibut fry in laboratory scale and field trials will be carried out in the 1994 season. Infections of turbot and halibut larvae with bacteria of the genera Vibrio resulted in lower larval buoyancy compared to uninfected controls. These results may be the basis for the sorting out of infected larvae from a production line of these species.

Infectious Salmon Anemia (ISA)

The disease can be transmitted by injection of blood cells and plasma from diseased fish. In addition, the disease is spread via waterborn virus or by direct contact between fish. Experiments carried out in 1993 have shown that challenged fish excrete virus prior to any signs of illness is observed. It has also been shown that virus are excreted via faeces and mucus of deceased fish and that virus are taken up by the gills. ISA is primary affecting Atlantic salmon. Wrasse, turbot, Arctic char and rainbow trout seems to be resistant, whereas sea trout is reported to be a carrier of the infectious agent.

Infectious Pancreatic Necrosis (IPN)

Infectious pancreatic necrosis virus (IPNV) has been isolated from farmed halibut during a period of high mortality during the weaning period. Challenge experiments carried out in 1993 have shown that halibut is highly susceptible to IPNV infections in these life stages. Bath challenge of fish in the weight range 0.1 - 5.0 g resulted in high mortality (up to 100%). The mortality was higher at 15°C than at 12°C indicating that the susceptibility is temperature dependent. Histological examination revealed that the liver of moribund fish is necrotic and contained high virus titres.

IPNV was also isolated from Atlantic salmon during a period of high mortality after transfer to seawater. Challenge of Atlantic salmon with this isolate resulted in 20% mortality, indicating that the virus may contribute to the mortality sometimes observed after transfer of Atlantic salmon to seawater.

A comparative study of stereotyping of IPN virus isolated from Atlantic salmon, marine fish species and molluscs revealed that all isolates belong to a relative homogeneous group.

Shellfish

The screening program of the health status of Norwegian bivalve molluscs has not revealed any serious disease or parasite being present. Work has been started to develop and improve methods for the study of antimicrobial defence reactions in bivalve molluscs.

INTERACTIONS BETWEEN AQUACULTURE AND THE ENVIRONMENT

Development of a management tool for regulation of the local environmental impact of aquaculture was initiated in 1993. The tool consists of two parts integrated in one regulation system; 1) a model which can simulate the environmental conditions on a site given information on the size and operation of the farm and the hydrodynamical conditions and the topography of the locality, and 2) a monitoring program which can survey the environmental conditions in the vicinity of the farm. The system will serve three purposes: 1) be helpful in maintaining satisfactory environmental conditions in and around the farm thus reducing health problems and subsequent use of antibacterial agents, 2) be useful for management of sites and coastal areas, and 3) provide documentation of the rearing conditions for marketing purposes.

In 1992 accumulation of antibacterial agents in wild fish was discovered and we have studied ways to minimize this effect. Medicated feed produced by a special heat-treatment technique gave higher uptake rates of oxolinic acid than conventional feed, which will reduce the output of antibacterial agents to the environment. To reduce waste feed, a lift-up system that collects particulate material under the net pens was tested. This reduced the concentrations of antibacterial agents in wild fish, but due to small particles the fish still contained some medicine during treatment.

The stability of seven antibacterial agents in sediment and seawater was tested. Only or- and trimethoprim were decomposed within two months in the sediment. Oxytetracycline, oxolinic acid, flumequine and sulfadiazin were stable for at least six months. In seawater or- and trimethoprim were stable for at least 21 days, whereas oxytetracycline, oxolinic acid, flumequine and furazolidone were photo oxidized. Sulfadimetoxin was partly degraded in both water and sediment.

UNIVERSITY OF BERGEN

(Department of Fisheries and Marine Biology)

Bergen

Halibut - retinal development

The history of the developing halibut eye, from yolk sac larvae 25 degree days after hatching to juveniles about 1 year old, has been completed. The undifferentiated retina of the yolk sac larva develops in sectors. At about 150°days all types of retinal cells but only one type of photoreceptor cell was found. These are probably cones, whose outer photosensitive segment is present, implying that the eye may be capable of photodetection at this point. The eyes are fully pigmented by the melanin granules around the time of commercial first feeding (210°days). At the end-of-yolk sac stage, the lens was anchored to a tendon and a possible muscle, indicating an ability to focus. Eye migration was concurrent with the appearance of a cone mosaic in the retina, and at the completion of metamorphosis the retina contained groups of rods between the cones.

Juvenile growth

Using fish originating from Sea Farm A/S, growth in juvenile halibut from about 2 - 500 grams has been investigated in two consecutive experiments. The growth was tested in response to temperature, photoperiod and light intensity. The smallest fish grew better at 14° than 11°C, and the lowest light intensity of 1 lux gave insignificantly better survival than 10 and 500 lux at constant photoperiod. Larger fish with a mean weight of 140 grams showed better growth at 11° than at 14°C, and best when transferred from previous maintenance at 14° to 11°C in the experiment. A possible growth enhancement due to the change from constant to natural photoperiod will be followed up.

Historical sections of the muscle of developing young halibut revealed alternating bands of red and white muscle fibres within the filet. The clear staining of the two fibre types diminished with time making the effect of temperature on the quantity of these fibres difficult to ascertain.

