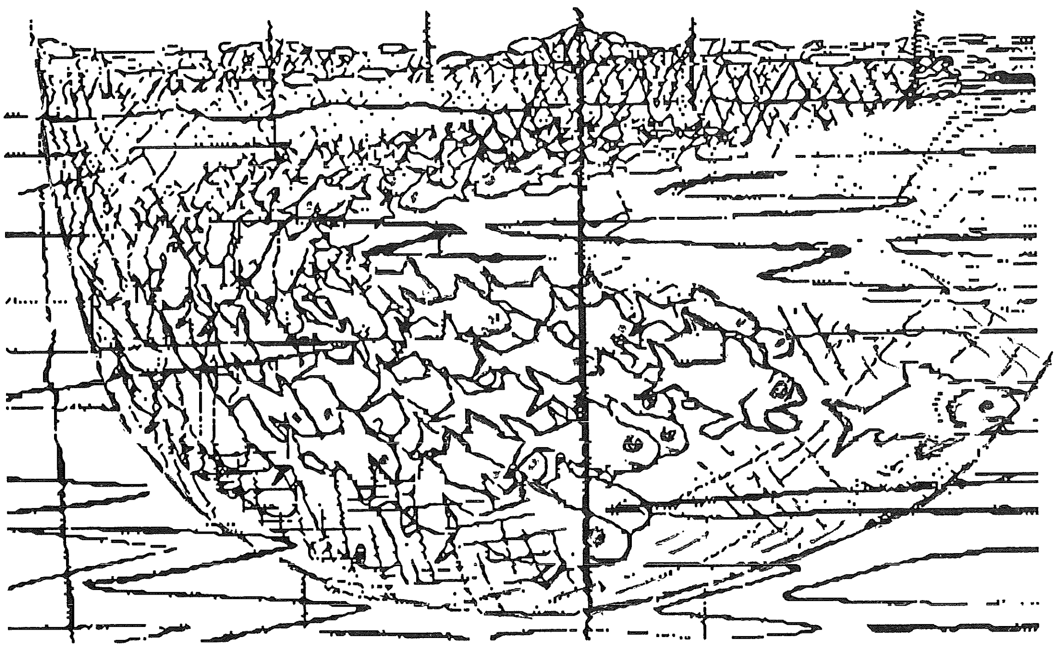
ICES International Council for the Exploration of the Sea

C.M. 1992/F: 14
Mariculture Committee
Theme Session 0
Ref.: Marine Environmental Quality Committee, ACMP

Report of the Working Group on Environmental Impacts of Mariculture

Institute for Marine Science
at the Christian-Albrechts-Universität Kiel
Kiel, Germany, April 22 to 24, 1992



Do You Know any more Shortcuts ?

Address
General Secretary
ICES
Palægade 2-4
DK 1261 Copenhagen K
Denmark

Table of Contents

Summary

The ICES Working Group on the Environmental Impact of Mariculture met for three days (22-24 April 1992) in Kiel, Federal Republic of Germany. National reports clearly indicated that in the two years since the last meeting, there had been a marked hesitation in the growth of mariculture in the ICES area (particularly in salmon cultivation). This had arisen from combinations of disease and husbandry problems, relatively low prices, and production levels possibly exceeding the size of the market. Several countries had maintained active research programmes to meet these new challenges, and the need to continue the assessment of the effects of mariculture on the environment. Farming strategies were changing to economic, social and environmental pressures, and it was considered that these new factors would have impact on the priorities for the working group in the future. Accounts of current production trends, research activities and publications were prepared. The following further tasks were addressed:

1. A report was prepared on the environmental impact of mariculture in the Baltic Sea, drawing heavily on recent Finnish and Danish studies.
2. A report was prepared on the current status of macro-algal cultivation in the ICES area, together with a discussion of possible directions of development, and possible interactions with the environment.
3. Drafts were prepared of Technical Reports on "Chemicals in Mariculture" and "Management of the Environmental Impact of Mariculture", for presentation at the 1992 Statutory meeting. The latter document included an extended section on the role of mathematical modelling in site selection and impact assessment.

Other, less complet, discussions were held on current monitoring programmes related to mariculture. Note was taken of the general public perception of the effects of mariculture, the interactions between farm escapes and wild salmon stocks, and the suggested link between mariculture and the marked recent decline in sea trout stocks in some areas.
The Working Group recommended that its Terms of Reference should be amended before a further meeting in 1994 to reflect changing perspectives of the industry, and a short paper outlining the reasons for the proposed changes will be prepared by the Chairman.

Résumé

Le Groupe de Travail du CIEM concernant l'"Impact de 'Aquaculture sur l'Environnement s'est réuni pendant trois jours (du 22 au 24 avril 1992 à Kiel, R.F.A. Les rapports nationaux montrent clairement que durant les deux années écoulécs depuis la dernière rúnion du Groupe de Travail, l'augmentation des productions aquacoles dans la région couverte par le CIEM a margué un palier (en particulier la production de saumon). Ce fait est du conjointement à des problèmes pathologiwues et zootechniques, au prix relativement bas et à des niveaux de production dépassant probablement la capacité du marché. Pleusieurs pays ont maintenu une activité de recherche pour résoudre ces nouveaux défits et répondre au besoin toujours présent de prédire l'effet de l'aquaculture sur l'environnement. Les stratégies d'élevage ont changé en fonction des pressions économiques, sociales et environnementales, et il a été considéré que ces nouveaux facteurs devraient avoir une action sur les priorités du Groupe de Travail à l'avenir. Des comptes-rendus traitant des tendances de production, des activités de recherche et des publications ont été préparés. Les tâches suivantes ont été en autres effectuées:

1) un rapport a été préparé concernant l'impact de l'aquaculture dans la Mer Baltique, s'appuyant principalement sur des études finlandaises et danoises récentes;
2) un rsapport a été préparé sur l'état actuel de la culture d'algues macrophytes dans la région coucerte par le CIEM, en même temps qu'une approche du développement possible et des i nteractions potentielles sur l'environnement;
3) des ébauches des deux rapports techniques sur "Les Produits Chimiques en Aquaculture" et "Gestion de l'Impact de l'Aquaculture sur l'Environnement", qui seront présentées à la réunion pleinière de 1992. Ce dernier document contient un paragraphe plus développé sur l 'intérêt de la modélisation mathématique dans la sélection des sites et la prédiction de ll'impact.

D'autres discussions, moins avancées, ont concerné les programmes de suivi du milieu en relation avec l'aquaculture. La perception par le grand public des effts de l'aquaculture, les interactions entre les animaux échappés de fermes et les stocks sauvages ainsi que le lien apparent entre l'aquaculture et le déclin marqué des stocks sauvages de truites communes dans certaines zones ont été relevés.

Le Groupe de Travail recommande que ses termes de références soient amendés avant la prochaine réunion de 1994, afin de refléter les perspectives d'évolution des producteurs, et un court document mettant en évidence les raisons ayant conduit à cette proposition de modifications sera établi par le Chairman.

1. Introduction

The 1992 meeting of the ICES Working Group on "Environmental Impact of Mariculture" was held in Kiel, Germany, April 23 to 25, at and with the assistance of the Institut für Meereskunde of the University of Kiel.

1.1 Participation

There were 14 participants representing 11 member countries present:

Rosenthal, Harald (Chairman)	Federal Republic of Germany
Davies, Ian (Rapporteur)	Scotland
Black, Edward, E. (Rapporteur)	Canada
Alderman, David (Rapporteur)	United Kingdom
Anders, G.	Federal Republic of Germany
Aure, Jan	Norway
Böttger, U.	Federal Republic of Germany
Dijkema, Renger	The Netherlands
Dosdat, Anton	France
Doyle, Jaqueline	Ireland
Ervik, Arne	Norway
Hoffmann, Erik	Denmark
Mäkinen, Timo	Finland
Newell, C.	United States of America
Spencer, Brian	England and Wales
Stewart, James E.	Canada

A list of the Working Group membership is attached to this document as Appendix 2.

1.2 Terms of Reference

The Parent Committee supported the recommendations of the last Working Group meeting held in 1990. However, additional TORs have been suggested during the intersessional period and put forward during the Statutory Meeting of ICES in September 1991. These TORs were mainly in response to requests received from HELCOM and ACMP. The following terms of reference had been listed and presented through the Parent Committee to the Council:

(1) to finalize a report, containing as detailed data as possible, on the environmental impact of mariculture in the Baltic Sea area, including amounts and impacts of nutrients and organic matter, and report to the 1992 ACMP meeting,

(2) to update the catalogue of ongoing research programmes on environmental issues related to mariculture, and identify research priorities;

(3) to consider the advances made in commercial culture of macro-algae in ICES member Countries and assess the need for consideration of environmental issues in this sector of mariculture;

(4) to finalize the preparation of the technical reports on "Chemicals in Mariculture" and "Management of the Environmental Impcat of Mariculture and report to the 1992 ACMP meeting;

(5) prepare a status report on ongoing monitoring and modelling programmes related to the assessment of the impact of mariculture and report to the 1992 ACMP meeting.

These tasks were adopted at the Statutory Meeting (C.Res. 1991/2:43). Although the Terms contain additional tasks than previously proposed (mainly put forward by ACMP), the period allowed for the WG meeting was not increased. The WG noted the overwhelming work load associated with the preparation of the two Technical Reports and suggests that in the future the time allocation should be adjusted if additional tasks have to be addressed. It was also noted that shifting from an annual to a bi-annual meeting at a time when the mariculture industry is undergoing major changes in member countries has placed additional workload on the WG to update environmental information arising from these changes in activity. It is for these reasons that not all the TORs have been addressed in a satisfactory manner.

2. Comments on National Reports

2.1 Production trends

In contrast to earlier reporting periods, trends in freshwater aquaculture and mariculture production between 1989 and 1991 varied substantially between member countries. While in some countries salmon production continued to increase (e.g. Scotland, Canada), levelled in others (e.g. Sweden, Finland) and declined noticable in a few countries (e.g. Germany). These changes had arisen from combinations of disease and husbandry problems, relatively low prices, and production levels possibly exceeding the size of the market. Table1 illustrates these production trends for several ICES member countries.

Vaccination of fish has increased in several countries. The use of chemicals, however, does not show a consistent trend and is difficult to evaluate because of incomplete reporting. For some countries recent estimates are available (see country reports, Appendix 4).

More detailed data can be found in the national reports attached to this document as Appendix 4.

2.2 Research Activities

Several countries had maintained active research programmes to meet the new challenges, and the need to continue the assessment of the effects of mariculture. Research activities focussed more intensively on environmental and disease issues.

Table 1: Total Mariculture Production Trends (finfish and shellfish) in selected ICES Member Countries (1991 figures are largely estimates)

Year	1987	1988	1989	1990	1991
Canada		16,335	19,340		37,872
Denmark	3,500	5,500	6,759	6,000	6,300
Finland	8,784	12,875	13,459	13,193	13,000
France					198,490
Germany	?	30,595	19,120		
Ireland	14,786	20,881			
Norway	55,944	89,874	119,278	161,675	160,655
Portugal	11,500				
Spain					
Sweden	5,614	5,272	4,838	4,128	4,000
Scotland	13,430	18,592	29,711	32,350	40,593

The number of studies dealing with problems on the interactions between cultured and wild fish are increasing. Increasing concern is also placed on the fate of antimicrobials in the environment, especially on the development of resistance in bacterial populations. Studies on sediment-water interactions at salmon farm sites continue in several member countries and progress has been reported in modelling environmental conditions (e.g. nutrient flux, hydrodynamic modelling, etc) in areas with growing aquaculture activities, including both finfish and shellfish culture. Because of the changes in production strategies in some countries (fallow periods, site rotation; see also chapter 4.2 on "Trends in the development of farming systems in ICES countries"), the research need to determine recovery time at abandoned cage culture site is growing. Sofar, only very few research projects address this problem. Details on completed and ongoing research programmes can be taken from the project listings in Appendix 1.

3. Progress in preparing Technical Reports

3.1 Chemicals used in Mariculture

The initial structure of the report has largely been maintained as already outlined in the 1990 Working Group Report (CM 1990/F:12) The report will include
- an introduction which provides also definitions of terms,
- a section on veterinary medicines licensing controls,
- a short chapter on risks to operators,
- a section on the routes by which medication may impact the environment
- a note on drug resistance,
- a substantial chapter on "the Chemicals", divided in sections dealing with (a) non-therapeutants such as disinfectants and chemicals associated with constructional materials, and (b) therapeutic chemicals (e.g. antimicrobials).

Data sheets for the most important chemicals are also included, followed by a short listing of less frequently used substances. It is intended to also include a Cross Reference List of names (trade names, chemical name) in an Appendix.

Extended drafting sessions during the Working Group meeting have resulted in a final draft of the general chapters of the report. which will be further edited by correspondance.

Material has been added to the data sheets which contain information on
- the scientific name and trade name of the chemical,
- the chemical formula,
- CAS (Chemical Abstract) numbers,
- Synonyms,
- mode of treatment/use
- withdrawal period,
- information on environmental issues (when available) including toxicity, environmental persistence and degradation products, bioaccumulation, and stimulation of antibiotic resistance.
- literature citations pertaining to environmental and toxicity issues.

It is also intended to include a table indicating the various chemicals and their trade names used in various Member countries.

In attempting to collate information on the quantities of therapeutants and other chemicals used in mariculture, it became apparent to the Working Group that the quality of the information varied greatly between countries. In some cases, for example Norway, the centralised system of supply of therapeutants allows the collection of detailed and accurate information. In other countries, supply and delivery of chemicals is much more diffuse, and comparable information is therefore not available. Commercial confidentiality may also limit access to information from pharmaceutical companies. In the light of these difficulties, and the misleadingly incomplete data that could be collated, the tabulated data should be treated with considerable precautions and should not be presented in the Technical Report on "Chemicals used in Mariculture".

3.2 Management of the Environmental Impact of Mariculture

Substantial work on the report was completed during the Working Group meeting in Kiel. Chapters on site and project description, and monitoring were largely completed. Significant progress was also made on the chapters on the potential scope of impact and numerical prediction of impacts.

Rapid changes in our knowledge base since 1990 have required considerable redrafting of the original work especially in the areas of numerical prediction, and site and project description. These changes have made it imperative to continue to work on this report intersessionally in an effort to have a draft version ready for consideration by the Parent Committee at the Statutory Meeting of ICES in September 1992.

4. Specific Subjects

4.1 Statement on Public Perceptions

Over the past decade, discussions and reporting suggest that there is a widely held public view that mariculture activities have caused considerable harm and that future continued and expanded activities have the potential to add materially to these effects. Beginning in 1986, the Study Group on the Environmental Impacts of Mariculture and its successor Working Group have carried out a detailed examination of the impacts of mariculture. In the course of delineating the dimensions and nature of the various effects, the Working Group has concluded that the effects have not been as great as either they or the public perceived or anticipated. Instead, the

Working Group determined that the problems which did exist were amenable to correction and would yield to improved practices, notably through improved site selection and advances in husbandry. Thus, it is clear that mariculture conducted properly fits comfortably within the time honoured ICES maxim enunciated by Went (1972) referring to exploitation of the sea, i.e. "turning its resources to the best advantage in the present without prejudice to the future" or in today's crisper, but less precise terminology, "sustainable development."

4. 2 Trends in the development of farming systems in ICES countries

Due to economic, social, and environmental pressures, the WG noted changes in farming strategies were occurring in the industries. For example, cage management systems are evolving in ways that may have consequences on how the WG assesses priorities in the future. The changes noted refer to both sea and land based systems.

In Norway, a practice of clustering cage sites is developing and is encouraged by the authorities. Each cluster of sites keeps one year class at a time and fallows between year class introductions. A separation distance is applied (5 km) between clusters but not between sites within clusters. Each cluster then tries to apply antibiotic and sea lice treatments at the same time to increase the effectiveness of the treatments, and reduce the need for repeated treatments. The use of the same local stock of fish for smolts is also promoted. There has also been a move toward lower stocking densities (now about 25Kg/cu. m).

In Ireland there is a practice of fallow and harrow on shallow sites and where offshore technologies are involved there has been a shift to part time use of offshore technologies such that fish reared in cages are moved in the summer to take advantage of less extreme water temperatures and inshore in the winter to avoid the effects of storms.

Over the past year or so there have also been a number of developments in Scotland, mainly arising from the need to control problems of disease. There is a general tendancy towards lower stocking densities of salmon in cages - densities are now normally not above 15 kg/m^3. It is more common now for sites to be confined to single year classes of fish, which therefore requires a larger number of sites to be available. Larger companies may commonly have sufficient sites to undertake the rotations of stock, but a number of smaller companies have had to apply for additional sites to achieve saparation of year classes. A further advantage of single year class sites is that a site will naturally have a fallow period between the harvesting of one stock and the introduction of the next. This allows some degree of recovery of impacted sediment on the sea bed, and also may work to break the cycle of infection by diseases or parasites.

In the salmon farming industry, the trend to movement of culture offshore has slowed down and in many instances reversed. Storm damages have been more extreme than expected. The use of larger cages has often meant that each cage contains more fish, and when these cages fail structurally greater numbers of fish escape. The consequence is greater financial loss and a greater number of cultured salmon joining the natural salmon runs in rivers.

Use of the larger cages has often meant greater operational difficulties. Antibiotic or anti-parisite dip treatments are much more difficult to execute and control of dose is less precise. Further, greater quantities of chemicals are released into the environment during these treatments. The technology of offshore farming seems to have advanced mainly in terms of structural improvements but the need for parallel adjustment of operational strategies has not yet fully been recognised. Improvements are needed in management and husbandry issues, such as fish health, observation of the stock, effects of wave action on the stock, and stress reduction.

Offshore culture may also be more expensive to operate. A ship culture system for salmon cultivation was purchased in France and installed about 6 km from shore. The cost of production (COP) in the tanker is approx. 7-8 $/kg compared to 4 $/kg in nearshore cages. Studies concluded that large offshore plants for seabass culture in cages were not feasible.

Landbased technologies continue to be a small part of the global salmon culture industry. Both Norway and Scotland have onshore farms which continue to operate under the same management they have had since the mid 80's. In 1991, 828 tonnes of salmon were produced in land-based sea water tanks in Scotland. This is about 2% of the total Scottish production of salmon. In many jurisdictions (Iceland, Denmark, Ireland and Canada) it has been more common for land based farms to fail financially. The opinion expressed is that the failures are usually due to a lack of appreciation by engineers of the biological requirements of the cultivated species, leading to inappropriate application of technical expertise. It was acknowledged that such systems may have a slightly higher, but perhaps acceptable, COP. (The example given was of a French turbot farm which appears to be operating well but the COP in the land based sysem is 3-4 FF per Kg. more than cage culture.)

In France, 4 land-based farms are raising turbot which do not appear to do as well in cage culture. Three of these farms use underground marine wells as their water source. Germany uses land based marine farms for turbot culture. Norway and Scotland are also considering the use of landbased systems for halibut.

Regulatory trends with regard to effluent standards in EEC countries will continue to become more stringent and it is likely that due to these requirements land based systems will be more attractive as a marine fish farm technology.

The comment was made that the type of administration directing fish farms is changing. Accountants have had their try and proven that they make poor fish farm bussiness men. Biologist are being relied upon more in the development of farms.

4. 3 Sea trout *(Salmo trutta)*

4.3.1 Ireland

The gradual decline of sea trout catches in Ireland followed by the collapse in 1989 on the West Coast of Ireland was reported. This has occurred in areas of intensive salmon culture. In 1991 factors characterising the problem include premature return of smolts, severe infestation by sea lice and premature returns of severely emaciated fish. While is has not been possible to demonstrate a significant correlation between the production of lice from salmon farms and subsequent infestation of seatrout in specific bays, nevertheless there is a publicly stated belief by environmentalists and fishery owners that salmon farms are responsible and the industry is coming under pressure to relocate away from sea trout fisheries and to modify management practices to take account of seas trout migrations.