European lobster

In co-operation with the Inst. of Marine Research Lobster Center at Kyrksæterøra, the effects of initial claw number and substrate on the growth of juvenile (stage V onward) European lobster were investigated over 36 weeks. Initial mortalities were highest in those groups with 0 claws at stage IV, and growth was initially significantly affected by the original number of claws. After the regeneration had been well established, however, shell sand and quarts sand gave significantly better growth, both in terms of length and weight, regardless of initial claw number. In those lobsters with only one claw at stage IV, only about 75% of these developed the crusher claw on the intact side.

Tilapia

In cooperation with the National Center of Aquaculture in Fort San Lucian, Malta, the seawater adaptability of *Oreochromis spiluris* juveniles was tested. Time to full seawater strength (36.7 ppt) ranged from 48-120 hours and the size groups ranged from a few mg (newly emerged) to about 5 gms. There was good survival in all groups. All responded with immediate increase in the number of chloride cells, and although the two larger groups lagged behind in

the rate of increase, the blood plasma chloride levels indicated acceptable osmotic balance, implying active Na-K-ATPase. Growth rates were significantly affected only in the smallest groups, where those given the longest acclimation time attained better growth rates.

Atlantic salmon

Effects of seawater exposure on plasma ions, gill Na^+ , K^+ -ATPase and plasma growth hormone

Juvenile Atlantic salmon were exposed to different salinities for various lengths of time at intervals between February and June. The results are used to define the optimum combinations of salinity and exposure time for seawater challenge testes, and further, to obtain basic information on the interrelation between salinity, plasma GH and gill Na^+ , K^+ -ATPase activity.

Changes in hypoosmoregulatory ability in post-smolt Atlantic salmon fed different ration levels

On the basis of an experiment carried out in 1992, post-smolt Atlantic salmon were reared in either freshwater or full-strength seawater at four ration levels. The results indicate that sufficient feeding is important to maintain salinity tolerance, and further, that post-smolt mortality in freshwater can occur as a result of poor feeding and low conductivity freshwater conditions.

Growth of Atlantic salmon in seawater

Improved growth has been observed in Atlantic salmon in sea cages following exposure to continuous light from November to May. Similar results have been observed in 0+ Atlantic salmon post-smolts transferred to sea cages in November and exposed to continuous light until May.

INSTITUTE OF NUTRITION

Directorate of Fisheries

Salmonid nutrition

A feeding experiment was conducted to evaluate minimum dietary requirement and interactions between two B-vitamins, folic acid and vitamin B12, by multivariate data modelling. Conclusions from this experiment and a practical feeding experiment on these vitamins will be performed in 1994.

Although the requirement for biotin in salmon fry was found to be covered by the natural content in fish feed ingredients, supplementation of biotin (1 mg/kg) to smolting fish seem to be beneficial as judged from survival after seawater challenge and serum chloride regulation.

Different levels of n-3 fatty acids in the diet fed Atlantic salmon during smoltification, did not show any significant difference in mortality among the groups. The fatty acid composition of individual phospholipids of gills and kidney is at the moment under investigation.

A pilot study was initiated to investigate whether the new incidences of cataracts seen in some salmon farms, are nutritional. We are especially investigating whether the zinc levels are sufficient, both in the feed and in the eyes. The experiment is continuing into 1994.

Studies to elucidate the Atlantic salmon's capacity for carbohydrate tolerance and utilisation have been conducted. High tolerance for both wheat and corn starch were measured. For protein sparing a dietary inclusion of about 10% were found to be optimal. Feed conversion factors, apparent digestibility and energy retention were found to be dependent on the complexity of the starch as well as the inclusion level.

Knowledge about the amino acid requirements is important when designing fish feeds containing other protein sources than fish meal. Key amino acids may be methionine, arginine and lysine. Few data of the amino acid requirements of large salmon are available. Experimental data so far has shown a methionine requirement of 2.6 % of the feed protein to Atlantic salmon of 500 to 1000 g.

A long term study was performed to investigate the effects of mineral supplementation to fish meal based diets. Rather small supplementations of zinc and manganese did have substantial effect of the levels in the fish, while this did not seem to be the case for iron and copper.

In redox-reactions vitamin E and C depend on each other in a complex way. A study was conducted to evaluate vitamin E sparing effect of vitamin C, and how the vitamins influence overall redox-potential in the tissues. The study is a part of a thesis on vitamin E nutrition in Atlantic salmon.

Evaluation and consideration of present knowledge and futural aspects on how Atlantic salmon product quality is affected by the fish diet ("product tailoring") have been performed and a final report will be send to the Norwegian Research Council in April 1994.

Marine fish nutrition

A successful production of marine larvae and fry are essential to future farming of marine species. A proper nutrition of larvae and fry seem to be an eye of a needle to this success. The present status on nutritional knowhow and future aspects to be explored have been evaluated and will be reported to the Norwegian Research Council in April 1994.

The protein requirement of cod has been considered to be higher than that of salmonid species. Experiments have shown a requirement of 40-45% of the total feed energy as protein, which is more in accordance with that of other fish species. It is, however, possible that the texture of the feed affects the feed protein utilization.

The nutritional value of rotifers used as feed for marine fish was evaluated and compared to known nutritional requirements.

CENTRAL VETERINARY LABORATORY (former National Veterinary Institute)

FISH DISEASE STATUS FOR NORWAY 1993

No notifiable List A disease was recorded in Norwegian fish farms in 1993. The only recorded List A disease in 1993 was crayfish plaque (*Aphanomyces astaci* infection) in noble crayfish which were detected in three river systems in south east Norway in the same region as reported in previous years. The health situation in Norwegian fish farms have in general been reported to be good in 1993 and the diseases previously known to cause considerable problems have been significantly reduced in numbers and economic importance. The

reasons for this are several, but factors such as better vaccines, favourable environmental conditions, improved management and practices in the fish farms, and active contribution from governmental authorities have been of importance.