4.3.2 United Kingdom

Sea trout catches in Scotland have been unusually low in recent years in several areas, which can be partly explained by a reduced netting effort but rod and line catches have also been low with no evidence of reduced effort. The rod and line catches in 1990 and 1991 declined to levels unprecedented in the last 40 years. No evidence has been obtained so far to implicate salmon farms in the sea trout decline. Some areas of the country affected by marked declines have no salmon farms, e.g. Ayrshire, Solway Firth and Moray Firth. However, the possibility of localised effects superimposed on a general downturn in stocks cannot be discounted. A range of pathologies observed is being studied.

Sea trout stocks in Wales have also failed and there are no fish farms in this area.

4.3.3 Norway

The Norwegians have not noticed any problem in their sea trout stocks. However, their fjords have strong freshwater lenses which would discourage the development of sea lice infection in sea trout. Sea lice however appear to be a siting problem: There are farms which have never had sea lice and others, no matter how good their husbandry practices, cannot rid themselves of the problem.

4.3.4 Denmark

The Danish researchers report that their sea trout stocks have never been in better condition.

4.3.5 Conclusion

The WG observes that increased sea lice infestations of farmed and wild fish may be a response to a strong anomaly in sea surface temperatures in recent years and that sea lice may be responding to poor condition of the sea trout rather than causing it.

4.4 Commercial Culture of Macroalgae in ICES Countries

4.4.1 Current state of commercial development

4.4.1.1 Canada

Since 1968 there has been a concerted research and development effort in eastern Canada to reach a economically successful on land tank culture of *Chondrus crispus*. The work began with laboratory scale experiments in small tanks by A. Neish and associates of the Atlantic Regional Laboratory of the National Research Council of Canada. This technology was then available to two companies interested in commercial scale culture. Over the next 22 years both basic and applied research on biological and engineering aspects of macrophyte culture ended with scaling up of production facilities to commercial size tanks, 2000 m2 at a 3.4 hectare facility in Southwestern Nova Scotia. In 1987 this operation produced 100 dry tonnes of lambda carrageenin producing *Chondrus crispus* and by 1990 approximately 500 tonnes dry weight met production targets. This operation ceased culturing *Chondrus crispus* in the fall of 1990 when the single purchaser for the cultured lambda carrageenin product in the United States ceased to require the raw material, for unknown reasons.

4.4.1.2 United States

In 1991, Nori spores were imported from Japan into Cobscook Bay, Maine as a candidate for aquaculture. The project, supported by the Maine Aquaculture Innovation Center, will resume in 1992 with field grow-out trials toward commercialization in future years. Salmon net pen operators in the region are considering Nori as polyculture at their sites.

4.4.1.3 United Kingdom

a) Scotland

There is no active macroalgal cultivation in Scotland. There is a small kelp processing industry on the west coast which relies for raw material on seaweed gathered from beaches after storms, etc. There have been some surveys of the potential for kelp harvesting, and some engineering consideration of the equipment that would be necessary to gather kelp sub-tidally, with a view to periodic cropping of natural kelp beds.

There is a very small industry based upon the gathering of intertidal species of algae, mainly for the specialist food (sea vegetable) or health products market. Although activity is on a small scale, there are at least 10 sea vegetable species, and other salad products already identified. The approach to be taken to harvesting, so as to produce a good product and protect the stock for future harvest, varies between species, but has largely been established. Cultivation, in one form or another, has attractions, in that a supply of the desired species will be found at a prepared location, and action can be taken to minimise adverse impacts from such factors as mechanical damage by storms, inclusion of sand, contamination by epibionts (either algae or animals), and would also allow control of the handling, processing, and drying, which are critical for product quality.

b) Isle of Man

Techniques have been developed for the cultivation of large brown algae (kelps) on ropes. Spores are seeded onto ropes in tanks, and once the young plants are established the ropes are transferred to the sea for on-growing for 5-7 months.

In addition, four species of algae for human consumption are under small-scale production. It is intended that dried product will be sold through specialist food outlets. Development plans of the company concerned include the expansion of production into Orkney and western Ireland.

4.4.1.4 France

The main target of French cultivation of macroalgae for human consumption is *Undaria pinnatifida* (the Japanese wakame). The alga was unintentionally introduced during the 1970s with oyster spat. The research programme on this species, led by IFREMER, began in 1983, and was directed towards definition of the potential for cultivation on the French coast, evaluation of the impact on autochthonous algae, and the establishment of an artificial production cycle based on "free living" techniques.

The results of the investigations showed that it is possible to cultivate 2 or 3 crops per year of the alga over the entire French coast, including in the Mediterranean . The quality of the alga is good, even superior to Japanese products. The propagation of the alga is possible in the environment, but very slow. *Laminaria digitata* and *Sacchoriza polyschides* are strong competitors, and Undaria needs special conditions to reproduce successfully. Propagation by multiplication of gametophytes (free living) is readily adapted to commercial conditions, and economically valuable.

The first farm began in 1986, and two farms are now (1992) operating. The overall production in 1991 was about 100 tonnes.

Research on land-based plants for *Chondrus crispus* production has led to the construction of a pilot scale farm using an underground source of nutrient-rich salt water. It is predicted that the annual production will be 40 tonnes by 1997.

4.4.2 Approaches to Cultivation, and Associated Environmental Issues

4.4.2.1 Non-endemic species

The culturing of non-endemic species brings the risks of escapement into waste water effluent and then on into the ecosystem. The impact of new species on existing marine plant communities is then an unknown. An additional concern arises when an animal species at any life stage accompanies the exotic seaweed species upon introduction. Introductions will not be discussed here, however, since they are covered adequately in the Annual Reports from the ICES Working Group on Introduction and Transfers of Marine Organisms (1981-1991).

4.4.2.2 Endemic Species

The various approaches that have been considered in the exploitation of endemic species may be classified as follows:

a) Wild gathering. This represents current practice, with no intervention in natural processes to improve the product.

b) Ranching. This category enters the field of cutting wild crops in such a way as to maintain or encourage future production. It includes such processes as leaving part of the plant in place to allow further growth, or cutting to allow future recolonisation.

c) Conventional farming. This involves cultivation of algae on some substrate (e.g. ropes) fixed to a floating, fixed or shore-based structure. The substrate needs to be "seeded" with early life stages in some way, either by allowing natural settlement of spores etc., or artificially introducing small plants which then grow on the substrate.

d) Successional gardening. This involves the creation, usually by mechanical or chemical means, of a space in an inter-tidal area at such a time of year as to encourage the preferential colonisation of the cleared area by species of commercial interest. It therefore has some parallels with the deployment of clean ropes sub-tidally for the collection of spores etc. of particular species, but is based on the natural substrate, and currently is confined to intertidal areas.

e) Ranching polyculture. In this process, the herbivorous predators of the desired algal species are controlled in some way, to encourage growth of the algae. Ideally, the predators (e.g. echnoderms) would themselves be of value, and could be captured and sold rather than eliminated in some other way.

f) Other possible situations for the cultivation of algae include polyculture of algae with fish, worms, etc., either separately using the same water supply, or together in tanks or runways. The algae benefit from the nutrients released by the co-cultured species. Similarly, nutrient-rich effluent streams from other processes could be used to stimulate algal growth, and reduce the input of nutrients to the wider environment.

4.4.2.3 Associated Environmental Issues

Very few field studies have been carried out to explore the environmental effects from the exploitation of macroalgal species. There is, however some information on to effects of the accidentally introduced, but non-commercial Japweed, *Sargassum muticum*. The range of potential effects is wide and dependent upon the approach taken to culture and exploitation.

These arise from:

i) The origin of the plants to be cultivated. Would the collection of juvenile stages have any effect on natural communities? The possible introduction of non-endemic species, and the possible effects of escapees of non-endemic, or "improved" stocks on the endemic flora.

ii) The physical effects on the coastal environment of the introduction of large structures supporting cultivated stocks.

iii) The depletion of nutrients in the sea water that would normally have been used for the support of endemic macro and micro algae.

iv) The possible effect of the increased production of exudates.

v) The effect on the coastal ecosystems of an increase in the surface area of algae. This may enhance populations of epibionts (algae, or animals).

vi) The effect of more interventional farming practices, such as might be needed under d) and e) above. These might include the use of physical or chemical means to prepare the ground for cultivation, or to control predators, or pests such as bacteria or fungi.

vii) The effect on wildlife of disturbance of possibly remote areas.

viii) The effect on the local environment, and possibly on other activites such as recreation and tourism, of the presence and visual impact of structures.

ix) Where tanks or ponds are used for more intensive culture greater use of fertilizers and therapeutants may occur, thus producing enriched effluents which must be dealt with in relation to the specific nutrients released in the effluents.

4.5 Modelling

The Working Group considered both the carrying capacity models (principally for shellfish) and those for determinating the holding and assimilative capacity of the environment (principallly for finfish). Models for both open coastal embayments and fjordic inlets were considered, with hydrodynamic models and a variety of sub-models used to determine the fluxes of nutrients, oxygen, parasiticides and particulate matter.

The effects on primary and secondary production are starting to be modelled, but further work is needed in these areas.

A draft of chapter 5, Modelling, in the Working Group Technical Report "Management of the environmental impacts of mariculture" is included as Appendix 1.

5. Environmental load from Mariculture in the Baltic Sea

In response to the request from the Mariculture Committee, the WG presents the following information on the impact of marine aquaculture in the Baltic Sea. The Baltic Sea area is defined here as all areas with ICES code numbers from 21 to 31.

5.1 Production trends

Mariculture production in countries bordering to the Baltic Sea has been growing rapidly in Finland and Denmark. However, a turning point was experienced in all countries in 1989 when, for the first time over fifteen years, the production figures started to decline. Danish production has stabilized over the last three years, while German marine production has decreased. Little information is available from Poland, Latvia, Estonia or Lithuania, but some data indicates that the marine fish production in these countries has been minimal, and is today almost zero. The overall production figures for marine aquaculture for the Baltic area for the last five years are given in the table 1 below :

Table 1 Fish production (gross production) in tonnes per year in marine and brackish waters of the Baltic Sea

	Gross production (tonnes/year)				
Country	**1987**	**1988**	**1989**	**1990**	**1991***
1.Denmark	3,500	5,500	6,700	6,500	6,300
2.Finland	8,784	12,875	13,459	13,181	13,000
3.Federal Republic of Germany	35	40	25	-	-
4.German Demo.Republic	789	814	570	-	-
5.Germany after 1989	-	-	-	524	247
6.Sweden	3,270	3,281	4,838	4,128	4,000
Total	16,376	19,635	25,592	24,311	23,524

* estimated

5.2 Nutrient loads

The most reliable estimates available on nutrient inputs from fish farming are from Finland and Denmark. For Denmark, the inputs are based on knowledge of the production, the feed conversion coefficient, and the nitrogen (N) and phosphorus (P) content of the dry pellets. The Finnish data are based on mandatory tests paid for by farmers and on balance calculations made by the authorities. The total loads are estimated, as for Denmark, from data on production, the average feed coefficient and the average nutrient content of the feeds used.

The table below shows estimates of N and P loadings to the Baltic from marine fish farming activities. In the calculations it is assumed that, on average100 tonnes of produced fish release 7 tonnes of N and 1.1 tonnes of P.

These values for N and P release rates depend on the feed conversion coefficient and the amounts of N and P in fish and feed. The values of *F, N-feed and P-feed* vary from country to country. In the table below some observed values are given.

Feed conversion coefficient (F):	1.3 – 1.7%
Amount of N in feed:	6.6 – 6.7%
Amount of P in feed:	0.9 – 1.0 %
Amount of N in fish:	2.7 – 3.0 %
Amount of P in fish:	0.35 – 0.45 %

Table 2 Estimates of N and P loads (tonnes/year) to the Baltic Sea from marine fish farming

Country	1987		1988		1989		1990		1991*	
	N	P	N	P	N	P	N	P	N	P
1.Denmark	248	35	323	42	306	41	294	37	267	32
2.Finland	615	97	901	142	942	148	923	145	910	143
3.Fed. Rep. of Germany	2.5	0.4	2.8	0.4	1.8	0.3	-	-	-	-
4.Dem.Rep. of Germany	55	9	57	9	40	6	-	-	-	-
5.FRG after 1989	-	-	-	-	-	-	35	5	16	3
6.Sweden	230	36	230	36	339	53	289	45	280	4
Total	1151	177	1514	229	1629	248	1541	232	1473	222

*estimated

The calculations above are made on the *gross production* tonnages, which are the only data available, and therefore all values in the table above are maximum values. Calculations carried out on the *net production* will give lower loadings with N and P.

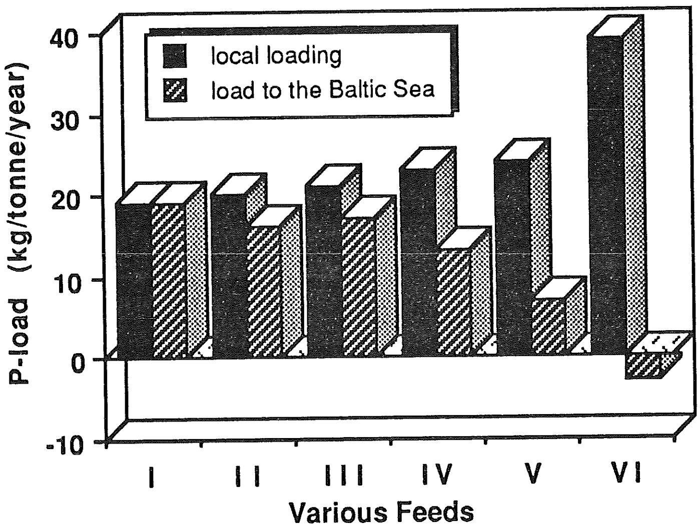
5.3 Chemical usage

Only a few figures are available on the amount of therapeutants used in marine fish farming in the Baltic. Data from Denmark for the year 1989 indicate a total use of chemotherapeutics of about one tonne. This equals a consumption rate of 180 g chemotherapeutics per tonne fish produced. The amount used in Sweden in the same year is estimated to be about 384 kg, giving a value of 44 g per tonne produced. The amount used in 1991 was 425 kg. The amount of antibiotics used in Finnish Aquaculture is estimated to be around one tonne or about 40 g per tonne produced. In Norway the use of antimicrobials was around 200 g per tonne produced. The most common substances used were oxytetracycline, oxolinic acid and sulfametoprime.

5.4 Opportunities to manage the impact of mariculture in the Baltic

Recent studies and practice show that the amounts of nutrients released to the environment do not necessarily have to increase at the same rate as production. With a lower feed conversion coefficient and reduced N and P content in the dry pellets, the amount of N and P released to the environment will be reduced. In Finland the total phosphorus load from fish farming has increased by only 23 % while fish production more than tripled. In Denmark, the production has increased four times since 1984 and in the same period the total nitrogen loading increased only by a factor of two (Christensen og Horsted 1991).

In a project sponsored by the Nordic Council of Ministries in 1987-90 a method was developed to estimate the effect of marine fish farms (Mäkinen 1991). Through careful site selection wins the methods developed it is possible to avoid any local effects due to nutrient loading.



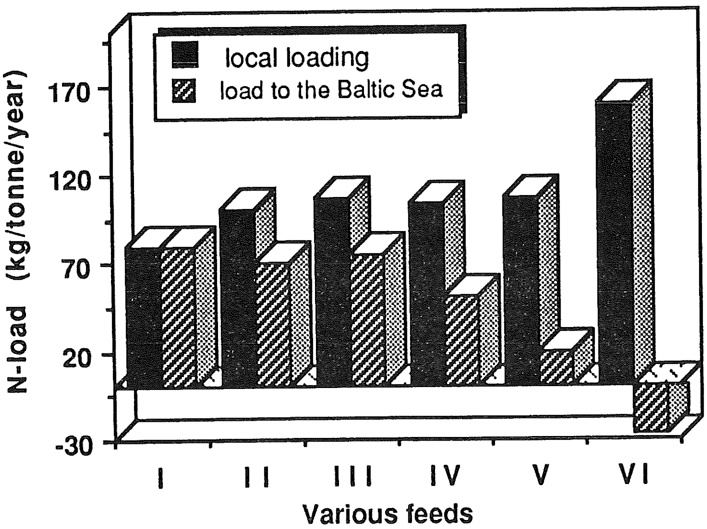


Figure 1. Phosphorus and nitrogen loading with different feeds. For the loading figures to the Baltic Sea nutrients from Baltic herring are reduced. I = commercial dry feed, II - V = different types of semimoist feed, herring as raw material, VI = gutted herring (Ruohonen & Vielma 1991).

In Finland, a new project was started in 1990 promoting the use of herring as raw material for the fishfeed used in Baltic aquaculture. The aim was to reduce the nutrient loading coming to the Baltic Sea from outside the region. As, there is no fish meal manufactering based on the Baltic herring fishery, the use of herring is based on direct use of fresh fish. For this reason , as a first step, the effect of the herring content in the feed on the growth, and the consequent nutrient load in fish farming was studied.

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

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

6. Genetic interactions of cultured and wild fish

The Working Group acknowledges that this subject has been addressed by the Genetics Working Group and the WG on Introductions and Transfers of non-indigenous marine organism (in conjunction with NASCO). Recently, however, an increasing number of publications do appear to which the WG draws attention. The most recent publications are included in the literature list. The WG discussed the subject briefly (especially in conjunction with the paper by Hindar, 1991) and felt that the present elaborations within the scientific community point to the need define more clearly the level of risk of significant negative interactions occurring between wild and cultured salmon stocks. In order to define this level of risk it is necessary to meet the conditions required for significant negative interaction. These have two components:

(I) the probability that the fish will co-occur on the same redd and
(II) the requirement that the fish are biologically predisposed to negative interactions.

In discussing these components, the following aspects were mentioned and may need further consideration:

I. Conditions required for the fish to enter the same stream are that:
(a) the cultured fish are not sterile; (b) the cultured fish home to the area of the river estuary; (c) the cultured fish are capable of migrating up the stream to the redds.

II. Conditions required for the occurrence of biological negative interactions include:
(a) the wild population must be a stable locally adapted stock, e.g.
- not an enhanced local stock
- a stable genetic pool with an effective breeding size well over 1000 individuals,
- must not have suffered from recent founder effects,
- must not suffer from high level of gene flow from external populations
- should reside in a stable, undisturbed habitat

(b) the cultured stock must be a potentially viable cross with an distinct genome, e.g.
- form an externally adapted stock,
- not spatially isolated
- not behaviourally isolated,
- capable of producing viable hybrids
- the number of cultured salmon participating in reproduction with the wild stock must be significant relative to the size of the wild stock

The Working Group suggests that these aspects are considered by the Parent Committee for further comment and identification of research priorities.

7. Recommendations

The Working Group discussed its original terms of reference adopted by the Council in 1986 and 1987 (ICES CRes 1986/2:36; C.Res. 1987/2:40) and recommends that the scope of the group be broadened to encompass the interaction of mariculture with other human activities. To reflect this it is recommended that the Working Group be renamed.

(1)The Working Group is to be named the

"Working Group on the Environmental Interactions of Mariculture".

2. It is recommended that the new and extended **Terms of Reference** of the Working Group should be:

(a) to delineate the dimension of the problem,

(b) recommend a course of action which will lead to the development of criteria and to a standard system of monitoring and reporting,

(c) To delineate of the scope and nature of environmental interactions between mariculture and other users of coastal marine resources.

(d) To provide advice on approaches notably in areas such as improved site selection and through advances in husbandry to minimise conflicts between mariculture and other coastal zone activities.

(e) To review and evaluate national monitoring programmes and prepared regular status reports on the impacts of mariculture in the ICES Region.

3. The Working Group recommends that it meet for 5 days in March 1994 in Dublin (Ireland) to undertake the following tasks:

(a) to update the catalogue of ongoing research programmes on environmental interaction issues related to mariculture;

(b) to examine biological interactions between types of mariculture, and with other coastal zone usage;

(c) to identify major long-term research priorities, particularly in the subject area of resolving conflicts in the use of the marine environment;

(d) to review to work intersessionally to assemble and compile information on ongoing monitoring programmes in each country related to the assessment of the impacts and interactions of mariculture, with the intention of presenting a report for publication in the Cooperative Research Report series;

(e) to evaluate the potential environmental effects of new culture systems in ICES member states ;

(f) to assemble and provide comment within the Working Group Report on the evidence for the interactions of complexed and/or particle-bound contaminants (e.g. antibiotics, antifoulants, parasiticides, etc) from fish farms with marine flora and fauna, and the significance of these interactions within marine ecosystems;

(g) to prepare guidelines on the ecotoxicological information necessary to permit assessment of the relative environmental impacts of therapeutants.

8. Literature

Alsted, N. 1991. Studies on the reduction of discharges from fish farmes by modification of the diet. pp. 77-89. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-29).

Anderson, J.S:, Anderson, D.M., Lall, S.P., McNiven, M. 1991. Nutritional and chemical characteristics of Canadian fish meal. Aquacult. Assoc. Can. 8th Ann. Meet., St. Andrews, N.B., June 10-13, 1991, p 44. (Abstract).

Anonymous, 1991a. Animaux, pathologie et environnement. Office National des Epizooties, pp 547-884.

Anonymous, 1991b. Salmon genetics research program annual Report 1990/1991. Atlantic Salmon Federation, St. Andrews, N.B., 38 pp.

Anonymous, 1991c. Atlantic Salmon Workshop. Proceedings from a workshop held on October 17, 1989, St. Andrews, N.B., SGRP Rep. Ser. Tech. Rep 131: 57pp.

Aoki, T. 1989. Ecology of antibiotic-resistant determinants of R plasmids from fish pathogenic bacteria. In: T. Hattori, Y. Ishida , Y. Maruyama, R.Y Morita and A. Uchida (eds) Recent Advances in Microbial Ecology, p.571-576. Japanese Scientific Societies Press, Tokyo.

Aure, J., Stigebrandt, A. 1989a. Fiskeoppdrett og fjorder. En konsekvensanalyse av miljøbelastning for 30 fjorder i Møre og Romsdal. Rapport FO 8803 Havforshninginst. 1989.

Aure, J., Stigebrandt, A. 1989b. On the influence of topographic factors upon the oxygen consumption rate in sill basins of fjords. Estuarine, Coastal and Shelf Science 28: 59-69.

Aure, J., Stigebrandt, A. 1990. Quantitative estimates of eutrophication effects of fish farming on fjords. Aquaculture 90: 135-156.

Austin, B., Al-Zahrani, A.M.M. 1988. The effect of antimicrobial compounds on the gastrointestinal microflora of rainbow trout, *Salmo gairdneri* Richardson. J. Fish Biol. 33:1-14.

Austin, A.P., Boettger, B. 1992. *Furcellaria lumbricalis* (Huds) Lam - a case study of a fragile resource. In: I. Akatsuka (Ed.). "The biology of economic seaweeds. SPB, The Hague.

Bailly, D. 1991. Aspects économiques et sociaux de la gestation des bassins conchylicoles: le cas de Marennes-Oléron. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 234-241.

Bannister, R.C.A., Pawson, M.G. 1991. A perspective on the management of enhanced fish and shellfish stocks in the territorial seas of England and Wales. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 242-246.

Barton, B.A., Iwama, G.K. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the responses and effects of corticosteroids. Ann. Rev. Fish Diseases 1: 3-26.

Baum, N., Concklin, D.E., Castell, J.D., Boston, L.D. 1991. Nutritionally induced molt death syndrome in aquatic crustaceans. III. The effect of varying levels of calcium in the reference diet. BML 61S for juvenile *Homarus americanus.* The Crustacean Nutrition Newsletter 7(1): 115-118.

Bergeron, P. 1991. Évolution temporelle du recruitement de *(Mytilus edulis)* à Carleton et effet de la prolifération du naissain sur le redement commercial des boudins. MAPAQ, Direction de la recherche scientifique et technique. Cahier d'information 127: 49 pp.

Bergheim, A., Aabel, J.P., Seymour, E.A. 1991. Past and present approaches to aquaculture waste management in norwegian net pen culture operations. pp. 117-136. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Bernard, T. 1991. P.E.I. Mussel Monitoring Program, 1991 Report. Dept. Fish. Aquacult., P.E.I., Canada Tech. Rep. 202: 18 pp.

Bettig, R.B. 1991. Conflicts between salmon mariculture and capture fisheries. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 213-217.

Bjørdal, A. 1990. Sea lice infestation on farmed salmon, possible use of cleaner-fish as an alternative method for de-lousing. Can Tech. Rep. Fish. Aquat. Sci. 1751:85-89.

Björklund, H. 1989. Analysis of ocilinic acid in fish by high-performance liquid chromatography. J. Chromatogr. 530: 75-82.

Björklund, H. 1991. Oxytetracycline and oxolinic acid as antibacterials in aquaculture - analysis, pharmacokinetics and environmental impacts. Acta Academiae Aboensis, Ser. B., Vol. 51, Nr. 6. Åbo Akademis Förlag. 47 pp.

Björklund, H., Bondestam, J., Bylund, G. 1990. Residues of Oxytetracycline in Wild Fish and Sediments from Fish Farms. Aquaculture, 86: 359-367.

Björklund, H., Bylund, G. 1989. Rapid HPLC-analysis of oxolinic acid in fish tissues. p. 150. In "Diseases of Fish and Shellfish" IV EAFP International Conference, Santiago de Compostela, Spain, September, 24-26, 1989. (Abstract).

Björklund, H., Bylund, G. 1990. Temperature related absorption and excretion of oxytetracycline in rainbow trout *(Salmo gairdneri* R.). Aquaculture 84: 363-372.

Black, E.A:, Whyte, J.N.C., Bagshaw, J.W:, Ginther, N.G. 1991. The effects of *Heterosigma akashiwo* on juvenile *Oncorhynchus tshawytscha* and its implications for fish culture. J. Appl. Ichthyol. 7: 168-175.

Blancheton, S.P., Coves, D. 1992. Closed systems in intensive marine finfish hatcheries. State of the art and future prospects. Colloque Bordeaux Aquaculture 1992 (in pres).

Bouchez, P., Azzi, D. 1991. Biotechnology: Use of hydrolytic enzymes in preprocessing of feedstuffs. pp. 91-101. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Bruno, D.W., Munro, A.L.S., McHenery J.G. 1990. The potential of carbaryl as a treatment for sea lice infestations of farmed Atlantic salmon, *Salmo salar,* L. J. Appl. Ichthyol. 6:124-127.

Brylinsky, M. 1992. An analysis of data on mussel performance. Acadia Centre for Estuarine Research Publication No. 19: 1-102.

Brylinsky, M., Sephton, T.W. 1991. Development of a computer simulation model of a cultured blue mussel *(Mytilus edulis)* population. Can. Tech. Rep. Fish. Aquat. Sci. 1805: VIII+81 pp.

Caine, G.D., Castledine, A.J. 1991. Environmental regulations framed to minimize waste in aquaculture effluents in British Columbia. pp. 263-269. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Carlsson, S.-A. 1991. Fish feed and environmental impact: A review of the swedish developement during the last decade. pp. 111-114. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceeding so f the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Christensen, K.D., Hørsted, J. 1991. Miljøbelastning fra havbrug og saltvandsbrug (Marine fish farming and the impact on the environment). (Danish Inst. Fish. and Mar. Research.) DFH Rapport No. 397: 1–90.

Christensen, K.D., Hoffmann, E., Hørsted, J. 1991. Impact of marine aquaculture on the wild fish population. In: *Aquaculture an the environment. Special Publication no. 14, European Aquaculture Society.*

Corley-Smith, G.E., Tsumura, K., Siemens, M., Godin, T., Donaldson, E.M. 1991. Preservation of wild stocks by triploid sterilisation of introduced brook trout. NATO Advanced Study Institute: Genetic conservation of salmonid fishes. Moscow, Idaho and Pullman, WA, June 24-July 5, 1991 (Poster No. 4).

Davies, I.M:, Turrel, W.R., Wells, D.E. 1991. The observation and simulation of the dispersion of DDVO in Loch Ailort - August 1990. Scottish Fisheries Working Paper No 15/90.

Donaldson, E.M. 1991a. Application of biotechnology to biological problems associated with offshore mariculture. National Sci. Foundation Workshop on Engineering Research Needs for Offshore Mariculture Systems. East-West Center, Univ. Hawaii, Sept 26-28., 1991, 23 pp.

Donaldson, E:M. 1991b. Containment of genetically altered fish (Abstract). NATO Advanced Study Institute: Genetic conservation of salmonid fishes. Moscow, Idaho and Pullman, WA, June 24-July 5, 1991.

Dosdat, A. 1992. L'excretion chez les poissons tèleosteèn. I. L'agote la Pisciculture Française (in press).

Dushkina, L.A. 1991. Relationships between mariculture and natural poulations in the seas of the USSR (Abstract).In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 68.

Edwards, P., Pullin, R.S.V. (Eds.). 1990. Wastewater-Fed Aquaculture. Proceedings of the International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India, 6-9 December, 1988. Asian Institute of Technology and ICLARM, pp XXIX, 1-296. (ICLARM Contribution No 684) (ISBN 974-8201-082)

Erard-LeDenn, E., Ryckaert, M. 1990. Trout mortality associated with *Distephanus speculum* in Dararneneg (France). 4em Conf. Int. "Phytoplankton toxique", Lund (Sweden) in "Toxic marine Phytoplankton" (E.Graneci, Ed.), Elsevier Sci. Publl., 132-136.

Ervik, A., Farresveit, E., Jørstad, K.E., Erison, A.G., Lerøy, R., Aure, J. 1990. Genetikk og Miljø-optimal matfiskproduksjon. Sluttrapport NFFR. Senter for Havbruk. Havforskningsinstitutet.

Eskelinen, E., Mäkinen, T., Vielma, J. 1991. Fish farming and water pollution control in Finland - future challenges. EAS Special Publication No. 14, p. 93-94.

Faure, A., Quillet, E., Chevassus, B., Krieg, F., Harache, Y. 1991. The potential of brown trout *(Salmo trutta)* for aquaculture. Proc. Study Course Aquac. Arctic Char and Brown trout, Reykjavik, Aug. 16-18., 1991.

Folke, C., Kautsky, N. 1991. Ecological, economics principles for aquaculture development. pp. 207.-222 In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Fréchette, M., Booth, D.A. 1991. Variability and transport of organic seston near a mussel aquaculture site. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 24-32.

Friars, G.W:, Benfey, T.J: 1991. Tripoidy and sex reversal in relation to selection in the Salmon Genetics Research Program, p. 81-97. In: V.A. Pepper (Ed.). Proc. Atlantic Canada Workshop on Methods for the Production of Non-maturing salmonids: February 19-21, 1991, Dartmouth, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci 1789.

Gaudreault, J., Myrand, B. 1991. Transferts de stocks à différents sites des Iles-de-laMadeleine. Bull. Assoc. Aquic. Can. 91(2): 17-21.

Gaudreault, J., Myrand, B. 1991b. Transferts de stocks à différents sites des Iles-de-laMadeleine. p. 117-128. In: CAPQ (Ed). Atelier de travail sur la mortalité estivale des moules aux Iles-de-la-Madeleine (Québec, 23-25 avril, 1991), 196 pp.

GESAMP (IMO/FAO/Unesco/WHO/IAEA/UN/UNEP 1991. Reducing Environmental Impacts of Coastal Aquaculture. *Rep. Stud. GESAMP*, (47):35p.

Gowen, R.J., Weston, D.P., Ervik, A. 1991. Aquaculture and the benthic environment: A review. pp. 187-205. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Grenz, C., Masse, H. 1991. An estimate of the energy budget between cultivated biomass and the environment around a mussel-park in the northwest Mediterranean Sea.In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 63-67.

Håkanson, L., Wallin, M. 1991. Use of ecometric analysis to establish load diagrams for nutrients in coastal areas. Nord 1991: 22, 9-23.

Hansen, J.R., Larsen, J.L., Hansen, D. 1989. Vaccination trials with a new Danish ERM vaccine. p. 136. In "Diseases of Fish and Shellfish" IV EAFP International Conference, Santiago de Compostela, Spain, September, 24-26, 1989. (Abstract).

Hansen, P.K., Pittman, K., Ervik, A. 1991. Organic waste from marine fish farms. Effects on the seabed. Nordic 1991:22, 105-119.

Hedrick, R.P., Groff, J.M. Foley, P. McDowell, T., 1988. Oral administration of Fumagillin DCH protects chinook salmon *Oncorhynchus tshawytscha* from experimentally-induced proliferative kidney disease. Dis. aquat. Org., 4:165-168

Henriksson, S.-H. 1991. Effects of fish farming on natural Baltic fish communities. Nord 1991: 22, 85-104.

Héral, M. 1991. Approches de la capacité trophique des écosystèmes conchylicoles: synthèse bibliographique. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 48-62.

Higuera, I.C., Brown, J.H.,Jauncey, K. 1990. Leaching of oxytetracycline from pelleted shrimp feeds. Abstract from a lecture held at the Conference 26 to 29 June "Bacterial Diseases of Fish", University of Stirling, Scotland.

Hoffmann, E., Horsted, J. 1991: Havbrug og det marine miljo (Marine fish farming and impact on the environment) FISK OG HAV 1991 pp. 39 - 46.

Hoffmann, E., Persson, R., Gaard,E., Jonsson, G.S. 1991. Havbrug og miljø. (Marine fish farming and the environment. In Scandinavian languages with summaries and some papers in English. Nord 1991: 10

Hole, R., Øines, S. 1991. Can fish silage be used as a nutritional solution to reduce aquaculture waste when considering the slaughtering quality of fish. pp. 103-109. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Horsberg, T.E., Høy, T. 1989. Diflubenzuron orally against salmon lice - clinical effect and pharmacokinetic properties. p 119. In "Diseases of Fish and Shellfish" IV EAFP International Conference, Santiago de Compostela, Spain, September, 24-26, 1989. (Abstract).

Husevåg, B., Lunestad, B.T., Johannessen, P.J., Enger, Ø. Samuelsen, O.B. 1991. Simultanous occurrence of *Vibrio salmonicida* and antibiotic resistant bacteria in sediments at abandoned aquaculture sites. J. Fish Disease 14: 631-640.

Iwama, G.K., 1991. Interactions between aquaculture and the environment. Crit. Rev. Environ. Control 21: 177-216.

Jacobsen, P., Berglind, L. 1988. Persistence of oxytetracycline in sediments from fish farms. Aquaculture 70:365-370.

Jensen, J.B. 1991. Environmental regulation of fresh water fish farms in Denmark. pp. 251-262. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Johnsen, F., Wandsvik, A. 1991. The impact of high energy diets on pollution control in the fish farming industry. pp. 51-63. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Johnsson, J.I., Abrahams, M.V. 1991. Interbreeding with domestic strain increases foraging under threat of predation in juvenile steelhead trout

(Oncorhynchus mykiss): an experimental study. Can. J. Fish. Aquat. Schi. 48: 243-247.

Juell, J.E. 1991/92. Hydroacoustic detection of foodwaste - a method to estimate food intake of fish populations in sea cages. Aquacultural Engineering (in press).

Juell, J.E. 1990. Hydroacoustic detection of food waste- a method to estimate maximum food intake of fish populations in sea cages. ICES, C.M. 1990/F:7 (Mariculture Committee).

Kallio-Nyberg, I., Pruuki. V. 1990. Diversity in the salmon stock *(Salmo salar* L.) of the Tornionjoki River and rehibilation strategy. Finnish Fish. Res. 11, p. 45-52.

Karttunen, E., Ritola, O., Matinvesi, J. 1991. Hydral conditions and the feed spill distribution in the land-base raceways. In: EAS Special Publications No. 14, Aquaculture and Environment, Bredene.

Kase, K., Baily, D. 1991. Introduction aux problèmes socio-économiques de la mariculture extensive: expériences japonaises. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 226-232.

Kaushik, S.J., Cowey, C.B. 1991. Dietary factors affecting nitrogen excretion by fish. pp. 3-19. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Keränen, A.-L., Koski, P., Kulonen, K., Ek-Kommonen, C., Neuvonen, E. 1991. Occurrence of infectious fish diseases in fish farms in northern Finland. Acta Vet. Scand. (in press).

Kiaerskou, J. 1991. Production and economics of "Low Pollution Diets" for the aquaculture industry. pp. 65-76. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Kils. U., Ruohonen, K., Mäkinen T. 1991. Daily feed intake estimates for rainbow trout (*Oncorhynchus mykiss* Walbaum) evaluated with SONAR and X-ray techniques at commercial net cage farms. ICES C.M. 1991/F:3.

Klepper, O. 1989. A model of carbon in relation to macrobenthic food supply in the Oosterschelde estuary (S.W. Netherlands). Thesis, Agricultural University, Wageningen.

Klose, S.R. 1991. Current Ontario ministry of the environment approach to the control of environmental impacts from the qauaculture industry. pp. 271-274. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Langvad, F. 1989. Some new fungicides and their possible use in treating fungal fish diseases. p. 115. In "Diseases of Fish and Shellfish" IV EAFP International Conference, Santiago de Compostela, Spain, September, 24-26, 1989. (Abstract).

Larkin, P.A. 1991. Mariculture and fisheries: future prospects and partnerships. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 6-14.

Laurén-Määttä, C., Granlid, M., Henriksson, S.-H., Koivisto, V. 1991. Effects of fish farming on the macrobenthos of different bottom types. Nord 1991: 22, 57-83.

Le Bris, H., Pouliquen, H., Buchet, V., Debernardi, J.M. 1992. Variations des concentrations on oxytetracycline de l'eau de mer et des sédiments marine au cours et après traitement therapeutique d'elevages piscicoles. Colloque Bordeaux Aquaculture 1992.

Lee, E. G.-H., Evelyn, T.P.T. 1991. Broodstock erythromycin injection prevents *Renibacterium* vertical transmission. FHS/Am. Fish. Soc. Newsletter 19(4): 1.

Lockwood, S.J. (Editor) 1991. The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 1-248.

Lunestad, B.T., Gøksøyr, J. 1990. Reduction in the antibacterial effect of oxytetracycline in sea water by complex formation with magnesium and calcium. Diseases aquat. Organisms 9: 67-72.

Mackie, A.M., Johnstone, A.D.F. 1991. Carotenoid pigments in saithe, *Pollachius virens* (L.) from the vicinity of salmon farm cages. Scottish Fisheries Working Paper No. 22/91.

Mäkinen, T. (ed.), 1991. Marine Aquaculture and Environment. Nord 1991: 22, 1-126 pp.

Mäkinen, T., Ruohonen, K., Suuronen, P. 1992. Ruokintatavan ja tekniikan vaikutus kuormitukseen verkkoallasviljelyssä. Suomen kalankasvattaja 2/92 (in press).

Malik, Sz., Jeney, Z. 1989. Toxicity of malachite green-formaline mixture for one summer old carp *(Cyprinus carpio* L.). p, 193. In "Diseases of Fish and Shellfish" IV EAFP International Conference, Santiago de Compostela, Spain, September, 24-26, 1989. (Abstract).

Mauvais, J.L. 1991. The role of hydrodynamics in environmental studies. The case of tidal area. Oceanologica Acta 11: 29-46.

McHenery, J., 1990. Comparative toxicity of DDVP to marine invertebrates. Scottish Fisheries Working Paper No 7/90.

McHenery, J.,1990. Toxicity of dichlorvos to stage 4 Homarus gammarus larvae. Scottish Fisheries Working Paper No. 8/90.