However, the diseases furunculosis, infectious pancreatic necrosis (IPN), infectious salmon anemia (ISA), salmon lice (*Lepeophtheirus salmonis*), cold water vibriosis (*Vibrio salmonicida*) still cause some problems. The problems due to furunculosis have however, been reduced significantly in 1993 compared to previous years, also resulting in a strong reduction of the use of antibacterials. The "Stop ISA" campaign introduced by the Veterinary Authorities have played an important role regarding the problems associated with infectious salmon anemia (ISA). Although many farms still are under restrictions due to ISA, the number of farms with clinical outbreaks of the disease has been reduced. At the end of the 1993, all ISA infected fish had been removed from the cages.

Salmon lice, however, seem still to cause problems in the Norwegian fish farming industry.

Cold water vibriosis is causing some disease problems in Northern Norway in spite of vaccination programmes. The reasons for this are not known. The reported amount of antibacterials used in the region, are used as treatment against this disease. Other bacterial infections such as classical vibriosis (*Vibrio anguillarum*) and bacterial kidney disease (BKD, *Renibacterium salmoninarum*) are still of some significance, but do not create large problems.

The swimbladder nematode *Anguillicola crassus* in eel was recorded for the first time in Norway in an eel farm in south east part of Norway. The affected eel had been caught live in the border area of Sweden (Hvaler) and brought to the farm for farming purposes.

RESEARCH ON FISH DISEASES

Furunculosis

A polymerase chain reaction (PCR) based assay for the detection of *Aeromonas salmonicida* in kidney, spleen tissue and gill swabs has been developed.

The method has been tested on farmed Atlantic salmon assumed to be "latent carriers" of *A. salmonicida*. *A. salmonicida* was not detected either by PCR or bacterial cultivation. The results reveal that knowledge on the carrier state is incomplete. The PCR technology is so far only applicable for research purposes.

Farmed fish in Norway, is now fully vaccinated against furunculosis. We have shown that dead *A. salmonicida* from the vaccine were detectable in head kidney and spleen 4 month after i.p. vaccination by the PCR technique. In order to improve the identification, further studies have been initiated. These are in cooperation with laboratories in other European Countries.

The antibiotic substance florfenicol has been tested on various bacteria including *A. salmonicida*. Strains resistant to other antimicrobials used in fish farming were included in this study. MIC values and zone diameters have been determined. The results indicated that the bacteria tested were sensitive to florfenicol.

Infectious salmon anemia (ISA)

Infectious Salmon Anemia (ISA) was first reported in Norway in 1984. The clinical pathological, ultrastructural and haematological aspects of the disease has been described.

The causal agent of ISA has not been identified. However, strong evidence exists that it is an enveloped virus. So far, the causal agent has neither been propagated in cell cultures nor been identified by immunological methods. The work is now focused on finding fish cell cultures that are susceptible to virus growth. Recent research suggests that it might be possible to propagate the infectious agents in leucocytes from Atlantic salmon.

Efforts have been made to establish specific antibodies to the ISA agent. Antiserum produced in Atlantic salmon, immunized with the ISA agent, has shown promising results in several serological assays. Attempts are also been made to produce monoclonal antibodies to the ISA agent.

The authorities need information on disease transmission to be able to make administrative directives. Much effort has been made to investigate the resistance of the causative agent. The ISA agent is sensitive to chloroform, diethylether and formalin as well as heat, and low and high pH.

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

Virus-infections

In addition to Infectious Salmon Anemia (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. The studies have shown that the Sp. serotype is the most frequent. Work on rapid diagnostic tests for IPN is in progress. Studies on possible interactions between ISA and IPN have been done. An ELISA-method for detection of salmon anti-IPNV antibodies has been established. Examinations of anti IPNV antibodies in Atlantic salmon are in progress in connection with a research project on smolt mortality and studies of pathogenesis of IPN.

Parasite infections

The research on parasitic infections have been concentrated on studies of *Gyrodactylides* and parasitic copepods. The infestation and taxonomy of *Gyrodactylus salaris* in Atlantic salmon parr and of *G. callariatis* in young Atlantic cod have been studied in particular. Infestations of *Lepeophtheirus salmonis* and *Caligus elongatus* in wild salmonids, mainly sea trout (*Salmo truttae*), have also been studied.

The swimbladder nematode (*Anguillicola crassus*) has also been studied to some extent from a taxonomical point of view.

Laboratory experiments with a *Hexamita* sp. reported to cause systemic infection in farmed salmonids in Northern Norway have been carried out.

Immunology and immune prophylaxis

The specific immune response after use of different vaccines in Atlantic salmon is characterized by use of several techniques; ELISA, ELISPOT and lymphocyte stimulation test. Studies regarding vaccination against furunculosis have concentrated on the aspects of side effects; local reactions at the injection site and effect on fish weight gain. In connection with oral administration of vaccines against furunculosis, studies are carried out on local immune response and uptake of antigens in the intestine. Immuno histochemical methods are important instruments in this work.

By use of ISCOM-technique, experimental vaccines against furunculosis based on different antigens from *Aeromonas salmonicida* have been constructed. Some of these have generated a good immune response in fish.

The possible transfer of maternal immunity is studied by vaccinating mother fish in order to protect their fry against infections caused by bacteria (*Yersinia ruckeri*) and virus (infectious pancreatic necrosis virus). No specific protection has been detected in fry against yersiniosis. Experiments with IPN are in progress.

UNIVERSITY OF TROMSO
Norwegian College of Fishery Science
Tromsø

Salmonids

Studies were carried out within the following areas:

- Effects of environmental factors, both biotic and abiotic, on energy partitioning and growth;
- Quantitative analysis of food intake and feeding behaviour ("feed management");
- Energetics of fish under prolonged swimming activity.

Sea ranching

A national-funded sea ranching experiment has been carried out since 1990 on Arctic charr (*S. alpinus* L.) in Lake Møkkeland (1.3 km²) in Troms county. The population being 2 years + has been estimated to 30,000 with 1,000 migrating downstream yearly with 80% survival of veterans and 25% survival of first time migrants after about 30 days in the coastal waters resulting in a 80% weight increase. Feeding conditions were improved through a reduction of the lake population resulting in better growth and higher rate of migrants in the population. Higher return rates have been achieved by transferring small charr (10 cm) to feeding tanks and returning them to the lake after half a year so that first time migrants were bigger.

Cod

Behaviour

Cannibalism has been studied in tanks and shallow raceways with cod fry sized 15 mm to 80 mm as predators on smaller cod. The effect on feeding success of flickering light has been studied on first-feeding cod larvae.

Reproduction

Coastal cod with a normal spawning peek in April had a two-three month delayed spawning season with peek spawning in June when given a delayed light regime.

Juvenile cod production

Cod juveniles were produced in 500 m³ plastic bags situated in a closed pond where the larvae were offered live natural zooplankton (*Eurytemora* sp.) and about 200,000 2-4 cm juveniles were transferred to net pens. Rather high mortality during weaning reduced overall survival to stocking size (15 cm) to about 50,000.

Fjord ranching

This program was continued and most of the produced cod were released in the Sørfjorden area. Tag returns are still at a low level.

Halibut

In parallel to the production of cod juveniles, a small number of halibut were produced in plastic bags on natural zooplankton.

Common wolffish (*Anarhichas lupus*)

Reproduction

A number of females were stripped and fertilized and the eggs incubated in 20 l incubators at three temperatures. Egg development was examined all the way to hatching.

First-feeding and nutrition

Newly hatched wolffish alevin were offered two types of formulated diets with one of them giving a 80% survival for 60 days and twice the weight increase compared to those given the other diet. The study was carried out in shallow raceways. Older wolffish offered a floating extruded pellet with 10% shrimp meal which obtained a very high acceptance from the wolffish in raceways.

Spotted wolffish (*Anarhichas minor*)

Reproduction

For the first ever, a number of females were stripped and fertilized and the eggs incubated in 20 l incubators at three temperatures. Egg development was examined all the way to hatching. Eggs from a hybrid between female spotted and male common wolffish developed normally.

Turbot

A pilot-scale production of warm-demeaning juvenile turbot from first-feeding was carried out using the plastic bag method in a closed pond at 70°N. The juveniles survived the winter on 2-3°C in an in-door raceway. Pilot-scale rearing of turbot in the size range 0.5-1 kg was carried out in a shallow raceway with the fish in 2-3 layer and with extruded floating pellet offered as food. No mortality was observed even at 2.5°C. Compensation growth studies was carried out at three temperatures with young turbot (about 300 gram) being kept in advance at 4°C for half a year with no food uptake.

Sculptured shrimp (*Sclerocrangon boreas*)

A special raceway system was developed for sculptured shrimp. Failure of the eggs on egg-carrying females to hatched brought the effort on *S. boreas* to a halt.

Land-based rearing technique

The study of demersal fish species in shallow raceway systems continues. The effect of stocking densities corresponding to 300% coverage of the bottom has been studied for young halibut and turbot and with densities of about 800 kg/m³ for wolffish and 200 kg/m³ for young cod. Extruded floating pellets have been tested as food. The fish could easily snap this food from the surface both by pelagic as well as bottom-dwelling fish in raceways with a maximum water depth of 10 cm.

SINTEF

Norwegian Hydrotechnical Laboratory

Trondheim

The activity in 1993 has been focused on bringing the three following technological research programs within the Research Council to a conclusion:

- * Closed production systems on land and at sea
- * Industrial production of marine fish fry
- * Open production plants

During the last 5 years the SINTEF Group has been responsible for coordinating these programs on behalf of the Research Council and the SINTEF Group has carried out several projects within the programs.

The production costs in landbased fish farms that utilizes available technology is comparable with those in open sea cages. Solutions that ensure environmental control in the rearing units is provided. Particle traps at the outlet from rearing tanks make it possible to collect particles and thereby control the feeding and reduce the impact on the external environment. A new oxygenation system, designed to oxygenate each tank individually, has performed favourably during the past year. Tests have demonstrated that it is possible to attract fish along a transport channel by the use of water current and new equipment and procedures for internal transport and grading based on this principle is developed. Atlantic salmon in closed production systems have a growth rate that is equal the rate achieved in open sea cages and the growth rate remains high even at as high stocking densities as 80 - 100 kg/m³. High stocking densities also minimize the problems of early sexual maturity. Adequate current velocity also contribute to a high quality product.