McHenery, J.,1990. Effects of repeated short exposures to dichlorvos on lobster larvae. Scottish Fisheries Working Paper No 9/90.

McHenery, J.,1990. Lobster and mussel deployments in sea lochs to monitor fish farms. Scottish Fisheries Working Paper No. 10/90.

McHenery, J., Forsyth, S.W. 1991. Effects of dichlorvos exposure on acetylcholinesterase levels of lobster larvae and mussels deployed in the vicinity of a salmon farm. Scottish Fisheries Working Paper No 8/91.

McHenery, J., Linley-Adams, G.E., Moore, D:C. 1991. Effects of diclorvos exposure on the acetyllcholinesterase levels of the gills of the mussel, *Mytilus edulis* L., experimental and field studies. Scottish Fisheries Working Paper No 16/91.

McHenery, J., Saward, D., Seaton, D.D. 1990. Toxicity of dichlorvos to larvae of the common lobster *(Homarus gammarus* L.) and herring *(Clupea harengus* L.). Scottish Fisheries Working Paper No 7/90.

McLean, E. 1991. Alternative technologies for the delivery of bioactive materials to aquacultured teleosts. p. 25. In: E.M. Donaldson, Y. Inui (Eds.). Final REport of the Canada/JApan Aquaculture, Biotechnology Workshop, Vancouver, BC, March 18-20, 1991.

McLean, E., Teskeredzic, E., Donaldson, E:M., Teskeredzic, Z., Pitt, C., Souza, L.M. 1991. The growth response of coho salmon *Oncorhynchus kisutch* (Walbaum), to bioengineered porcine somatotropin, delivered by a prolonged release, injectable pellet. (ABstract). Int. Congr. on Res. for Aquaculture: fundamental and applied aspects. Antibes, Juan-Les-Pins, France, Oct. 6-10, 1991. p. 3.12, p. 156.

Menesguen, A., Monbet, Y. 1990. Numerical modelling of the role of residual currents, N- and P-loading in eutrophication of a shallow bay (St.Briens, France). Proc. 5th Int. Congr. Ecol. (28-31,Aug 1990) Yokohama, Japan.

Merceron, M. 1991. Water quality and summer mortalities of sea farmed Atlantic Salmon *(Salmo salar)*. A site comparison. ICES, C.M. F:33, 9 pp.

Merceron, M., Dosdat, A., Kempf, M. 1992. Interactions entre environnement et pisciculture marine intensive. La Problematique Française, Colloque Bordeaux Aquaculture 1992.

Murai, T. 1991. Various measures undertaken in Japan to prevent enviromental pollution by fish farming. pp. 241-249. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Murison, D.J., Moore, D.C., Davies, J.M., Gamble, J.C. 1990. Survey of invertebrate communities in the vicinity of salmon farm cages in Scottish west coast se lochs. Scottish Fisheries Working Paper No. 11/90.

Neori, A., Krom, M.D. 1991. Nitrogen and phosphorus budgets in an intensive marine fish pond: The importance of microplancton. pp. 223-230. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Nilakul, C.; Tuntimavanich, S., Sukroongreuung, S. 1984. Susceptibility of *Aeromonas* spp. isolated from infected fish, fish ponds and humans to various antibiotics. J. Thai. Vet. Med. Assoc. 35(1): 39-45. (IN Thai).

O'Grady, P., Moloney, M., Smith, P.R., 1988. Bath administration of the quinoline antibiotic flumequine to brown trout *Salmo trutta* and Atlantic salmon *S. salar.* Dis. aquat. Org., 4:27-33.

Olivier, G., Claveau, R., O'Halloran, J., Fildes, J., Zwicker, B., Cornick, J. 1991. Multiple antibiotic resistance profiles of *Aeromonas salmonicida* in two hatcheries experiencing recurrent furunculosis outbreaks. (Abstract). Aquaculture Canada '91, St. Andrews, NB., June 6-11, 1991.

Parks, L.M., Parks, J.W., Solar, I.I:, Donaldson, E.M. 1991. Sterilization and feminization of brook trout *(Salvelinus fontinalis)* by androgen and estrogen treatment. Aquaculture Canada'91, St. Andrews, NB.,June 6-11, 1991 (Poster, p 53.).

Perez, R., Kaas,R., Deffemd,A., Le Bayon,N. 1991. Production de gametophytes en "free living" par la culture de l'algue brune Laminaria japonica. Aquarevue 37.

Perez, R., Kaas, R., Barbaroux, O., Arbault, S., Le Bayon, N., Moigne, J.Y. 1991. *Undaria,* une japonaise en Bretagne: nouvelle technique de culture d'une algue alimentarie. Equinoxe 36: 19-30.

Persson, G. 1991. Eutrophication resulting from salmonid fish culture in fresh and salt waters: Scandinavian Experiances. pp. 163-185. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Poonsuk, K., Saitanu, K. 1980. In-vitro susceptibility of *Aeromonas hydrophila* strains isolated from catfish *(Clarias batrachus)* to fourteen antimicrobial agents. J. Aquat. Anim. Dis. 3(1): 9-14. (In Thai).

Poonsuk, K., Saitanu, K., Wongsawang, S. 1984. The minimal inhibition concentration of chlortetracycline to *Aeromonas hydrophila.* Thai J. Vet. Med. 14(4): 285-296. (In Thai).

Poonsuk, K., Jerngklinchan, J., Jantanalanjakorn, K. 1985a. The MIC and MBC of neomycin and streptomycin to *Aeromonas hydrophila*. J. Aqwuat. Anim. Dis. 8(3): 145-157. (In Thai).

Poonsuk, K., Jerngklinchan, J., Jantanalanjakorn, K. 1985b. The minimal inhibition concentration of four antibiotics to Aeromonas hydrophila. J. Aquat. Anim. Dis. 8(1): 27-38. (In Thai).

Prein, M. 1990. Wastewater-fed Aquaculture in Germany. pp. 13-48. In: Edwards, P., Pullin, R.S.V. (Eds.). "Wastewater-Fed Aquaculture." Proceedings of the

International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India, 6-9 December, 1988. Asian Institute of Technology and ICLARM, pp XXIX, 1-296. (ICLARM Contribution No 684) (ISBN 974-8201-082)

Prins, T.C., Smaal, A.C. 1990. Benthic pelagic coupling: the release of inorganic nutrients by an intertidal bed of Mytilus edulis. In: M. Barnes & R.N. Gibson (Eds.). "Trophic relationships in the marine environment". Aberdeen University Press, pp. 89-103.

Råbergh, C.M.I., Bylund, G., Eriksson, J.E. 1991. Histopathological effects of microsystin -LR, a cyclic peptide toxine from the cyanobacterium (blue-green alga) Microcystis aeruginosa, on Common carp *(Cyprinus carpio* L.). Aquatic toxicology 20: 131-146.

Raillart, O., Deslous-Packi, J.M., Héral, M., Razet, D. 1991. Modelisation du compartement de nutrition et de croissance de l'huitre japonaise *Crassostrea gigas* du bassin de Marennes-Oleron (France). Can. J. Fish. Aquat. Sci. (Submitted).

Raillart,O., Razet,D., Pron, S., Héral, M. 1991. Modelisation de l'ecosystème du bassin de Marennes Oléron. Rapport IFREMER DRV/91-07: 107 pp.

Ravail, B., Héral, M., Maestrini, S.Y., Robert, J.M. 1990. Incidena du débit de la Charente sur la capacité biotique du bassin ostreicole de Marennes Oleron. J. Rech. Ocean. (in press).

Rintamäki, P., Valtonen, E.T. 1991. *Aeromonas salmonicida* in Finland: pathological problems associated with atypical and typical strains. Journal of Fish Diseases 14: 323-331.

Robertson, N.A:, Murison, D.J., Moore, D.C., McHenery, J.G. 1991. Studies on invertebrate assemblages associated with seaweeds on roxky shores adjacent to salmon farm cages in Scottish sea lochs. Scottish Fisheries Working Paper No 17/91.

Rönnberg, O., Ådjers, K., Ruokolahti, C., Bondestam, M. 1992. Effect of fish farming on growth, epiphytes and nutrient content of Fucus vesiculosus L. in the Åland Archipelago, northern Baltic Sea. Aquatic Botany 42: 109-120.

Ruohonen, K., Mäkinen, T. 1991. Potential ways to diminish the environmental impact of mariculture on the Baltic Sea. Finnish Fish. Res. 12: 91-100.

Ruohonen, K., Mäkinen, T. 1992. Ravinteiden kierrätys vähentäisi kalanviljeyn ympäristöhaittoja. (Recirculation of nutrients will diminish the environmental impact of mariculture.) Suomen Kalastuslehti 99: 14-18. [in Finnish]

Ruohonen, K., Vielma, J. 1991. Silakan käyttö kirjolohen rehuna. Vuosiraportti 1991. (Baltic herring used as food for rainbow trout. Annual report 1991.) Mimeograph. 32 pp. [in Finnish]

Ruohonen, K., Vielma, J. 1992a. Silakka rehuista apu kalastajille ja kalanviljelijöille. (Baltic herring based feeds benefit both fishermen and fish farmers.) Suomen Kalankasvattaja 1/92: 34-37. [in Finnish]

Ruohonen, K., Vielma, J. 1992b. Silakan käyttö kirjolohen rehuna puhdistaa Itämerta. (Use of Baltic herring as food for rainbow trout removes nutrients from the Baltic Sea.) Suomen Kalastuslehti 99: 19-21. [in Finnish]

Salomon, J.C., Breton, M. 1988. Ferne aquacole en Baie de Marlaine. Etude de comant et de dispersion. Role de la méterologie. Rapp. IFREMER/DERO-EL. 40 pp.

Salomon, J.C., Breton, M. 1990. Etude comantologique et de capacité dispersive de la Grande Rade de Chubang. Rapport IFREMER/DERO. El/08, 87 pp.

Salomon, J.C:, Pommepuy, M. 1990. Mathematical model of bacterial contamination of the Marlaix estuary (France). Water Res. 24: 983-994.

Salonius, K., Iwama, G.K. 1991. The effect of stress on the immune function of wild and hatchery coho salmon juveniles. Proc. 8th Ann. Meeting, June 10-13, 1991, St. Andrews, NB, Canada. Bull Aquacult. Assoc. Cann. 91(3): 47-49.

Samuelsen, O.B. 1989. Degradation of oxytetracycline in seawater at two different temperatures and light intensities and the persistence of oxytetracycline in the sediment from a fish farm. Aquaculture 83: 7-16.

Samuelsen, O.B: 1990a. High-performance liqhid chromatographic determination of furazolidone in Atlantic salmon *(Salmo salar)* tissue. J. Chromatography 528: 595-600.

Samuelsen, O.B: 1990b. A simple and rapid method for the determination of flumequine and oxolinic acid in salmon (*Salmo salar)* plasma by high-performance liquid chromatography and fluorescence detection. J. Chromatography 530: 452-457.

Samuelsen, O.B., Lunestad, B.T., Husevåg, B. Hølleland, T., Ervik, A. 1992. Residuals of oxilinic acid in wild fauna following medication in fish farms. Diseases aquat. Organisms 12: 111-119.

Samuelsen, O.B., Lunestad, B.T., Solheim, E. 1991. Fat and microbiological effects of Furazolidone in marine aquaculture sediment. The Science of Total Environment 108: 275-283.

Samuelsen, O.B., Svardal, A.M., Hjeltnes, B. 1990. The change in liver gluthione concentration in salmon *(Salmo salar)* and char *(Salvelinus alpinus)* during and after medication with furazolidone. Bull. European Assoc. Fish Pathol. 10(2): 35-36.

Särkkä, J., Luukko, A., Horppila, P., Jämsä, A., Valtonen, T. 1991. Chernobyl cesium fallout in the sediment and fish of lakes of different sizes in Finland. Verh. Internat. Verein. Limnol. 24: 2346-2351.

Saunders, R.L. 1991. Potential interaction between cultured and wild Atlantic salmon. Aquaculture 98: 51-60.

Sephton, T.W. 1991. Summer mortality of cultured mussels in Prince Edward Island, Canada. Bull. Aquacult. Assoc. Can. 91(2): 46-48.

Shanks, A.M., Bruno, D.W:, Mitchell, C.G:, Munro, A.L.S. 1991. The use of aquagard and the prevalence of cataracts among farmed Atlantic salmon *(Salmo salar* L.). Scottish Fisheries Working Paper 7/91.

Smaal, A.C., van Stralen, M.R. 1989. Average annual growth of mussels as a function of food supply. Nydrobiologia 195: 179-188.

Solar, I.I., Donaldson, E.M. 1991. A comparison of the economic aspects of monosex chinook salmon production versus mixed sex stocks for aquaculture. Proc. Aquacult.'91, St. Andrews, NB., June 10-16, 1991. Bull. Aquacult. Assoc. Can. 91(3): 28-30.

Stewart, J.E. 1991. Approaches to problems of disease in aquaculture. ICES Mar. Sci. Symp. 192: 206-210.

Stigebrandt, A., Aure, J. 1988. Observation of plant nutrients in some Norwegian fjords. Sarsia 74: 303-307.

Stigebrandt, A., Aure, J. 1989. Vertical mixing of basin water of fjords. J. Phys. Ocean. 19(7).

Thomsen, Støttrup E. 1991. Kriterier for udvælgelse af lægemidler til fisk. In: Hoffmann et all. Eds.(1991): Havbrug og Miljø. Nord 1991:10

Traxler, G.S., Roome, J.R:, Kent, M.L. 1991. Transmission of IHN virus ti sockeye *(Oncorhynchus nerka)* and Atlantic salmon *(Salmo salar)* in seawater. FHS/Am. Fish. Soc. Newsletter 19(2): 6-7.

Troadec, J.-P. 1991. Extensive aquaculture: a future opportunity for increasing fish production and a new field for fishery investigations. In: Lockwood, S.J. (Editor) The Ecology and Management Aspects of Extensive Mariculture. ICES mar. Sci. Symp. 192: 1-5.

Turrel, W.R. 1990. Simulation of advection and diffusion of released treatments in Scottish Sea lochs. Scottish Fisheries Working Paper No 16/90.

Turrell, W.R., Gillibrand, P.A. 1992. Assessing the environmental effect of new and existing fish farms in Scottish Sea Lochs. Fisheries Research Services Report No 3/92: 1-22, plus Tables and Figures.

UNEP/ILO/WHO, 1989. Dichlorvos. Environmental Health Criteria 79., 157 pp. (IPCS International Programme on Chemical Safety) ISSN-0250-863x

Valtonen, E.T., Rintamäki, P., Koskivaara, M. 1991. Occurrence and pathogenocity of Yersinia ruckeri at fish farms in northern and central Finland. Journal of Fish Diseases (in press).

Varadaraj, K., Pandian, T.J. 1991. Effect of Solubilizing 17 alpha-Ethylnyltestosterone in three Different Solvents on Sex Reversal of Mozambique Tilapia. Progr. Fish-Culturist 53:67-71.

Verspoor, E., Fraser, N.H.C., Youngson, A.F. 1991. Protein polymorphism in Atlantic salmon within a Scottish river: evidence for selection and estimates of gene flow between tributaries. Aquaculture 98: 217-230.

Videau, C., Merceron, M., 1992. Impact de la pisciculture marine intensive sur l'environnement. Revue Bibliographique, Rapport IFREMER/DEL/92,13: 108 pp.

Wallin, M., Håkanson, L. 1991. Nutrient loading models for estimating the environmental effects of marine fish farms. Nord 1991: 22, 39-55.

Watanabe, T. 1991. Past and present approaches to aquaculture waste management in Japan. pp. 137-154. In: Cowey, C.B., Cho, C.Y. (Eds.). "Nutritional Strategies and Aquaculture Waste.". Proceedings of the 1st Intern. Symp. on Nutritional Strategies in Management of Aquaculture Waste, NSMAW). University of Guelph, Ontario, Canada. (ISBN 0-88955-294-0).

Webb, J.H., Hay, D.W., Cunningham, P.D., Youngson, A.F. 1991. The spawning behaviour of escaped farmed and wild Atlantic salmon *(Salmo salar* L.) in a northern Scottish river. Aquaculture 98: 97-110.

Webb, J.H., Youngson, A.F. 1992. Reared Atlantic salmon, *Salmo salar* L., in the catches of a salmon fishery on the western coast of Scotland. Aquaculture and Fisheries Management 23: 217-221.

Wells, D.E., Robson, J.N., Finlayson, D.M. 1990. Fate of Dichlorvos (DDVP) in sea water following treatment for sea louse, *Lepeophtheirus salmonis*, infestation in Scottish fish farms. Scottish Fisheries Working Paper No 13/90.

Whyte, J.N.C. 1991. The effects of Heterosigma akashiwo on juvenile chinook salmon, p. 3-8. In: J.R. Forbes (Ed.). "Pacific coast research on toxic algae. Can Tech. Rep. Hydrogr. Ocean Sci. Ser. 135.

Wiklund, T. 1990. Atypical *Aeromonas salminicida* isolated from ulcers of pike, Esox lucius L. J. Fish. Diseases 13, p. 541-544.

Wiklund, T., Bylund, G. 1990. *Pseudomonas anguilliseptiga* as a pathogen of salmonid fish in Finland. Diseases of aquatic organisms 8: 13-19.

Yoshikawa, H., Ishida, Y., Ueno, S., Mitsuda, H. 1988. Changes in depth of anesthesia of the carp anesthetized with a constant level of CO2. Bull. Jap. Soc. Sci. Fish. 54(3): 457-462. [In Japanese].

Youngson, A.F. 1992. Escapes of reared salmon and future genetic management of wild salmon populations in Scotland. Institute of Fisheries Management (in press).

Youngson, A.F., Martin, S.A.M., Jordan, W.C., Verspoor, E. 1989. Genetic protein variation in farmed Atlantic salmon in Scotland: comparison of farmed strains with their wild source populations. Scottish Fisheries Res. Rep. No. 42: 12 pp.

Youngson, A.F., Martin, S.A.M., Jordan, W.C., Verspoor, E. 1991. Genetic protein variation in Atlantic salmon in Scotland: comparisons of wild and farmed fish. Aquaculture 98: 231-242.

Zhang, Z.S. 1990. Wastewater-fed Fish Culture in China. pp. 3-12. In: Edwards, P., Pullin, R.S.V. (Eds.). "Wastewater-Fed Aquaculture." Proceedings of the International Seminar on Wastewater Reclamation and Reuse for Aquaculture, Calcutta, India, 6-9 December, 1988. Asian Institute of Technology and ICLARM, pp XXIX, 1-296. (ICLARM Contribution No 684) (ISBN 974-8201-082)

Appendix 1

Studies related to environmental aspects of mariculture
(Completed, on-going and new projects)

During the intersessional period a number of new projects have been initiated on which brief information is provided. As far as possible, the earlier listings have been updated. Unfortunately, information on progress and completion of listed projects has not been obtained for all those reported in the 1990 Working Group Report. Therefore, the projects which have been reported as completed in the 1990 report as well as those for which no information on progress has been made available, have been deleted from the Table. The numbering system, however, has been maintained in order to permit project identification with the former listing and to allow also updating at a later date. Projects which have not yet been reported in any previous Working Group report have been assigned continuing numbers, appear at the end of the table and are also marked by an asteric.

No	Project Description	Completion Date	Country and Reference, if any
(1)	Investigation into the effects of fish cage culture on: benthos, hypernutrification, eutrophication, wild fish populations, and bacteria. Laboratory experiments to investigate the nutrient load in relation to temperature, food type and fish size.	Dec. 1990	Denmark

Study completed in 1990. Publications ar in the literature list, papers by Christensen & Horsted 1991, Christensen et al. 1991 and Hoffmann & Horsted 1991.