A large scale production unit for cod juveniles has been established in Bessaker on the west coast north of Trondheim. The project is focusing on methods and equipment for the production of marine fish juveniles but also includes broodstock nutrition and evaluation of egg and larval quality. New self-cleaning tanks for juveniles have been designed. Water hydraulics and particle transport have been studied.

Large scale production of rotifers and Artemia has been successful at the pilot production plant for live feed in Bessaker. Use of microalgae together with rotifers during first feeding of marine larvae resulted in higher survival and growth of the fish. The algae serving as food for the rotifers in the fish tanks maintains the nutritional value of these zooplankton for the fish larvae. The lipid- and omega 3 polyunsaturated fatty acid contents of the rotifers can readily be manipulated at different phases of the production process. Long-term enrichment of the fatty acids during the cultivation phase is the best method for producing fairly lean rotifers with a high and stable content of omega 3 fatty acids.

New knowledge and efficient methods for enrichment of live feed have also contributed to the progress in halibut fry production and a protocol for intensive large scale production of yolk sac larvae in flow through silos followed by successful introduction to cultivated live feed is developed.

The future expansion in the aquaculture industry is predicted to include more exposed waters, where the carrying capacity is much higher. The Polar circle pilot farm concept includes flexible PEH cages connected to a feed and service platform. Both the cages and the platform are designed to withstand tougher environmental conditions than has been common in fish farming so far.

The research program on open production plants has also resulted in several computer approaches for analysing fish farming concepts.

- * NOTDRAG is a PC program for calculation of current forces on fish farms.
- * NOTSIM is a PC program calculation the total forces on fish nets exposed to current and waves. Using NOTSIM, is helpful when checking design criteria and choice of materials.
- * The methods are also integrated in SIFICA-F, an advanced finite element analysis program for all kinds of floating fish farms.

In the strategic program "Quality in production and product" we have focused on live transport, slaughtering, cooling, freezing and processing of salmon (from cage to market) and on rearing technology for halibut. Technology that can reduce the investment and operational cost in halibut production significantly are being tested. This is solutions that utilize volumes and areas much more efficiently and solutions that reduce the water demand.

UNIVERSITY OF TRONDHEIM

Brattøra Research Station, Department of Zoology - Aquaculture

N-Dragvoll

Salmonids

Atlantic salmon

Stress related to aquaculture practice (standardised as reduced water level) is dependent on the severity of the stressor. Repeated treatment for several times inhibited the humeral immune response to a T-dependent antigen, while a single treatment did not.

Arctic char

A recirculation system ("Biofish" production unit) has shown to be appropriate for landbased production of Arctic char. The biological filter which consists of nitrogen consuming bacterias tolerates the change from fresh water to sea water, allowing the fish to smoltify within the production unit. The use of malachite and formaline treatment does not affect the survival of the bacteria within the filter.

Stress related studies have demonstrated that a sudden decrease in temperature (from 9 to 3°C) led to a reduction of the humeral immune response to a T-dependent antigen, compared to fish kept at 9 or 3°C.

Marine species

Cod

Egg quality studies have concentrated on maternal effects on egg and larval viability. Egg groups from wild Arcto-Norwegian cod females in different stages of spawning were selected for further studies on egg quality and vitality of early larvae. The results so far showed that fertilization rate decreased with increasing stage of spawning, and that a high incidence of normally developing embryos was always correlated to a high fertilization rate. Larval vitality also seemed reduced in groups originating from cod females at the end of their spawning period. Studies on effects from over-ripening of eggs showed a reduced viability of eggs and larvae if eggs were fertilized later than 8 hours after ovulation.

Studies (in cooperation with the University of Bergen) on digestive mechanisms in cod larvae have focused upon biochemical and immunocytochemical characterisation of lipase secretion and distribution during larval development.

Halibut

Studies on weaning halibut fry (>0.5 g) from live feed organisms to various types of processed food were performed in cooperation with Institute of Marine Research. Histological studies of the digestive system revealed that water content and physical properties of the food had a profound effect on liver and gut epithelium appearance.

Turbot

Studies of larvae fed rotifers with different lipid enrichment, showed that the lipid composition clearly affected the absorption and intracellular digestive pattern in the intestine. Further morphological and physiological studies of lipid digestion in larvae are now carried out. Effects from weaning larvae on different dry diets are studied by morphological techniques.

General

The aquaculture research unit has been broadly extended with new experimental facilities for marine and salmonid species, a special laboratory for studies in aquatic sensory physiology, and a technical system which enables a fully computerised control of environmental parameters like feeding, light, and temperature regimes. Laboratories for techniques in radio-immuno assays, histology and morphology have been established.

POLAND

by

Wojciech Pelczarski

(Sea Fisheries Institute)

Department of Biology and Conservation of Fish Resources

Gdynia

The rearing of Atlantic salmon spawning stock (Dougava River origin) in sea cages was continued. The main purpose was to obtain eggs necessary for reintroduction of this species into Polish rivers. Experiments on fish behaviour, growth rate, mortality and fecundity were carried out.

The observations on effectiveness of delayed releasing of sea trout (*Salmo trutta*) smolts in Bay of Puck were conducted. A total of 2,470 smolts were tagged. At present, approximately 2% were returned.

As a part of reintroduction program of whitefish (*Coregonus lavaretus*), the experiments with feeding juvenile fish on several available artificial food were conducted. Total of 26,000 whitefish fingerlings were released into the Bay of Puck in June and July.

The seminar "Aquaculture in Poland" was organized by Sea Fisheries Institute. The main topics were: present status and potential development of mariculture in Polish EEZ.