No	Project Description	Completion Date	Country and Reference, if any
(2)	Algarve: Environmental studies at Faro-Olhao sea agoon "Ria Formosa". Regular monitoring of phytoplankton; changes in bacterial population inside and outside the lagoon and in bivalves; sediment - water column exchange of oxygen and nutrients; studies on PCB in cultured species and wild populations; studies on water exchangerates; studies on the pathology of clams and otherbivalves; eutrophication, bacteria, chemicals.	3 years	Portugal

(no information on progress received during 1991)

No	Project Description	Completion Date	Country and Reference, if any
(3)	Mondego estuary: Regular monitoring of phyto-, zoo-and ichthyoplankton, and of physical conditions; studies on water exchange rates and fish pathology.	2years	Portugal

(no information on progress received)

No	Project Description	Completion Date	Country and Reference, if any
(4)	Calibration and validation of two ecosystem simulation models with which the carrying capacity for mollusc shellfish culture can be assessed in the Waddenzee and the Oosterschelde estuary.	1991-1994	Netherlands

Status: Oosterschelde model: being validated Waddenzee model: being improved
Publications available: Smaal et al (see litterature list)

No	Project Description	Completion Date	Country and Reference, if any
(5)	Research to assess the influence of two types of mollusc dredges, used for for musseland oyster cultivation, on the substrate of natural intertidal mussel beds and cultivation plots.	1994	Netherlands

Status: first field experiments completed

---

(6) Measurement of in situ production of nutrients and consumption of particulate food by mussels and the communities on cultivation plots. — 1992 — Netherlands

Status: on-going

---

(7) Research into suitable sites for mussel cultivation in the Oosterschelde in relation with current velocity and food availability. — originally in 1991 — Netherlands

Status: on-going

---

(8) Development of a model for regional planning and site selection of mariculture in the coastal zone. The aim is to avoid brackish areas prone to eutrophication effects caused by net cage culture. Measurements of bottom dynamics, hydraulics and biological parameters in the vicinity of fish farms are made. — 1990 — Finland
Ervik, et al., 1987
Håkansson et al.1988,
Mäkinen (ed.)1991

(A report by Håkanson, L., Ervik, A, Mäkinen, T., Møller, B, 1988 is now available. The publication is entitled "Basic concepts concerning assessment of environmental effects of marine fish farms": see literature list. The final report Mäkinen 1991, see litterature list)

---

(9) Project has been deleted from the earlier listing (dublication of no 8)

---

(10) Antibiotics in farmed fish, wild fauna and sediment, and degradation rates of chemicals — 1988 — Finland

Publication available: Björklund et al. 1989 (see litterature list)

(11-13) No information has been made available during the intersional period — United States

---

(14) Status reported in Country report — Eastern Canada

---

(15) Letang Inlet aquaculture project — continuing, anticipated completion date 1996 — Eastern Canada

A summary of the findings to date include: (a)predictions from the hydrodynamic model of regions of poor water quality due to the accumulation of wastes, (b) nitrogen input by salmon farms is four times the capacity for natural nitrogen regeneration in the area; (c) benthic oxygen uptake under fish farms is as mus as ten times that observed at control sites; (d) repsiration of the caged salmon is many times greater than this elevated benthic oxygen demand. For more details see country report in App. 4.

---

(16) The effect of blue mussel culture on the benthic environment in Nova Scotia and Prince Edward Island — begun 1991, anticipatedcompletion date 1993 — Eastern Canada

No report available yet; Publication of a final report is planned for the Acadia University Center for Eastuarine Resource Publication Series. contact: M. Brylinsky, Acadia University

---

(17) The cause of summer kill in cultured blue mussel — begun in1989, completed in 1990 — Eastern Canada

The kill is a direct result of an overwhelming genetic component. Different stocks have widely varying thermal sensitivities. Contacts: A. Mellet, C. Carver, K.

Freeman DFO, Scotia & Fundy Region, Halifax Lab., PO Box 550, Halifax, NS, B3J 2S7, Canada

---

(18) Phytoplankton profiles .... 1992 Eastern Canada

For detailed information see country report (Eastern Canada, no 3 on p.56))

---

(19) Corss contamination of oysters...... commenced in 1989 probably terminated Western Canada

See ICES document presented in 1991 ICES Theme Session on antibiotic contamination in shellfish

---

(20) Plankton watch for marine aquaculture........ Western Canada

Internal reports available, contact E.A. Black (address see membership list)

(21- 22) Completed, no longer listed. Western Canada

Reported in 1990 WG report: contact E.A Black, Victoria BC (see WG member list)

---

(23)A winter disease profile, survey of a quarter of existing fish farms...... Western Canada

Report being compiled. Contact E.A. Black , Victoria BC (see WG member list)

---

(24)Antibiotic resistance of pathogens in the vicinity of fish farming......... 1992 Western Canada

Internal report. Contact Mr. B. Kay, Environment Canada, 1801 Welch St., North Vancouver, Canada, V7P1B7

---

(25)Marine anemia: a case study of disease transfer between wild and cultured fish........ 1992 Western Canada

Work ongoing

---

(26) The use of pigments and oxytetracycline to differentiate wild and cultured salmonids..... Western Canada

Work ongoing

---

(27) A review of the impacts of salmon farming on the phytoplankton........ 1989 Western Canada

Finished and reported in 1990 working group report.

---

(28)A study of the enriching effects of two salmon farms...... 1989 Western Canada

Finished and reported in 1990 working group report.

---

(29)Serological test for Paralytic Shellfish Poison (PSP)... 1989 Western Canada

Finished and reported in 1990 working group report.

---

(30)Plankton response to commercial fish feed nutrients 1990 Western Canada

Finished and reported in 1990 working group report.

Finished and reported in 1990 working group report. (21- 30) Completed, no longer listed.
Western Canada

For information on earlier reports contact E.A Black, Victoria BC (see WG member list)

---

(31) Phytoplankton identification video — Western Canada

The video is still available from Univ British Columbia, Media Services Department, Vancouver, B.C..Finished and reported in 1990 working group report.

---

(32) Surveying algal blooms: A compilation and analysis of data on the 1989 Heterosigna bloom — 1990 — Western Canada

Contact E.A. Black

---

(33) Experimental demonstration of the existance of Heterosigma toxin. — 1990 — Western Canada

Published: Black et al., 1991. J. Appllied Ichthy.

---

(34) Respiratory response of salmon exposed to Heterosigma akashiwo — 1989 — Western Canada

Finished and reported in 1990 working group report

---

(35) Characterization of the agent causing fish mortalities in Heterosigma blooms. — 1989 — Western canada

Work ongoing

---

(36) Monitoring of shellfish growing areas for Paralytic shellfish poisoning. — ongoing — Western Canada

This is an ongoing Fisheries Inspection Branch program which issues annual reports covering the occurrence and levels of PSP contamination in various shellfish species along BC's coast.
Contact: E.A. Black, B.C. Ministry of Aquaculture and Fisheries, Victoria, B.C.
Contact Mr. R. Chang, D.F.O. Inspection Branch, 2250 Boundry Rd., Vancouver, B.C., Canada, V5M 4L9

---

(37) A review of the impacts of salmon farming on benthos. — 1989 — Western Canada

Finished and reported in 1990 Working Group report

---

(38) A survey of the effect of B.C. salmon farming on the benthic environment. — 1991 — Western Canada

Contact E.A. Black

---

(39) Rate of recovery of the benthic community from the impacts of fish farm sedimentation. — 1991 — Western Canada

Thesis expected 1992. Contact E.A. Balck

---

(40) Monitoring of shellfish growing waters for bacterial contamination..... — ongoing — Western Canada

Contact Mr. B. Kay - as above

---

(41) Mandatory monitoring of waste loading at fish farm sites and trends in water quality — ongoing — Western Canada

Finished and reported in the 1990 Working Group report

---

(42) Review of the impacts of freshwater aquaculture on the environment — terminated — Western Canada

Finnished and reported in 1990 Working Group report

---

(43)An investigation of the impact of fish farming on the nearshore environment — terminated — Western Canada

Finnished and reported in 1990 Working Group report

---

(44)An experiment on the contamination of the environment by aquaculture (anti-fouling preparations — Western Canada

Finnished and reported in 1990 Working Group report

---

(45)Culture of oysters in salmon farm effluent — 1991 — Western Canada

as per project No. 19

---

(46)An assessment on the impacts of fish farming on herring spawning — 1991 — Western Canada

To presented at the AAC Annual meeting in June 1992

---

(47) Predation by cultured salmon on wild organisms — terminated — Western Canada

Finnished and reported in 1990 Working Group report

---

(48) Survey of salmon farm waste handling practices — terminated — Western Canada

Finnished. For further information contact Mr. J. Willow (same address as E.A. Black)

---

(49) Biophysical capability studies of the BC coast for marine salmon aquaculture — completed — Western Canada

A total of 4 reports have been completed recently. Contact: Mr. J. Truscott (same address as E.A. Black, Victoria, BC).

(50-53)projects have been completed, ***no further information available*** — Sweden

---

(54) Investigation of the impact of marine fish farms on the receiving water body. Keywords: nutrition, salts, sedimentation, benthic fauna — completed, no longer listed — Norway

Results have been published, see literature list : Aure et al. 1988

---

(55) Fate of organic waste from marine fish farms. — completed 1990 will no longer be listed — Norway

Report available: see literature list under Hansen et al, 1991 Nord (22), p.105-120.

---

(56) Development of a data base — completed in 1989 deleted from listing — Norway

No status information has been made available

---

(57) Development of methods for treatment of fish farm wastes — completed no longer listed — Norway

Report available from: Jordforsk, Norges Landbrukshøgskole Ås

---

(58) Isolation and investigation of potentially toxic flagellates (especially *Chrysochromolina)* — completed — Norway

For information contact: Prof. E. Paasche, Universitetet I Oslo, Postboks 1066, Blindern 0316 Oslo 3

---

(59) Deleted from the list, no status reports have become available — Norway

---

(60-62) projects have been completed, — Norway
(60) Environmental factors influencing growth of salmon
(61) Effect of crude oil exposure on fish farms,
(62) Development of low density fish feed

Information available from ROGALANDSFORSKNING, Postboks 2503, Ullandshaug , N-4004 Stavenger

---

(63) Development of an efficient tool of coastal zone planning (LENKA) — completed 1990/91 — Norway

Several reports have been prepared. Final versions are available from the Ministry of Environment of Norway, Postboks 8013, Dep 0030 Oslo 1

---

(64) Investigations of the effects and fate of antibiotics — 1991 — Norway

The study includes aspects of the ecological impacts of antimicrobials. At present no additional info on the status of the project is available other than publications listed under references

---

(65) Quantitative estimates of eutrophication effects of fish farming in fjords — 1986-92 — Norway

Description: Dealing with the effects of fish farming on eutrophication of the upper layer and the increased oxygen consumption in the basin water of fjords. Contact person: Jan Aure, Inst Mar. Res., Norway

The project has resulted in a publication (see Literature list: Aure and Stigebrandt, 1990)

---

(66) Level of drugs in farmed fish, wild fauna and sediment.... — completed — Norway

Information on project results available from NIVA, Postboks 69, Korsvoll, 0808 Oslo 82

---

(67) Investigation into resistant microflora in the sediments beneath fish farms — completed, — Norway

Information on project results available from V. Torsvik, IPM, Univerista of Bergen, Allegt 70, N-5000 Bergen

---

(68) Investigation on feeding behaviour and control by hydroacustic detection of feewaste and vertical rfish distribution — 1988-92 — Norway

Several publications have appeared during the intersessional period. See literature list

---

(69-70) deleted from the list; for some projects references can be found in the literature list. — Norway

---

(71) Alternative traetment of salmon lice. — 1989-92 — Norway
The project deals with alternative chemicals in lice control.

Contact person: Jens Chr. Holm, Inst.Mar. Res., Norway.

Info on progress should be available from this contact; a publication has appeared, see literature list

---

(74) Stress in Fishes begun in 1989, completion date 1993 Norway
contact: Per Enger, Biologisk Institutt , Univ. Oslo, P.O.Box 1066 Blindern, 0316 Oslo 3
Tlf 02 454671)

(72-78) deleted from the listing, because no reports on progress have become available

---

(79) Biological control of sea lice project dates:1988-1992 Norway
Contact person (new address): Åsmund Bjordal, Inst.Mar. Res., Norway.

Besides the report presented at the 1988 Statutory Meeting, no further reports have yet become availalbe

---

(80-100) Projects have been deleted from this list because no further information Norway
on their progress could be traced during the intersessional period; projects
(80 to 112 , and 116 are disease projects and - with a few exceptions
are no longer considered to be relevant to this report

---

(101) Chemotherapeutica in fish farming. completed 1991 Norway
Optimization of dosage and compounds

Several publications have appeared during the intersessional period. Contact address:
Svein Olav Hustvedt, AKVAFORSK, Boks 10, 1432 Ås-NLH, Norway

(102-106) Projects have been deleted from this list because no further information Norway
on their progress could be traced during the intersessional period

---

(107) Hitra-disease among salmonids, environmentally ongoing, until 1992 Norway
mediated effects, physiology and morphology

No status report available. Info should be available from the Veterinarinstituttet, Norges Veterinarhogskole, Oslo, Norway

---

(108-114) Projects have been deleted from this list because no further information Norway
on their progress could be traced during the intersessional period

---

(115) The role of benthic fauna in decom- completion date 1992 Norway
position of organic waste from aquaculture

In this ongoing project the dose-response relationship between sedimentation and benthic community is presently studied. No reports have yet been made available

---

(116) Project is deleted from this list because no further informationNorway
on their progress could be traced during the intersessional period

---

(117) Genetic influence of escaped farmed fish completion date 1992 Norway
on wild populations of Atlantic salmon

No status report available. Info should be obtainable from: Petter Larsson, Zoologisk Museum, Universitetet i Bergen, Museplass 3, 5007 Bergen, Tel. 05-212905 and/or from NINA, Tungesletta 2, N-7047 Trondheim, Tfl. 07-913020

---

(118) Control of escaped farmed fish completion date 1992 Norway

No status report available. Info should be obtainable from: Bror Johnsson, Norsk Institutt for Naturforskning, Tungesletta 2, 7047 Trondheim, Tfl. 07-913020

---

(119) Escaped farmed fish - influence on completion date 1992 Norway

populations of wild Atlantic salmon

No status report available. Info should be obtainable from: Bror Johnsson, Norsk Institutt for Naturforskning, Tungesletta 2, 7047 Trondheim, Tfl. 07-913020

---

(120) Project has been deleted from this list completed 1990 Norway

Information on the outcome of the project available from D. Furevik, Havforskinst. Postboks 1870, N-5024, Bergen-Nordnes

---

(121) Development and transfer of resistance against antibiotics completion date 1992 Norway

No status report available. Info should be obtainable from: Kåre Fossum, Norges Veterinærhøgskole, Postboks 8146, Dep. 0033 Oslo 1, Tlf: 02-693690

---

*(126) Laboratory studies of the toxicity and sublethal effects of dichlorvos and possible alternatives for sea lice treatment. Field and laboratory investigations of the impact of cichlorvos treatment on non-target organisms, including adult and larval molluscs and crustaceans. ongoing Scotland

At the present time there is no information on status and interim results of the project available

---

*(128) Recovery of environments exposed to TBT: as part of an on-going monitoring of the impact of TBT on marine life. ongoing Scotland

At the present time there is no information on status and interim results of the project available

---

*(130) An investigation into hypernutrification eutrophication with the aim of determining the holding capacity of sea lochs. Hydrographic and modelling studies of sea lochs. The impact of farming operations on benthic communities completed Scotland

Report : R.J. Gowen and I.A. Ezzi 1992: "Assessment and prediction of the potential for hypernutrification and eutrophication associated with cage culture of salmonids in Scottish coastal waters." Report available from: Dunstaffnage Marine Laboratory, Oban, Scotland, 136 pp.

---

(131) project terminated in 1988, Thesis prepared by F. Johnson, available from Stirling University, Scotland

---

New projects not previously listed in any WG report

---

*132 Effects of cage culture in tropical marine environments 1990-1992 F. R. Germany Contact: H. Rosenthal, Kiel

The study takes place in the Gulf of Acaba (Eilat, Red Sea) as part of the German-Israeli Cooperation Program and uses newly developed vidio imagery technique in combination with well established methods to budget environmental parameters altered by cage culture of sea bass and sea bream.

The study progresses according to plan. First reports are anticipated in the fall of 1992.

*133	Kiel cage performance The project aimed at optimizing feeding strategy under widely fluctuating temperatures and oxygen levels (farm situated in the waste heat plume of a coastal power station.	1990-1991 completed	F.R. Germany

Projects reports (in german) are available from the Dep. of Fishery Biology, Univ. Kiel. Interim results were presented as Doc. ICES. C.M. F:....1990. For further details see country report.

*134	Sedimentation under cages in a non-tidal inlet	1991, completed	F.R.Germany

Changes in sediment geochemistry and in benthos composition have been demonstrated. A publication is presently under preparation. contact: H. Rosenthal, Dep. Fishery Biology, Univ. Kiel.

*135	Effects of intermittant (tidal) oxygen depletion on Pacific salmon Aim: establishing an ethnogram that permits to identify early warning sings in stressed fish	1991-1992	F.R.Germany Western Canada

contacts: Dr. U. Waller, Dep. Fishery Biology, Univ. Kiel. For further details see country report for Germany

*136	Oyster culture site selection and monitoring program for New Brunswick	begun in 1988 anticipated completion 1995	Eastern Canada

A collaborative program involving the New Brunswick Dept. of Fisheries and Aquaculture, Canada Dep. of Fisheries and Oceans, and the Environmental Research Unit of the Université de Moncton with the oyster growers. For details see the Canadian Country report. Contact Person: Dr. A. Boghen, Dept. if Biology, Université de Moncton, Moncton, New Brunswick.

*137	Determinatin of metabolites produced by three marine, non-salmonid fish species	ongoing	France

No results yet reported contact:Mr Dosdat IFREMER

*138	Modelling of nutrient effluents in marine fish farms	ongoing contact:	France Mr. Dosdat, IFREMER

Study conciders turbot and sea bass; conditions followed are: Fish farm management, nutritional requirements and resulting environmental parameters

*139	Reduction of fish farm effluents through improved nutrition and water treatment	ongoing contact:	France Mr. Dosdat, IFREMER

Study on digestibility of feeds and their energy content; waste output in hatcheries; research on recirculation systems (land-based systems) for turbot, sea bass and brown trout.

*140	Potential interaction between shellfish and finfish culture	ongoing contact:	France Mr. Dosdat, IFREMER

Study on accumulation of antimicrobials in farmed shellfish, Analysis for pathogenic bacteria, Study on transfer of faeces and organic matter from various origin (e.g. shellfish, finfish, phytoplankton, sewage) in relation to suspended solid output from finfish culture

*141	Characterisation of organic matter derived from fish faeces under culture conditions	ongoing contact:	France Mr. Dosdat, IFREMER

The studies considers sedimentation rates from turbot and sea bass farms as well as leaching of material (laboratory study).

---

* 142 Modelling the impact of nutrient release on the environment — ongoing — France
contact: Mr. Dosdat, IFREMER

The study employs hydrodynamic and primary production models for macro-tidal Atlantic environments as well as Mediterranean situations

---

*143 Causes of summer mortality in Atlantic salmon smolts — completed — France
contact: M. Merceron, IFREMER, Brest

---

*144 Preliminary research on indsutrial offshore fish farming in the Mediterranean coastal zone — completed — France
contact: A.Febvre, IFREMER, Chemin de Maguelace, 33 Palavas les Plots

---

*145 Nutritional needs of cultured shellfish species — ongoing — France
contact: Mr. Dosdat, IFREMER

Studies on nutritional requirements of oysters, mussels and Manila clam and their competiotors (Crepidula, zooplankton, etc) in relation to environmental factors (salinty, temperature, food quakity)

---

*146 Nutrient flux in caostal areas — ongoing — France
contact: Mr. Dosdat, IFREMER

Modelling of nutrient flux between open ocean and inshore areas, including estuaries. Models aimed at describing the evolution of impacts in order to improve ecosystem management approaches in relation to human resource uses

---

*147 Evaluation of the return of escaped salmon to the River Polla — 1989-1990 — Scotland
contact: Dr. Youngson, Aberdeen

The project has been extended to include the second year following their escape. Evaluation of the genetic consequences of the spawning of escaped salmon in the Polla in 1989 and 1990.