SPAIN

by

Ignacio Arnal

(Instituto Espanol de Oceanografia)

The more relevant events of 1993 were two meetings: the World Aquaculture Congress, held in Torremolinos (Málaga) from may 26th to 28th and the 4th National Aquaculture Congress, held in Arosa Island (Pontevedra) from September 21st to 24th.

The World Aquaculture Congress was co-organized by an spanish aquaculture producers association (APROMAR), the EAS and the WAS. About 600 communications, posters or conferences were presented at the congress and about 130 (22 %) of them were presented by spanish scientists (a list with spanish papers presented at this congress will be included in the list of spanish publications of interest for aquaculture in 1993). Simultaneously to the scientific sessions, a trade exhibition took place showing products of 76 companies.

The National Aquaculture Congress is convened in Spain approximately every two years. The 4th convention took place in september 1993 an a total of 137 communications were presented, virtually all of them by spanish scientists. The thematic distribution of this papers was as follows: 31 % on fish culture, 21 % on mollusc culture, 4 % on crustacean culture, 31 % on pathology and 13 % on general and other aspects of aquaculture (a list with papers presented at this congress will be included in the list of spanish publication of interest on aquaculture in 1993).

Official data of mariculture production for 1992:

The production data for 1992 are:

ONGROWING PRODUCTION

<u>Species</u>	<u>Production mt</u>	<u>% Variation vs. 1991</u>
Fishes		
Turbot	1,622	+96.91
Seabass	143.1	+55.37
Seabream	1,676	+56.12
Mulletts	52.3	+93.99
Yellowtail	22	-29.03
Sole	13.2	+45.05
Atl. salmon	229	+41.41
TOTAL FISHES	4,384.6	+65.12
Molluscs		
Clams	3,531.3	- 9.97
Oysters	2,662.1	+18.47
Mussels	138,910	-28.24
Scallops (<i>Pecten</i>)	120	0
TOTAL MOLLUSCS	145,223.4	-27.93
Crustaceans		
Shrimps (<i>Penaeus</i>)	42.4	+ 32.5
Prawns	111.2	+270.7
TOTAL CRUSTACEANS	153.6	+147.7

HATCHERY PRODUCTION

<u>Species</u>	<u>Production (x 1,000)</u>
Fishes	
Turbot	1,012.3
Seabass	2,370
Seabream	15,660
Mulletts	358.3
Atl. salmon	489.6
TOTAL FISHES	19,890.2
Molluscs	
Clams	74,600
Oysters	16,100
TOTAL MOLLUSCS	90,700
Crustaceans	
Shrimps (<i>Penaeus</i>)	21,000
TOTAL CRUSTACEANS	21,000

SWEDEN

by

P-O Larsson

(Institute of Marine Research)

Lysekil

The development of Swedish oyster cultivation continued at Tjärnö Marine Biological Laboratory. In 1993, the activity was focused on hatching, on-growing and setting experiments in the new (built in 1992) hatchery for bivalves.

At the Institute of Marine Research, Lysekil, further research and development work was done with the hatching and rearing system for cod, plaice and turbot, intended to produce fish mainly for stock enhancement releases. Part of the work (regarding hatching cod) is in co-operation with the Ar laboratory (on Gotland) of Stockholm University. A few hundred 12-17cm cod of the Skagerrak coastal (fjord) cod were tagged and released in a fjord near Lysekil. About 300 cod fry, 12.5-18cm, of the Baltic eastern stock were marked with Carlin tags, transported to the coast of the Bothnian Sea (Subdivision 30) and released there. Another 300 cod, 8-12.5 cm, were marked with Alizarin red, kept in a fish farm at the coast of the Bothnian Sea for some time to study adaptation problems to the low salinity and then released.

Cod yolk-sac larvae from the Lysekil hatchery were released to "fjord-like" basins in the Baltic Main Basin (about 1.2 million) and the southern Bothnian Bay (about 600,000), part of them marked with Alizarin red. The predator situation in those areas are believed to be favourable for the cod larvae, giving a reasonable survival, compared to experiences from experiments in USA and Norway.

About 350 plaice, 15-25cm, produced in the Lysekil hatchery, were tagged (Floy T-bar tags) and released at the coast in Lysekil.

At the Ar laboratory, research continued on the basic mechanisms in cod (egg/larvae) adaptation to the troublesome environmental conditions in the Baltic, especially low salinity and oxygen content, making mariculture activities still more difficult with Baltic cod than with Atlantic cod.

The Salmon Research Institute, Älvkarleby, continued experiments with delayed release of salmon (post) smolts at the Baltic coast.

Results (recapture rates) continue to be high in several experiments, while some release sites (and short delay) have given low recapture rates, down to 10%. Apart from that, emphasis has been given to diseases, especially "M74" (see below), flexibacteriosis/myxobacteriosis and vaccination methods. Also, a number of genetic projects were started, regarding several aspects related to the aquaculture activities.

The Institute of Aquaculture in Umeå has concentrated its activities on freshwater species like Arctic char and noble crayfish but some basic research on Baltic salmon has bearing on the delayed release experiments with that species. Net-pen rearing of Arctic char at the coast of the Bothnian Sea and Bay has been considered but still not tested.

At the Department of Zoophysiology, University of Goteborg, research continued on nutrition and reproductive physiology in fish. The species in focus are salmonids and flatfishes, i.e., turbot and halibut. The work involves quantification of reproductive hormones, controlling the initiation and development of sexual maturation and ovulation. Further, characterization of requirements of essential fatty acids for female broodstock, egg and larvae. The transfer of fatty acids from the female to the eggs is of special interest.