---

*148 Distribution of the progeny of female salmon which have escaped from aquaculture — ongoing — Scotland
contact: Dr. Youngson, Aberdeen

Fry bearing canthaxanthin were detected in 14 of 16 western and northern Scottish rivers. Overall, 5% carried canthaxanthin.

---

*149 Studies of structuring among wild salmon populations — ongoing — Scotland
contact: Dr. Youngson, Aberdeen
SOAFD Marine Laboratory

---

*150 Investigation of the factors affecting the rate of recovery of the benthic environment at abandoned fish farm sites — **new project** four years from1992 — Scotland
Contact:Dr. A. Bullock
Dunstaffnage Marine Lab Oban

Interim reports not expected prior to fall 1993

---

*151 Development of analytical methods for the determination of antibiotic residues in sediment and biota at Scottish fish farms, including field studies at 3 farms in Shetland — **completed** — Scotland

Report available from: J.C. McKie, SOAFD Marine Laboratory, Aberdeen

---

*152 Development of mathematical models of water — ongoing — Scotland circulation and dispersion in Scottish sea lochs, to assist in the assessment of the carrying capacity of lochs for farmed fish

Contact address: Dr. I.M. Davies, SOAFD Marine Laboratory, Aberdeen

---

*153	Development of mathematical models of the interaction between sea bed sediments and water quality in Scottish sea lochs	new project start 1992	Scotland

Contact address: Dr. I.M. Davies, SOAFD Marine Laboratory, Aberdeen

---

*154	Improvement in the control measures for furunculosis	continuing	Scotland

Objectives: (a) Development of an effective vaccine and optimising immunisation regimes; (b) Identification of more effective antimicrobial compounds; (c) Improvement in epidemiological knowledge in wild and farmed populations with the objective of improved husbandry methods of control. Contact Address: Dr. A.L.S. Munro, SOAFD Mar. Lab., PO Box 101, Victoria Rd, Aberdeen AB9 8DB

---

*155	Vaccination of salmon against sea lice	continuing	Scotland

Objective: To develop an effective vaccine against sea lice infestation. Contact Address: Dr. A.L.S. Munro, SOAFD Mar. Lab., PO Box 101, Victoria Rd, Aberdeen AB9 8DB

---

*156	Diseases in wild and farmed fish	continuing	Scotland

Objective: Establish if any correlation exists between disease in farmed fish and the recent decline in catches of wild salmon and sea trout. Contact Address: Dr. A.L.S. Munro, SOAFD Mar. Lab., PO Box 101, Victoria Rd, Aberdeen AB9 8DB

---

*157	Examination of the fatty acid and pigment composition of feral fishes at and remote from fish farm sites to determine if wild fish populations are consuming uneaten commercial salmon feed at salmon farms.	1992	Western Canada

A report is expected by September 1992. For detailed information contact Dr. D. Hay, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*158	An examination of the behavior of fish in and around salmon culture cages in response to a number of biotic and abiotic stimuli.	1992	Western Canada

A report is expected in Nov.1992. For detailed information contact Dr. K. Groot, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*159	Determination of whether the disease marine anemia may be transmitted from farmed salmon to Sockeye salmon or other wild non—salmonid population. Also some initial work on tests for the sub—clinical occurrence of this disease.	1993	Western Canada

A report is expected in April 1993. For detailed information contact Dr. M. Kent, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*160	Determination of the mechanism of fish mortalities associated with blooms of the algae Heterosigma akashiwo.	1993	Western Canada

A report is expected in April 1993. For detailed information contact Dr. N.J.C. Whyte, Dep.of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*161 A Study of how the timing of fish feeding affects growth of cultured salmon and the amount of waste feed produced. 1993 Western Canada

A report is expected in April 1993. For detailed information contact Dr. H. Krieberg, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*162 Field and Laboratory test to determine if the Pacific Oyster is likely to take up lipid and water soluble antibiotics from the medicated fish feed used on samlon farms. 1991 Western Canada

A report has been recieved and is summarised in ICES CM 1991. For further details contact E.A. Black (for address see WG membership list).

---

*163 A survey for the occurrence of farmed Atlantic salmon in the rivers of B.C. 1993 Western Canada

A report is expected in April 1993. For detailed information contact Dr. K. Groot, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*164 An examination of the frequency ofoccurrence of salmon which have eaten commercial salmon feed on the redds of wild salmon populations. 1993 Western Canada

A report is expected in April 1993. For detailed information contact Dr. N.J.C. Whyte, Department of Fisheries & Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*165 A study of the effects of crowding, starvation and stress on the severity, time to onset and incidence of Marine Anemia. 1993 Western Canada

A report is expected in April 1993. For detailed information contact Dr. M. Kent, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C.

---

*166 A Study to examine the viability of progengy from the hybridization of Atlantic and Pacific Salmon. 1994 Western Canada

A report is expected in April 1994. For detailed information contact Dr. R. Devlin, Dep.of Fisheries & Oceans, West Vancouver Laboratory, West Vancouver, B.C.

---

*167 A study of the site characteristcs associted with salmon farm sites which have little sedimentation under the cages. 1994 Western Canada

A report is expected in April 1994. For detailed information contact C. Backman, B.C. Ministry of Agriculture Fisheries and Food, Courtney, B.C.

---

*168 A survey of the seasonal occurence of diseases on salmon Farms in B.C. 1993 Western Canada

A report is expected in September 1993. For detailed information contact Dr. R. Armstrong, B.C. Ministry of Agriculture Fisheries and Food, Abbotsford, B.C.

---

*169 A Survey of the types and frequency of predation on farmed salmon, and the effectiveness of mitigative techniques. 1993 Western Canada

A report is expected in September 1993. For detailed information contact W. Harrower, B.C. Ministry of Agriculture Fisheries and Food, Courtney, B.C.

---

*170 A review of the effect of algal blooms on the shellfish industry in B.C. with discussion of possible mitigative measures. 1993 Western Canada

A report is expected in September 1993. For detailed information contact Dr. W. Heath, B.C. Ministry of Agriculture Fisheries and Food, Courtney, B.C.

---

*171	Development of a ensiling technology to dipose of fish mortalities on salmon farms.	1993	Western Canada

A report is expected in September 1993. For detailed information contact J. Willow, B.C. Ministry of Agriculture Fisheries and Food, Victoria, B.C.

---

*172	Response of benthic comminuties to organic enrichment from salmon cages. Includes sediment trap data, microbiological processes, effects on benthic species composition.	Dates 1990-1992	Maine, USA

Contact: Dr. Les Watling and Robert Findlay, University of Maine , Tel: (207) 563-3146
Darling Marine Center
Walpole, Maine 04573 U.S.A.
Status: measured rates of carbon accumulation were much less than predicted by existing models. Low current sites exposed to waves were compared with high current, sheltered sites.

---

*173	Rigorous evaluation of the role of computer models in the environmantel regulation of net-pen aquaculture, uses physical computer models at two contrasting Maine sites to aid in "bay-wide" regulation of salmon farms in Maine.	Dates: 1992-1993	Maine, USA

Contact: Dr. Vijay Panchang and Carter Newell
Dept. Civil Engineering
University of Maine (707) 581-1110
Orono, Me. U.S.A. 04469

---

*174	Underwater video assessment of the effects of trout cages on lobster populations.	Dates: 1990-1991	United States

Contact: Dr. Robert Bayer
Dept. Animal, Veterinary and Aquatic Sciences
University of Maine
Orono, Me. 04469 (707) 581-1110
Status: There was an increase in the number of lobsters near a small trout culture operation.

---

*175	Development of a model to seed mussel bottom leases to their carrying capacity.	Dates: 1987-1991	United States

Contact: Carter Newell
Great Eastern Mussel Farms
PO BOX 141 707-372-6317
Tenatz Harbor, Me. U.S.A. 04860
Site specific two-dimensional flow models coupled with vertical transfer of particulate food and mussel growth predicts optimal seeding density for mariculture sites. A separate finite difference model predicts depletion contours in relation to current speed, water depth and mussel biomass.

---

*176	Antibacterial agents in the marine environment.	completion 1994	Norway

Description: Dealing with the fate of dissolved antibacterial agents, and metabolism of antbacterial agents in fish. Contact person: Arne Ervik Inst.of Mar. Research, Norway.

---

*177 Effects of chemotherapeutics on the environment of fish farms — 1993 — Norway

Ongoing: contac person H. Hektoen, NIVA, Postboks 69, Korsvoll, 0808 Oslo 822

---

*178 Genetic evolution of salmon tribes — 1992-93 — Norway

Contact person: H.B. Bentsen, AKVAFORSK, N-6600 Sundalsøra

---

*179 Identification of escaped farmed salmon: studies of DNA — 1992-94 — Norway

Ongoing: contact person K. Hindar, NINA, Tungesletta 2, 7047 Trondheim

---

*180 Sediment- chemical studies of the recovery of fish farm sites — 1992-93 — Norway

Ongoing: contact- M. Frog, Nordlandsforskning, Postboks 6003, N-8016 Mørkved

---

*181 Effects of salmon lice infection from fish farms on wild populations of salmon — 1992-94 — Norway

Ongoing: contact P.J. Jakobsen, Zoologisk Museum, Museplass, N-5007 Bergen

---

*182 Epidemioologic investigations of connections between environmental factors. — 1992-94 — Norway

Ongoing: contac person H. Hektoen, NIVA, Postboks 69, Korsvoll, 0808 Oslo 822

---

*183 Analysis of the reason for different resistance towards furunculosis in salmon. — 1992 — Norway

Ongoing; contact person T. Gjedrem, AKVAFORSK Postboks 10, N-1432 Ås - NLH

---

*184 Furunculosis in populations of wild salmon — 1991-93 — Norway

Ongoing: contact person B. Johnsson, NINA, Tungesletta 2, 7047 Trondheim

---

*185 Fish health and infrastructure in fish farming industry. — 1991-93 — Norway

Ongoing: contact person Fiskerisjefen i Møre og Romsdal, N-6000 Aalesund

---

*186 Environmental hygiene in fish farming . — 1992-94 — Norway

Ongoing: contact J. Glette, Havfforsk.Inst.Postboks 1870, 5024 Bergen-Nordnes

---

*187 Survival and transport of Areomonos salmonicida n the marin environment. — 1991-93 — Norway

Ongoing, contact person: J. Goksøyr, IMP Allegt 70., N-5000 Bergen

---

*188 Spread of furunkulosis by latent carriers — 1991-93 — Norway

Ongoing, contact person S. Høie

---

*189 Stock assessments of mussels and cockles in the Dutch coastal waters in order to determine the carrying capacity for molluscs-eating birds — 1995 ongoing — Netherlands

Ongoing, Contact person. Dr. Renger Dijkema (see Appendix 2)

---

*190 Stadies into waste production of intensice eel culture reccirculating systems — 1994 — Netherlands

Starting in 1992, contact Dr. Renger Dijkema (see Appendix 2)

Appendix 2

Working Group on "Environmental Impact of Mariculture"

List of WG Membership 1992

Professor Dr. H. Ackefors
Fisheries Resarch Institute
Department of Fisheries
Ministry of Agriculture
11700 Gelugor, Penang
Malaysia

Dr. D. Alderman
Fish Diseases Lab.
14 Albany Rd
Weymouth, Dorset DT 4 9TH
United Kingdom
Tel: +44-305-772137
Fax: +44-305-770955

Dr. E. Anders
Inst. of Fisheries M/V
Südstr. 10
0-2382 Born
Federal Reublic of Germany
Tel: Born 297

Mr. J. Aure
Institute of Marine Research
POBox 1870
5024 Bergen - Nordnes
Norway

Dr. E. A. Black
Aquaculture and Commercial
Fisheries Branch
808, Douglas Street
Victoria B.C. V8V 2Z7
Canada
Tel: 604-387-9686
Fax: 604-356-7280

Dr. U. Böttcher
Bundesforschungsanstalt für Fischerei
Institut für Ostseefischerei
An der Jägerbäk 2
2510 Rostock 5
Federal Republic of Germany

Dr. I. M. Davies
Marine Laboratory
POBox 101
Victoria Road
Aberdeen AB9 8DB
United Kingdom
Tel: 44 224 876 544
Fax: 44 224 295511

Mr. R. Dijkema
Netherland Institute of Fishery Research
POBox 77
4400 AB Yerseke
Netherlands
Tel: 1131 2791
FAx: 1131 3477

Miss J. Doyle
Dept. of the Marine Fisheries Res. Centre
Abbotstown
Dublin 15
Ireland
Tel: 01 8210111
Fax: 01 8205078

Mr. M. A. Dosdat
IFREMER
Brest Center
Bp 70
29280 Plouzane
France
Tel: 98 22 40 40
Fax: 98 22 45 47

Dr. (Ms) L. A. Dushkina
VNIRO
17, Verkhne Krasnoselskaya
Moscow B-107140, Russia

Ms. M. Engelstad
Ewos Aqua A/S
POBox 73
1373 Skæresletta
Norway

Mr. A. Ervik
Institute of Marine Research
POBox 1870
5024 Bergen - Nordnes
Norway
Tel: 05 23 83 00
Fax: 05 23 83 33

Mr. E. Gaard
Fiskirannasoknarstovan
POBox 3051, Noatun
FR-110 Torshavn
Faroe Islands
Denmark

Ms. F. Geoghegan
Ireland

Dr. R. Gowen
Dept. of Agriculture of N.I.
Aquatic Sciences Research Div.
Newforge Lane
Belfast, Northern Ireland
United Kingdom

Mr. K. Grave
Norwegian College of Vet. Medicine
POBox 8146 Dep.
0033 Oslo 1
Norway

Mr. E. Hoffman
Danmarks Fiskeri- og Havundersøkelser
Charlottenlund slot
2920 Charlottenlund
Denmark
Tel: 45 3162 8550
Fax: 45 3162 8536

Dr. M. Héral
IFREMER
B.P. 133
17390 La Tremblade
France
Fax: 46 36 18 47

Mr. R.Lauterbach
Institut für Ostseefischerei
An der Jägerbäk 2
2510 Rostock-Marienehe
Federal Republic of Germany

Mr. T. Mäkinen
Finnish Game and Fisheries Res. Institute
Aquaculture Division
POBox 202
SF-00151 Helsinki
Tel: +358 0 624 211
Fax: 358 0 631 513

Mr. P. Margonski
Sea Fisheries Institute
Kollataja 1
81-322 Gdynia, Poland

Mr. J. Menezes
Inst. Nacional de Investigação das Pescas INIP
Avenida de Brasilia
1400 Lisbon
Portugal

M. M. Merceron
IFREMER
Centre de Brest
BP 70
29280 Plouzané
France
Tel: 98 22 40 40
Fax: 98 22 45 48

Dr. A.L.S. Munro
Marine Laboratory
POBox 101
Victoria Road
Aberdeen AB9 8DB
United Kingdom
Tel: 44 224 876 544
Fax: 44 224 295511

Mr. C. Newell
Great Eastern Mussel Farms
POBox 141
Long Cove Road
Tenants Harbor ME 04860
USA
Tel: 201-312 6317
Fax: (8256)

Prof. F. Ollevier
Zoologisch Institut
Naamsestraat 59
3000 Leuven
Belgium

Mr. W. Pelczarski
Sea Fisheries Institute
ul. Kollataja 1
81-322 Gdynia
Poland

Mr. M.M. Roberge
Dept. of Fisheries & Oceans
POBox 5667
St John's, Nfld A1C 5X1
Canada

Prof. Dr. Dr. H. Rosenthal (Chairman)
Institut für Meereskunde an der ul.
Universität Kiel
Düsternbrooker Weg 20
2300 Kiel 1
Federal Republic of Germany
Tel. (49) 431- 597- 3916
Fax. (49) 431- 565-876

Mr. F. Ruano
Inst. Nacional de Investigação das Pescas INIP
Avenida de Brasilia
1400 Lisbon
Portugal

Mr. B. E. Spencer
MAFF Fisheries Lab.
Benarth Road
Conway Gwynedd LL32 8UB
United Kingdom
Tel: 0492 59 3883
Fax: 0492 59 2123

Dr. E. Verspoor
Marine Laboratory
POBox 101
Victoria Road
Aberdeen AB9 8DB
United Kingdom

Dr. D.Wildish
Dept. of Fisheries & Oceans
Bedford Institute of Oceanogr.
POBox 1006
Dartmouth, NS B2Y 4A2
Canada

Dr. J.C. Smith
Dept. of Fsheries & Oceans
POBox 5030
Moncton, NB E1C 9B6
Canada

Dr. J.E. Stewart
Dept. of Fisheries & Oceans
Bedford Institute of Oceanography
POBox 1006
Dartmouth, NS B2Y 4A2
Canada
Tel: 902 426 8145
or 426 3258 (Division secretary)
Fax: 902 426 7827

Appendix 3

Working Group on Environmental Impact of Mariculture

April 22 to 24, 1992

Fisheries Department, Institute for Marine Science
University Kiel
Düsternbrooker Weg 20
2300 Kiel 1
Federal Republic of Germany

Tentative Agenda

(1) Opening of the Meeting

(2) Election of Rapporteurs(s)

(3) Adoption of the Agenda
(assignment to and timing of drafting sessions)

(4) Overview on recent ICES Activities related to Environmental issues (ACMP) the status of Working Group Recommendations and TORs

(5) Tabling of Documents (Country Reports on Production trends; Reports on ongoing research programmes, Research priorities) Material to update ourTable 1 of earlier WG Reports (ongoing/completed studies on environmental issues of mariculture)

(6) Environmental Impact of Mariculture in the Baltic (an assessment). ACMP task as a response to HELCOM a request

(7) Preparation of the Technical Report on
(7.1) Chemicals used in Mariculture
(7.2) Management of the environmental impact of mariculture
Forming subgroups and membership, assigning tasks to members for both of these reports

(7.1) Chemicals used in Mariculture
- finalizing the structure and layout of the report
- editing of existing text and drafting additional sections
- formulating additional text on chemicals commonly and less frequently used)
- updating the list of chemicals (final decision on substances listed)
- reconsidering and recalculating quantities used in member countries
- discussing the general content of the "information sheets" for individual chemicals
- editing the information sheets: chemical properties, reactions, toxicity, ecological effects, concerns on resistance and toxicity of degradation products,etc)
- Drafting the concluding section

(7.2) Management of the environmental impact of mariculture

- Editing the existing text
- Reconsidering the "Decision Path"
- Final discussion on Monitoring issues
- Drafting sessions for chapters on site selection and monitoring
- Discussing and drafting a chapter on "Carrying and holding capacity"
- additional issues related to management (coastal zoning?)
- drafting the concluding chapter

(8) Reports on other international activities related to issues on Environmental Impact of Mariculture

- EIFAC Working Party on "Fish Farm Effluents"
- Outcome of the Bellagio-Conferences 1990: Environmental Impact of Aquaculture in 3rd World countries

(11) Recent relevant literature

(12) Conclusions and recommendations

(13) Miscellaneous and date of next meeting (1994!!!)

Appendix 4

Country Reports

CANADA

by

J.E. Stewart
Department of Fisheries and Oceans, Scotia and Fundy Region,
Bedford Institute of Oceanography,
P.O. Box 1006, Dartmouth, N.S. B2Y 4A2, Canada

Production Trends

Production figures presented are estimated for the year 1991.