The Department of Physiological Botany, Uppsala University, has continued R&D on cultivation of marine algae. A long standing research activity is aimed at understanding the molecular details of immune reactions and defence towards parasites in crustaceans but also other invertebrate animals. With the great commercial interest in shrimp culture, this type of research may lead to better conditions for culture of marine animals.

The production by commercial aquaculture enterprises in 1990-1992 is shown in the table below. Production of the most important species - rainbow trout - has decreased during the period.

Species	1990	1991	1992
Rainbow trout	7,100	5,800	5,100
Blue mussel	1,200	1,600	1,350
Atlantic salmon	600	270	390
Eel	180	160	200

Compensation releases of hatchery-reared salmon smolt were about 2.25 million to the Baltic (Subdivisions 25, 27, 29N, 30 and 31) and about 133,000 at the west coast (Division IIIa). About 560,000 sea trout smolt were released to the Baltic (same areas as salmon) and 21,000 at the west coast (the Skagerrak).

Diseases

The so called M74-disease, which is a disease acting at and killing off yolk-sac fry of Baltic salmon, has increased considerably during the last years. In 1992, 50-80% (variation between river stocks) of yolk-sac fry suffered from this abnormal mortality in the hatcheries for Baltic salmon. In 1993, a further increase with 10-15% units was recorded. The disease is believed to be connected to high load of contaminants in the parental fish and the Swedish Environmental Protection Agency, and the Salmon Research Institute appointed a group of experts who have evaluated available data and proposed a strategy for further research activities which will be given very high priority.

The National Veterinary Institute is, apart from routine work with diseases in fish farms, running three projects of interest to mariculture. With BKD in salmonids, new diagnostic methods are being developed and immunological reactions studied. Vibriovaccine for oral distribution to salmonids is under development as is a vaccine for the same disease in eel.

UNITED KINGDOM

Scotland

by

Alan Munro
(SOAFD Marine Laboratory - Aberdeen)

Annual salmon production was 48,691 tonnes in 1993, the greatest yet achieved by the Scottish salmon farming industry, and up from 36,101 tonnes in 1992. The increase was largely due to greatly increased survival and greater weight at harvest of the 1992 smolt year class component of the production and not to increased numbers of smolts which have remained fairly constant in the last three years. The 1991 smolt year class component of production was much the same as in previous years. This production was achieved with the same metric cage capacity as in previous years. Industry comment has indicated that a dramatic control of the bacterial disease furunculosis has been responsible both directly in giving greater survivals and indirectly in reducing stress, such that greater growth rates were achieved. As the 1993 smolt year class and the remainder of the 1992 class are surviving and growing well, the indications are for a bigger tonnage in 1994.

Furunculosis control has been achieved by a combination of techniques including site fallowing and year class separation of all sites in areas sharing the same waters, the use of smolts free of infection and the use of newly developed more potent vaccines. Skin lice control and pancreas disease remain as significant problems for the industry. Regulatory measures keep bacterial kidney disease at a very low level and similarly so for IPN virus in fresh water, although virus still is present in many sea cage populations. Research continues into finding alternative treatments for lice and pancreas disease.

Rainbow trout production at 4,023 tonnes, almost exclusively in fresh water, remained at a similar level to the previous year. Molluscan shellfish production showed some marginal decline from the previous year at 2.6 million Pacific oysters, 119,000 flat oysters, 176,000 and 788,000 king and queen scallops, respectively, and 700 tonnes of mussels.

UNITED STATES

by

Dr. John B. Pearce

(National Marine Fisheries Service)
National Oceanic and Atmospheric Administration

During the past decade, the development of mariculture in the United States has grown relatively slowly, at least in comparison with other nations, e.g. in northern Europe and Asia. In part, this has been due to the fragmentation of programs within various US government agencies, including the Department of Agriculture, the Department of Commerce, and the Department of Interior, as well as a plethora of state and local agencies. During the past reporting year, however, it has become apparent that stocks of "wild fish" necessary to the provision of seafoods to the US markets have declined markedly. In recent months, restrictions on fishing have been promulgated and discussed, resulting in a greatly increased interest in mariculture.

Such interests are reflected in reports developed for the US government. One, written by the Environment and Natural Resources Policy Division, Congressional Research Service, Library of Congress, provides considerable background and detail that will be important as new legislation is passed which is designed to enhance mariculture in the United States. Similar reports have been developed by other federal agencies, including the Congressional Joint Sub-Committee on Aquaculture. In a report entitled "Aquaculture in the United States: Status, Opportunities, and Recommendations" a report is delivered to the Federal Co-ordination Council on Science, Engineering and Technology, providing a series of recommendations that were important to modifying the National Aquaculture Act of 1980. The report focused, primarily, on private aquaculture. The National Marine Fisheries Service (NMFS) also has had a number of individuals working on task forces to define what the role of the NMFS should be in future mariculture.

Recently, the North Atlantic Salmon Conservation Organization (NASCO), North American Commission, developed a document having to do with protocols for the introduction and transfer of salmonids. Again, this report details major concerns having to do with the ecological effects of large-scale salmon, and other finfish production, as well as concerns about the introduction of "exotic" species and concomitant development of diseases.