Atlantic coast	Production (Tonnes)	Value (Can$ 000's)
Newfoundland & Labrador		
Blue mussel	1,350.3	521.7
Rainbow trout	9.1	22.7
Arctic charr	0.1	5.2
Cod	17.6	5.2
Scallop	4.4	8.0
Subtotal	1,381.5	557.8
Nova Scotia		
Atlantic salmon	284.1	2,457.4
Steelhead trout	366.3	2,000.5
Trout	66.5	301.5
Blue mussel	348.3	501.5
American oyster	121.6	154.5
European oyster	5.5	8.9
Bay scallop	5.9	8.3
Subtotal	1,198.2	5,432.7
Prince Edward Island		
Blue mussel	3,404.0	3,745.0
Oysters	1,310.0	1,689.0
Rainbow trout	37.0	394.7
Subtotal	4,751.0	6,008.7
New Brunswick		
Atlantic salmon	9,000.0	79,912.0
Rainbow trout	272.0	1,700.0
Oysters	19.0	50.0
Blue mussel	41.0	45.1
Subtotal	9,332.0	81,707.1
Quebec		
mussels	79.5	166.5
Atlantic salmon	130.0	836.9
Subtotal	209.5	1,003.4
Pacific Coast		
British Columbia		
Marine salmonids	16,500.0	100,000.0
Pacific oysters	4,500.0	3,500.0
Subtotal	21,000.0	103,500.0
Total Mariculture Production (1991)	37,872.2	198,209.7

Atlantic studies related to environmental aspects of Mariculture

1) L'Etang Inlet Aquaculture Project:

Over the past 10 years salmon aquaculture in southwestern New Brunswick has grown from a few small farms to an industry with a 1991 harvest value of about $90 million. The industry is concentrated in a relatively shallow (~20 m at high tide) coastal area which is studded with numerous islands. The flushing of this area twice each day by the large (~8 m) tides of the Bay of Fundy make this area unique among salmon rearing sites. Concerns have been expressed by traditional fishermen, scientists, habitat managers, and the general public about the potential environmental impacts of this dense concentration of caged fish. Fish farmers themselves are concerned about the adverse impacts of the large oxygen demand and the release of organic and inorganic wastes from their farming operations. A reduction in water quality could result in stressed fish that are more prone to disease and resultant reduced growth rates.

The L'Etang Inlet project was initiated in 1986 to quantify the impacts of salmon cage culture on the environment. The project, expanded in 1989 to apply biological and physical models to assess the carrying capacity of the Inlet for aquaculture, was continued. Results from field studies conducted from 1988 to 1990 were analyzed, and two papers which summarize many of the results have been submitted for publication to the *Canadian Journal of Fisheries and Aquatic Sciences* and *Marine Ecology Progress Series.*

A tidally driven two-dimensional hydrodynamic model for the area has been completed. Information collected with the aid of this model indicates that other mechanisms such as the wind and density gradients are important at the scales critical to the aquaculture industry. A new physical oceanographic model of the region will be developed using the finite element method. The problems experienced with the finite difference model of grid size and water column stratification can be more easily addressed with this approach.

Refinement of the biological models which provide a dynamic description of the flow of energy and/or carbon through a single cage and a farm site were continued. Development of a computer-based decision-support system to assist managers in the licensing and siting of aquaculture facilities was initiated.

A summary of findings to date includes:

- predictions from the hydrodynamic model of regions of poor water quality due to the accumulation of wastes;

- nitrogen input by salmon farms is four times the capacity for natural nitrogen regeneration in the area;

- benthic oxygen uptake under fish farms is as much as ten times that observed at control sites; and

- respiration of the caged salmon is many times greater than this elevated benthic oxygen demand and of the same magnitude as the natural uptake of oxygen in the sediments and the water column in the entire area.

Managers and industry fully endorsed the nature of the research and the development of the decisionandsupport system.

Anticipated completion date: 1996

2) Classification of Estuaries, Inlets, and Coastal Embayments

Contacts: D. Gregory, B.D. Petrie, R.W. Trites
Department of Fisheries and Oceans
Scotia-Fundy Region
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, N.S. B2Y 4A2
Canada

The rapidly expanding aquaculture industry in Atlantic Canada, together with continuing urbanization and industrialization as well as increasing recreational uses of beaches, inlets, and coastal embayments, is placing an increasing demand for practical knowledge and understanding of the characteristics and important processes operative in this geographic zone. Many of the uses, or desired uses, frequently occupy the same zone including aquaculture, traditional fisheries, navigation, waste disposal, recreation, etc.; and thus the probability of conflicts among the users or potential users is relatively high. At the present time, knowledge of the physics, chemistry, biology, and sedimentology of the coastal zone in Atlantic Canada is at a level which, in large measure, is fragmentary or non-existent.

The Department of Fisheries and Oceans (DFO) cannot provide detailed data on the myriad of estuaries, embayments, and inlets along all of Canada's coastline. It should, however, be in a position to provide sound advice, recommend a methodology, and evaluate the adequacy of particular environmental assessment studies undertaken by other agencies. To do this meaningfully requires that researchers are actively engaged in inshore and nearshore studies. Freshwater discharge, tide, wind, atmospheric pressure gradients, offshore forcing, precipitation, heat flux, ice, waves, swell, bathymetry, and underlying geology are all potentially important candidates in determining the oceanographic features. For some areas tidal forcing may be the dominant mechanism; for others, it may be freshwater discharge, or wind, or a combination of several factors. A cursory examination of our coastal zone indicates that many of the areas have a number of common features, such as size, shape, bathymetry, tidal range, freshwater discharge, etc. In this project, based on existing information, all of the estuaries and embayments along the Atlantic coastline should be classified. Hopefully, they could then be grouped into a relatively small number of "classes."

This project is focused on the classification analysis, and initially is ilimited to the ScotiaandFundy and Gulf fisheries regions. If it proves as valuable as anticipated, it will probably be extended to other parts of Atlantic Canada. In principle, but not in detail, the approach for the oceanographic classification is similar to that followed for the Norwegian LENKA project. The project actually began in 1990 and is being carried out in three discrete steps:

1) Assembly of the database

2) Classification of the inlets and bays of Nova Scotia, New Brunswick, and Prince Edward Island (approximately 120 inlets)

3) Verification of the classification assignments using comprehensive data available for representative bays and inlets.

The anticipated completion date is 1994.

Publication will probably take the form of a technical report, and the information should also form part of an impending Geographic Information System (GIS).

3) Phycotoxins Research Program

DFO conducts a large national research program on harmful marine algae. Thirty-three projects are currently being conducted out of laboratories based in St. John's, Nfld., Halifax/Dartmouth, N.S., St. Andrews, N.B., Moncton, N.B., Mont-Joli, P.Q., Winnipeg, Man., Sidney, B.C., and Nanaimo, B.C., under the general headings of: 1) methodology and analytical support, 2) phytoplankton population dynamics, 3) biological and biochemical aspects of toxin production, 4) uptake, storage, and depuration of toxins by marine organisms, 5) effects of toxins on marine organisms, 6) fate of toxins, and 7) physical oceanography, chemical oceanography, and sedimentology.

Population Dynamics: A 3 year phytoplankton monitoring program to acquire a comprehensive picture of the species, their abundances and successions, plus data in oceanographic features, nutrients, radiation, etc., in the Québec, Gulf, and Scotia-Fundy Regions has been completed. Upon analysis, the data are expected to be available in the form of scientific papers, and data and technical reports.

National contact:: D.C. Gordon (Bedford Institute of Oceanography); contacts for population aspects: P.D. Keizer, S.R. Durvasula, and J.L. Martin (Scotia-Fundy Region), J. Smith (Gulf Region), M. Levasseur (Québec Region), J. Forbes (Pacific Region). The results show that potentially toxic phytoplankton species are widely distributed in the Atlantic Zone. It is important that this valuable database be carefully analyzed and interpreted on a multidisciplinary basis. A few stations in each Region will be selected for long-term trend monitoring (decadal time scales). Phytoplankton monitoring at other stations will also continue on a year to year basis in support of process-oriented research projects. A Toxic Algal Bloom Alert Network has been established in the Atlantic Zone which links DFO laboratories, the Institute of Marine Biosciences, provincial agencies, and aquaculture associations.'

4.) Chemicals in Atlantic Salmon Aquaculture

Contacts: L. Burridge, K. Haya, K.G. McKeigan, V. Zitko
Department of Fisheries and Oceans
Scotia-Fundy Region
St. Andrews Biological Station
Brandy Cove Rd.
St. Andrews, N.B. E0G 2X0
Canada

The project is designed to provide continuous chemical-analytical assistance to aquaculture, both directly and indirectly via DFO, provincial agencies, commercial laboratories, and aquaculture chemicals suppliers, and consists of the development and application of analytical methods to aquaculture-related materials and products and provision of hazard identification and risk assessment.

Many chemicals are used in aquaculture, both intentionally and unintentionally. They range from feed additives such as carotenoids and antioxidants through antibiotics (currently mainly oxytetracycline, some oxolinic acid and sulfonamides), and disinfectants, to pesticides and antifouling agents.

For example, we detected that the solvent in Nuvan (an organophosphate insecticide used against sea lice) is 40% dibutyl phthalate. Dibutyl phthalate is on the Canadian Environmental Protection Act Priority Substances List. As another example, we detected an undeclared additional active ingredient (TCMTB) in a newly proposed antifouling formulation based on chlorothalonil. We are intercalibrated with the Department of Health and Welfare in the measurement of oxolinic acid. A field method for the detection of feed medicated with oxytetracycline has been developed.

5) The Cause of Summer Kill in Cultured Blue Mussels
(Begun in 1989; completed in 1990.)

Contacts: A. Mallet, C. Carver, K. Freeman
Department of Fisheries and Oceans
Scotia-Fundy Region
Halifax Fisheries Research Laboratory
P.O. Box 550
Halifax, N.S. B3J 2S7
Canada

The kill is a direct result of an overwhelming genetic component. Different stocks have widely varying thermal sensitivities. The environmental conditions, mainly temperature, imposed at different intervals will cause major kills when it is appreciably above the thermal resistance level for that particular stock.

6) The Effect of Blue Mussel Culture on the Benthic Environment in Nova Scotia and Prince Edward Island
(Actually begun in 1991 with anticipated completion date of 1993. No report available yet.)
Contact: M. Brylinsky
Acadia University, Biology Department, Wolfville, Nova Scotia.

Publication of a final report is planned for the Acadia University Centre for Estuarine Resource Publication Series.

(7) Oyster culture site selection and monitoring program for New Brunswick
Contact Person: Dr. A. Boghen, Dept. if Biology, Université de Moncton, Moncton, New Brunswick, Canada.
The project begun in 1988; anticipated completion date =1995. A collaborative program involving the New Brunswick Dept. of Fisheries and Aquaculture, Canada Dep. of Fisheries and Oceans, and the Environmental Research Unit of the Université de Moncton with the oyster growers.

The project involves a shared and detailed monitoring of oyster growing sites, relating the obtained data to the degrees of success in oyster production. Parameters measured include: oyster growth and condition, predators, fouling agents, organic loading, heavy metals, bottom type, pH, salinity, oxygen, conductivity, suspended material, chlorophyll, phytoplankton, sediments, wavers and others.

The long-term objective is to provide the basis for a permanent monitoring programm for the oyster industry of New Brunswick.

Anticipated benefits:
(1) Identification of productive and less productive sites,
(2) Identifiaction of possible prevention of problems,
(3) A more effective strategy for cmmercialization, and
(4) Better use of human resources (industry, Government and new entries).

West Coast

Finfish culture

Annual harvest of cultured salmon continues to grow on Canada's west coast. In 1991 the harvest was 16,500 tonnes up from 11,800 tonnes in 1989 and 13,500 tonnes in 1990. Since 1989 hewever, substantial restructuring has been taken place in the B.C. salmon farming industry. As a result depressed prices for salmon, the effects of poor siting and algal blooms on the cost of production and highly leveraged financial structures 26 companies were placed in recieversship.

Though virtually all of the assests placed in receivership were purchased by other B.C. salmon farms the result has been a fundimental change of the composition and the distribution of the industry. Cooperate ownership has intensified in the industry. Small family or small company farms have all but dissappeared as a result of the need for considerable financial resources to survive downturns in salmon prices. Most of the failed farms in the Sechelt area have been removed bevcause of water quality problems. This has shifted the focus of production to the North end of Georgia Strait and the West Coast of Vancouver Island.

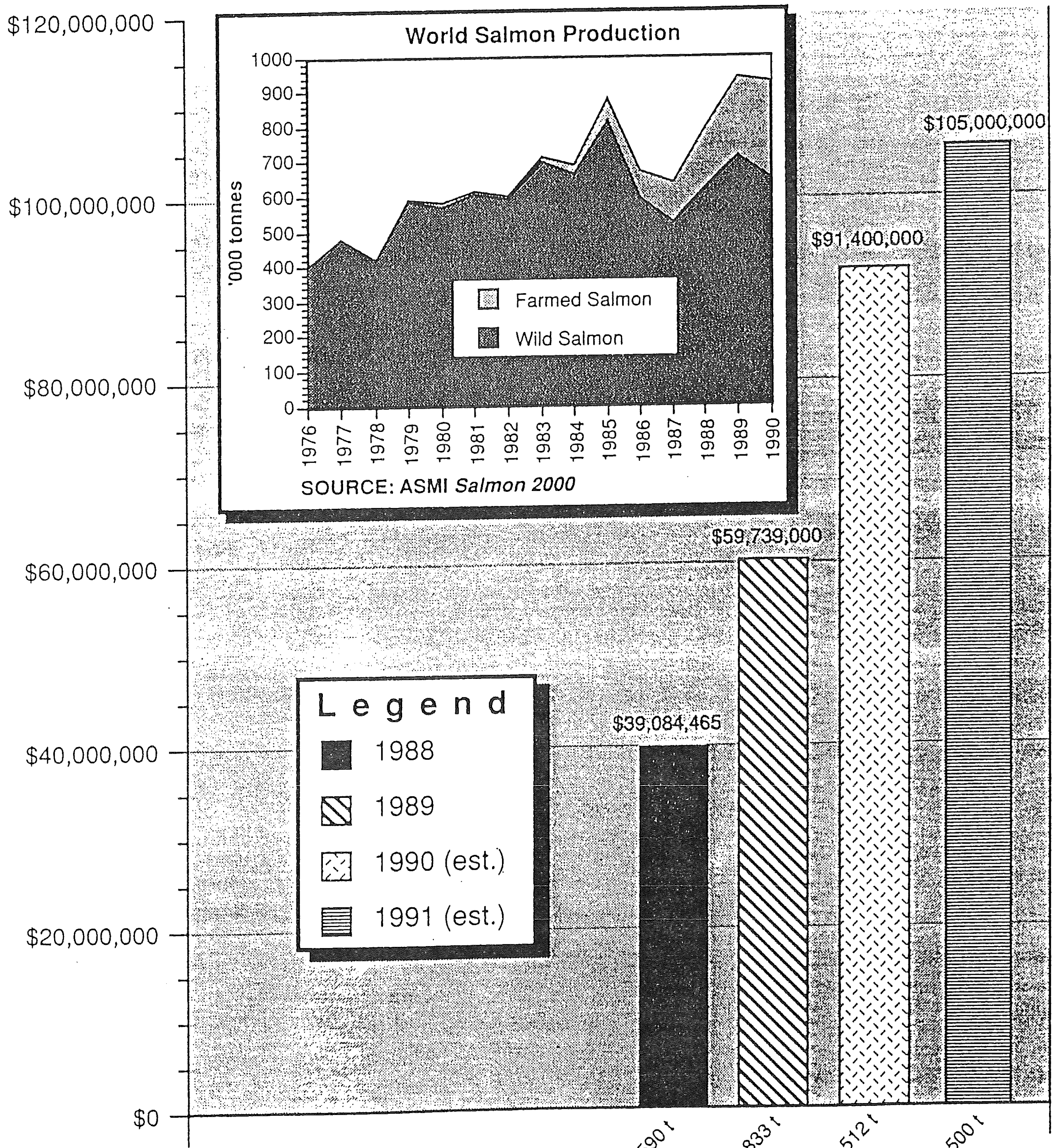
Confidence in the industry continues, in part because of growing technical expertise in the industry which has coincided with a $.36/kg reduction in the cost of production since 1989 and the development of better siting procedures and methods to limit the effect of algal blooms.

Shellfish culture

Oyster production continues to grow at a steady pace. 1991 production was 4,500 tonnes, up from 3,654 tonnes in 1989 and 4,106 tonnes in 1990. Clam production has doubled in this fledging industry from 31 tonnes in 1989 to 60 tonnes in 1991. Mussel culture has unfortunately fallen off to the point where only one farm is showing any production. The down turn in mussel production is a result of recognition of differences in the life history of the B.C. mussel compared to the mussel harvested in Europe.

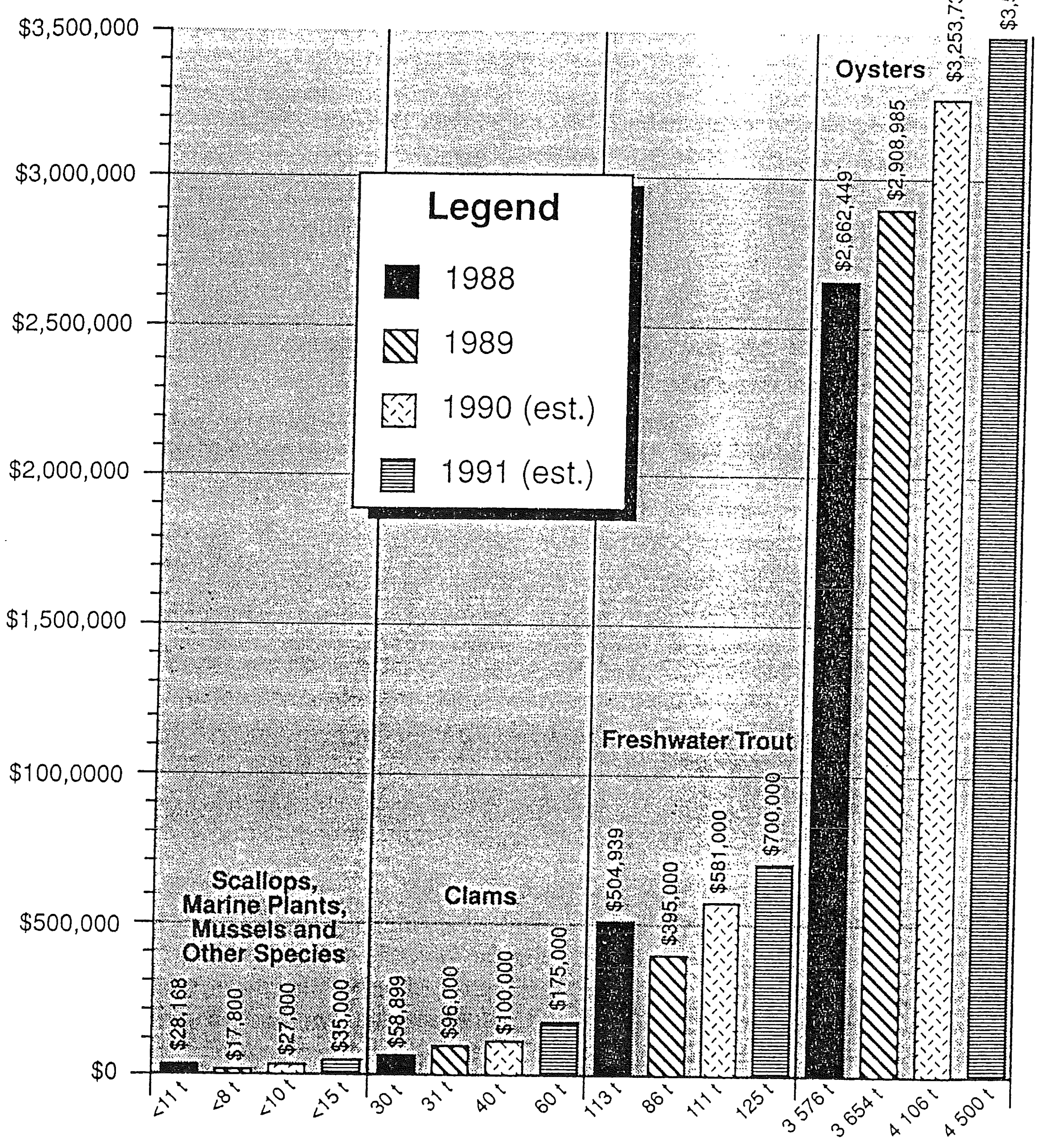
All the shellfish industries have expressed concern about the potential for water quality deterioration due to the increased urban and industrial activities on the B.C. coast.