While U.S. national interests are engaged in developing appropriate protocols and regulations to govern federal aspects of mariculture, many states have already made considerable progress. The State of Maine has formulated an aquaculture monitoring program, required to be followed by all finfish aquaculturalists. Local federal activities are, in some cases, predicated upon already existing state programs. Other states, including Massachusetts, are involved in drafting new legislation that would provide for the development of aquaculture in individual state or local waters. Generally, each state is creating in one form or another, aquaculture advisory boards, usually consisting of a commissioner of fisheries, as well as representatives from departments of environmental protection and fish & wildlife agencies, and representatives from local or national aquaculture associations, and inputs from major academic institutions within the political entity or region.

Even before new regulations have been implemented, however, during 1993, numerous individuals submitted proposals for pen-culture of finfish and shellfish. For instance, a proposal has been submitted to federal agencies to develop a "mixed-species pen-culture" of cod, haddock and fluke that would be carried out over some 200 acres of estuarine habitat at the eastern end of Long Island. Major universities held conferences this year on the rearing of cod, and other biologically difficult species. The Policy Center for Marine Biosciences and Technology, Marine Biological Laboratory at Woods Hole and the University of Massachusetts at Dartmouth sponsored an international workshop, "Aquaculture and the Marine Environment: The Shaping of Public Policy." The early draft proceedings stress the need for additional social and economic understanding, as well as new technology.

The NMFS was asked to assist the State of New York in developing information packages so as to provide guidance to applicants seeking state and federal authorization to propagate fish and shellfish in coastal waters.

Issues of concern still include water quality (how to prevent or reduce coastal and riverine pollution), disease, escape of exotic species, handling of live and processed product, and processing of mariculture production.

To address some of these concerns, marine scientists working at the University of Maine, Darling Marine Center, have spent several years investigating the effects of salmon cage-culture on surrounding ocean bottoms, and associated flora and fauna. Concentrating at net-pen sites at the Eastport and Swan Island, Maine areas, the research team looked at the interactions of biological, chemical and physical processes on the ocean bottom. Measuring the increase of and rate of organic (fecal) matter to sediments, and analyzing resulting data, their preliminary results show "limited negative effects associated with net-pen culture at sites studied."

Other researchers have proceeded to develop automated fish hatcheries systems of varying degrees of complexity. One of the great shortcomings for several marine teleosts has been to rear eggs to a state where the resulting larvae can sustain themselves until reaching juvenile feeding stages. One new system uses humidified air to culture eggs in eliminating the need for flow of large volumes of water or oxygenating the systems. It also seems to reduce disease and mortality and economies of scale.

Another factor behind the increasing interests in mariculture is the fact that many nations presently are exporting cultured seafoods to the US. China rears large volumes of scallops which are descendants of seedstock from Virginia and Cape Cod, furnished through NMFS to the Chinese some years ago. Many restaurants are becoming increasingly dependent on such materials and, therefore, there is growing concern that the U.S. should become involved with culturing of these shellfish in the northeastern United States. Also, the US is increasingly recognizing new markets abroad for materials cultured in the United States. For instance, the *Porphyria* seaweed is brought to the US as seedstock and cultured here to provide "nori" for export to other nations, as well as for internal consumption.

The increased level of activity has resulted in planning for a number of upcoming major meetings. The National Shellfisheries Association (NSA) is presently planning a major meeting, "Aquaculture '95," to be held in San Diego. The American Fisheries Society (AFS) is hosting a major meeting, "Uses and Effects of Cultured Fishes in Aquatic Ecosystems." These major national organizations, previously somewhat preoccupied with wild stocks of finfish and shellfish, are aggressively pursuing the new interest in marine mariculture.

Finally, these interests have resulted in a plethora of newly published volumes concerned with such esoteric subjects as the "Economics of Aquaculture" and the "CRC Handbook of Mariculture, Volume 1: Crustacean Aquaculture, 2nd edition."

The following table indicates the production of ocean cultured salmonids in just one state, Maine, in 1993:

**Maine 1993 Marine Finfish Aquaculture Harvest
(preliminary study)**

MONTH	ATLANTIC SALMON		TROUT	
	Pounds (whole)	\$	Pounds (whole)	\$
January	1,311,358	3,999,642	153,845	299,997
February	1,600,949	4,626,743	124,930	249,860
March	1,834,188	5,154,068	10,211	19,400
April	1,494,052	4,736,144	15,179	29,618
May	1,418,385	4,496,280	29,529	55,809
June	1,365,271	4,041,199	44,722	82,736
July	949,417	2,629,885	6,127	12,254
August	520,221	1,519,045	10,854	20,080
September	536,205	1,554,994	13,053	24,148
October	728,944	1,909,833	60,941	112,741
November	1,462,940	3,745,126	108,708	195,674
December	1,639,831	4,132,374	166,410	299,538
Preliminary	14,861,761	42,545,332	744,509	1,401,855

Total all 15,606,270 pounds (whole)
43,947,187 Farm Gate (averaged monthly value from pen)

A study by the University of Rhode Island and the University of Massachusetts estimated the total value of aquaculture products in the northeast United States to be \$146.4 million in 1992. The most valuable product was oysters at \$63.4 million, most from Connecticut waters. The Maine-based salmonid industry represented the second largest category at \$42.1 million. A copy of this report on aquaculture yields in the northwest Atlantic, off the northeast United States, can be obtained by writing the University of Rhode Island (URI) Co-operative Extension Service, Lippitt Hall, URI, Kingston, RI 02881, USA.