FIGURE 1: Recent Salmon and Marine Trout Production in British Columbia (metric tonnes and farm gate value)



SOURCE: MAFF; BCSFA

FIGURE 2: Recent Shellfish, Freshwater, and Other Aquaculture Production in British Columbia (metric tonnes and farm gate value)



Total Value of Recent Aquaculture Production in B.C.

1988 — $42,338,920

1989 — $63,156,785

1990 (est.) — $95,361,730

1991 (est.) — $109,410,00

SOURCE: MAFF

DENMARK

by

Erik Hoffmann
Danish Institute for Fisheries and Marine Research
Charlottenlund Castle
DK 2920 Charlottenlund

General observations

The marine fish farming activities in Denmark are of decreasing interest in these years mainly because of strictly environmental regulations resulted mostly from political pressure. The large research programme from 1988 on the impact of marine fishfarming on the environment has finished and a report in Danish has been published in 1991 (Christensen og Horsted 1991). Some of the results are summarized in the WG report from 1990 meeting (C.M. 1990/ F:12). The results from part of the work on the effects on the wild fish population have been presented at the EAS Aquaculture Europe Conference in Dublin in June 1991 (Christensen, Hoffmann and Horsted 1991) To day no research programmes on the impact of marine fish farming on the environment are carried out in Denmark .

Marine productions

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

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

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

Stocking programmes

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

Diseases and use of chemicals

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

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

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

For several years the amount of chemicals used in Danish marine fish farming have been of unknown size. For the year 1989 the amount was estimated based on informations collected from all Danish marine farmers, see table 1. It is not out of the question that these values are too low but up till now it is the only published data. A rough estimate for the following years is that for 1990 the amount of chemicals used were higher than in 1989 and 1991 the amounts used were lower than in 1989.

Table 1: The use of chemotherapeutics in Danish marine fish farms 1989. (from Thomsen 1991)

Oxolinic acid	977	kg
Oxythetracycline	142	kg
Sulfamerazine / trimethoprime (5:1)	98	kg
Sulfamerazine	14	kg
Total	1.231	kg

In the year 1989 the gross production of marine trout in Denmark was 6.690 tons with a net production of 4.805 tons. This gives a consumption of 0.18 kg chemotherapeutics per ton of fish produced (gross production). In Norway in 1989 the same values were calculated to be 0.17 kg medicine per ton produced (Thomsen 1991).

From 1990 on the feed producers are bound to give information to the The Ministry of Health on the amount of chemotherapeutics used in the production of medical feed, but no official statistics are avaiable on this matter. The fish farmers have also to report to the local county on their production, use of feed and also the amount of chemicals used in the fish farm. Unfortunately these figures are always minimum values and the overall conclusion is that the knowledge to the quantity of chemotherapeutics used in Danish marine fish farms is uncertain.

Impact on the environment

The impact on the environment from marine fish farming activities in Denmark expressed in total Nitrogen (N) and Phosphorus (P) discharged from the farms was in 1990 calculated to be 334 tons N and 41 tons P. These figures are below the licensed values which are 522 tons N and 55 tons P.

In a recent study it has been shown that the biomass of wild fish close to two marine fish farm units were higher that in the surrounding area. Dry pellets were found in the stomachs of about 25 % of the flouders caught in the area close to the farms.

FEDERAL REPUBLIC OF GERMANY

by

Harald Rosenthal (Kiel) and Wolfgang Jansen (Rostock)

Production Trends

Aquaculture in coastal waters of the Federal Republic of Germany remains to be a small industry. Shellfish production on leased plots along the coasts of Schleswig-Holstein and Lower Saxony reached about ... tonnes in 1990 and .... tonnes in 1991. This production level was far below the long-term average and has mainly been attributed to the low recruitment of the past years. Seed mussels were not available in sufficient quantities to relay the beds as planned. Finfish production was also small with continued operation of a small cage farm located at the power station of Kiel, producing about 22 tonnes of trout ("Lachsforelle"; market size 5-6kg) and a turbot hatchery, producing around 100, 000 seedlings per season. In the new states of Germany (Mecklenburg-Vorpommern), a brackish water adapted strain of trouts is grown in offshore cages.

The unification of the two German States is accompanied with major changes which also affects the aquaculture industry. In Mecklenburg-Vorpommern the trout production in offshore cages declined for economic reasons from over 800 tonnes to an estimated 120 tonnes in 1992 grown at three sites. Stocking of common carp in the backwaters (the Bodden chain) ceased because of financial problems.

Research

Recycling systems

Several eel farms in Germany employ recirculation systems, on uses slightly brackish well-water near the Danish border of Schleswig-Holstein. These systems are of different design. Most of the small-scale units are operated by newcomers, mainly agricultural farmers who wish to diversify their production. Knowledge and skills in fish culture among practitioners are variable and often very limited. It is therefore not surprising that most of these systems failed to perform as designed. Sofar, few data exist to document the overall performance of recycling systems with regard to water quality, fish growth and production. Respective research programmes are under way.

Kiel cage performance

Cage farming in heated effluents of coastal power stations is a limited activity in the ICES area. Elevated temperatures during the cold season are believed to offer advantages along our coasts. A study of the environmental conditions at a farm site located at the effluent plume of the Kiel power station along with observations on growth performance of the fish documents the large variability in fluctuation of temperature in both micro- and macroscale around the farm (including temporary stratification). Although elevated temperatures have some benefits during the cold season, there are a number of problems associated with the prevailing conditions. For example, it is extremely difficult to calculate feeding levels from available feed tables because the temperatures used to calculate growth and feeding level are based on average values and not on the actual exposure of the fish. Variations within cages may reach 2-3°C during the day, even within hours. Additionally, temporary low oxygen values in cooler waters near the cage bottom were fish tend to stay during the warm season affects also feed conversion efficiency. This is not compensated for in the routinely performed weekly adjustments of the feeding levels and complicates the optimization of feeding strategy. The study aimed at providing means to improve the calculations on optimum feeding levels under these conditions.

Environmental aspects of cage farming

This is a recently started cooperative research programme with Scotland, Ireland and Portugal mainly concerned with possible biological effects of hydrogen-sulfide release from sediments on fish held in cages. H_2S is often released in various quantities from sediments accumulated under cage systems and may affect fish at least during slag-tide when gas bubbles are likely to hit the cages. The study will continue in 1993 and first results are anticipated before the end of the year.

Effect of intermittant (tidal) oxygen depletion on Pacific salmon

Within the German-Canadian cooperation programme in aquatic sciences a study was undertaken on behaviour of Pacific salmon in relation to oxygen fluctuation and currents in cages. Both environmental parameters vary greatly in tidal zones and oxygen depletion is often greatest when tides are turning. This holds in particular if oxygen depleted water passes back through the cages. The study includes both, field and laboratory observations. It is intended to develop an ethnogram that permits to identify early warning signs in stressed fish.

Sedimentation of solids under cages in a non-tidal inlet (Kiel Bay)

The effects of a floating cage farm next to an effluent of a power plant in Kiel Bay was studied during the summer 1991, using underwater video and sediment and benthos samples. Changes in sediment geochemistry and in benthos composition have been demonstrated under the farm but failed to occur in nearby control stations. Organic enrichment under the farm, which is in operation for more than 10 years, showed a factor of 1.5 to 3.5 compared to the control station. Degradation rates were determined from core samples, indicating oxygen uptake and carbon release rates in the order of 100 to 150 mmol $m^{-2}d^{-1}$ during summer.

FINLAND

by
Timo Mäkinen, Helsinki

1. Production and number of fish farms

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

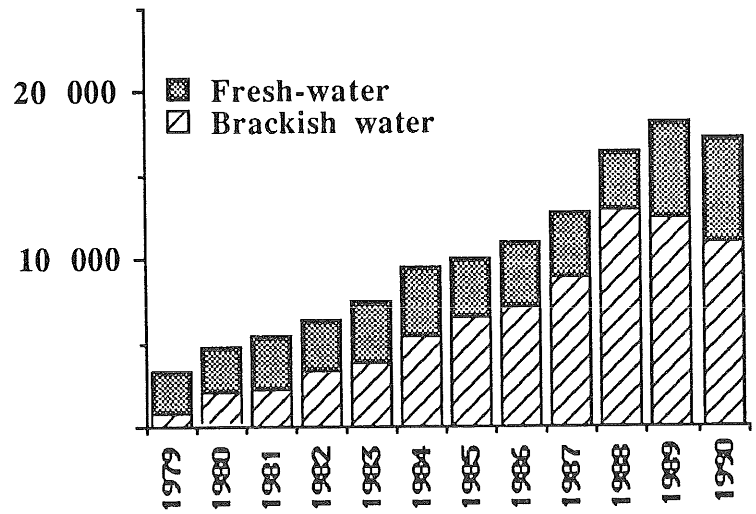


Figure 1. The production amount of rainbow trout in Finland in 1979-1990

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

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

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

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

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

In 1990 the output of salmonids (Salmo and Salvelinus sp.) for stocking and on-growing at the age of one summer or more was about 14 million. The corresponding number for whitefish species was 38 million, for other fish 16 million (grayling, pike, pike-perch, cyprinidae and burbot) and for crayfish 66 000. The value of the input was about 38 million USD, 70-80% of which for stocking (Appendix 1).

2. Fish diseases

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

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

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

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

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

3. Research regarding fish farm effluents

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

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

A new project aiming to promote the use of herring as raw material for the feed used in the Baltic aquaculture in order to reduce the nutrient loading coming to the Baltic Sea from outside the region was started in 1990. Because there is no manufacturing of fish meal based on the Baltic herring fishery must the use of herring be based on the direct use of the fresh fish. For this reason it was as a first step studied the effect of the herring content in the feed on the growth and the consequential nutrient load in rainbow trout farming.

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

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

The project is going on and will strive to examine how the compensation of the low energy feeds could be improved and the growth of the fish increased, how the local loading could be decreased and how the use of herring as feed would effect the economy of the farming.

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

4. Use of antibiotics in Finnish aquaculture

The estimated minimum of antibiotics used in 1991 in Finnish aquaculture is following (Koski 1992):

Antibiotic	Pure substance (kg)	Amount of fish treated (t)[1]
Oxytetracycline	470	630
Oxolinic acid	275	1 960
Sulfametoprime	150	500
other sulfa products	100	50
Total	995	3 140

1) Estimated on the basis of ten days treatment with usual dosage

If estimated according to the amount of the medical feed reported to manufactured by the feed factories the amount of antibiotics used has been in 1988 2 178 kg and in 1990 740 kg. In the southwestern region of Finland was used in 1989 at least 1 141 kg antibiotics. The values are estimated to be the minimum values of the use. Small amount of antibiotics goes directly from the veterinary practices to use at farms. Calculated per tonne produced fish the above mentioned figures means 40 - 50 g of antibiotics. In Norway in the same year the figure was about 234 g (Miljöhåndbok for fiskeoppdrett).

Reference

Koski, P. 1992. Kaloille käytetyt mikrobilääkkeet. Esitelmä kalaterveyspäivänä 25. 3. 1992, 2 s.

Fish Culture in Finland 1990

Appendix 1.

Food fish production[1]

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

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

Production capacity

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

Output of juveniles[1]

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

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

Value of juvenile production:

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

FRANCE

by
Antoine Dosdat
IFREMER

1. Production estimates 1990/1991

Salmonid marine production has reached a fairly steady level in recent years, attaining about 1,200 tonnes in 1991 (1,100 t in 1990). This production includes the following species:

Rainbow trout	800 t
Atlantic salmon	300 t
Brown trout	100 t

Marine salmon farming in France is undertaken in one large ongrowing plant only and is located at a fairly offshore site, using a converted tanker. The project, which was planned for more an annual production of more than 600 tonnes, reduced its output in response to the drastic decline in market price.

In relation with environmental problems (high temperature and high salinity during summer), new operations using brown trout began in 1990 and 1992, with an anticipated production of about 1,700 t targetted for 1994. This production will partly replace rainbow trout farming. Brown trout appears to be a species that is best adapted for farming in French coastal areas. Although assumed to be promising in the early 1980s, coho salmon production has disappeared in the early 1990s.

Cultivation of other species focused on 3 major species :

Sea bass *(Dicentrarchus labrax)*	700 t
Sea bream *(Chrysophrys aurata)*	30 t
Turbot *(Scophthalmus maximus)*	60 t

The production of these species is expected to increase during the next year, particularly for turbot farming higher yields are anticipated since for four large farms have recently been completed in 1990 and 1991. The production from these farms is estimated to reach 400 t within the next two years.

The number of fry produced in French hatcheries in 1991 was as follows:

Sea bass and sea bream	11 500 000
Turbot	500 000

Juveniles of these species produced in France are mainly exported to Italy and Greece (sea bass), and to Spain (turbot).

- Shellfish production in France reached in 1991 the following tonnage:

Oyster *(Crassostrea gigas)*	135 000 t
Mussel *(Mytilus edulis)*	60 000 t
Manilla clam *(Tapes japonicus)*	500 t
Flat oyster *(Ostrea edulis)*	1 000 t

Flat oysters are always threaten by parasites, and the production remains low. The development of manilla clam production is limited by a pathogenic bacteria *(Vibrio* sp) and the concurrence of fishing of that species who develops on both atlantic and Mediterranean coasts. Hatchery production of Manila clam spat had been 30 millons of juveniles, and scallop production still remains at a pilot scale. 20 t of *Penaeus japonicus* are still produced in southern France.

Seaweed production of the brown algae *Undaria pinnatifida* on the Northern Brittany coast reached 60 t in 1991. For market reasons, the increase of that production, which is for human consumption, will be low.

2.Use of chemicals

In samonid farming, the use of antibiotics during 1991 was about 50 kg of oxolinic acid, 50 kg of tribrissen and 20 kg of OTC. The major part of the rainbow trouts produced in France is vaccinated against vibriosis by injection. 90% of the vaccinated fishes are fully protected.

The treatment of ectoparasitic copepods, especially in brown trout farming during the summer, pure dichlorvos is applied in short term bath (usually for a few seconds). No dichlorvos is released into the environment.

For other species, the evaluation is much more difficult. This comes from the great number of little farms and the absence of centralised data. The estimation given by the veterinarian control is of 500 kg of nitrofurane, 200 kg of OTC, 50 kg of oxolinic acid and 50 kg of sulfamid. A major problem is the use of human antibiotics, without any control in the hatcheries, which is far to be neglected, but cannot be assesed. Formalin and malachite green are also used, respsctively 1000 kg and 50 kg a year.

3.Research programms.

Two main research programmes related to environmental issues are presently reported as ongoing in France:

3.1. Determination of carrying capacity for molluscs.

This project is the continuation of an earlier programme which aimed at modellinf of the Marennes-Oleron Bay in order to manage the shellfish stocks and to asses the productivity of the ecosystem in relation to human interventions such as dam construction on the Charente River or dredging activities in the Bay. Three compartments had been integrated in the model. These include phytobenthos production, sedimentological processes and dissolved substances. The design of several of the boxes within the model will have to be improved further (number and shape). It is hoped that with the calculation of mass flows between the identified boxes, the computation of the transport of particulate matter throughout the bay can be sufficiently described.

3.2. Interactions between finfish farming and environment.

This new research programme will deal with two main subject areas that attempt to model the nutrient levels in effluents from fish farms and evaluate the impact of these nutrients on the environment. This programm will run for the next four years and considers in particular sea bass, turbot and brown trout farming. Nutritional requirements and water treatment operations will be new research subjects. Physical models for water circulation and biological models for determining the primary production will also be applied. Sedimentation models will be developed together with a shellfish model. Several sub-projects are detailed in Appendix 1, among which the environmental impact of chemicals in relation to shellfish culture is an important issue considered by this Working Group.

The programm on the effect of the environment on summer mortalities of farmed Atlantic salmon has come to end. It did not demonstrate good correlations between mortalities and environmental factors such as temperature, salinity, dissolved ammonia, dissolved carbon dioxyde or light level.

IRELAND

by

Jacqueline Doyle
Fisheries Research Centre, Dublin

1. PRODUCTION TRENDS

1.1 Salmonid production increased further despite continuing high losses due to pancreas disease, sudden death syndrome and resistant strains of furunculosis.

1.2 The development of offshore sites using large flexible cages continues.

1.3 Production of rope culture mussels also increased. Protracted closures were necessary due to the presence of Diarrheic Shellfish toxin (DSP) from May to November/December. A new toxin was identified in 1990 DTX-2 (Hu et al. 1992) in collaboration with Canadian colleagues.

Production of native oysters has been affected by Bonamia disease.

Production trends (Tonnes)	1987	1988	1989	1990	1991	1992
Atlantic Salmon	2,232	4,700	6,200	6,271	8,690	(9,350)
Rainbow trout (marine)	320	500	200			

2. ADMINISTRATIVE MEASURES

2.1 A report was commissioned on the data collected from the mandatory monitoring programme to assess the impact of fin fish farming on the nutrient status, phytoplankton biomass and benthic ecosystem in Irish coastal waters (Gowen 1990). The data base was computerised and updated and provides useful information for site management.

2.2 All applications for Aquaculture licences for production in excess of 100 tonnes of fin fish are the subject of Environmental Impact Statements. These include *inter alia* choice of site, characteristics of the site (sediments, water quality, hydrography) production processes of the operation, quantity and type of emissions (organic, nutrient and therapeutic). Potential impacts on sediments and water quality, potential impacts on other resources (commercial activities - shellfisheries, tourism, wild and sport fisheries, recreational, landscape, flora and fauna) and measures envisaged to avoid, reduce and remedy impacts. The documents are available for public consultation and comment.

2.3. Inspections are carried out on all fish farms to ensure compliance with Aquaculture licences.

2.4 In 1991 a sea-lice monitoring programme was developed to follow the fluctuations of sea lice numbers and their population structure on cultivated salmon and is ongoing in 1992 (Jackson and Minchin 1992).

2.5 The water quality monitoring programmes have been supplemented by annual site audits including sediment quality impacts of benthos and underwater photography of sites.

2.6 Fallowing and harrowing of impacted sites and single generation production sites are encouraged.

2.7 Analyses for chemical and anti-biotic residues are routinely carried out.

3. RESEARCH PRIORITIES

3.1 Effective sea lice treatments
3.2 Studies on fate of chemicals and antibiotics in the environment
3.3 Studies on carrying capacity of sites including modelling
3.4 Waste minimization and site management techniques

NETHERLANDS

by

Renger Dijkema
Netherlands Institute for Fisheries Research, Yerseke

Production trends

Season 1991-1992:	**Mussels *(Mytilus edulis)***	**41,000**	**Tonnes**
	Cockles *(Ceratoderma edule)*	**13,000**	**Tonnes**
	Flat oyster *(Ostrea edulis)*	**200**	**Tonnes**
	Cupped oyster *(Crassostrea gigas)*	**1,000**	**Tonnes**
	Rainbow trout *(Oncorhynchus mykiss)*	**25**	**Tonnes**

Molluscs

In the Waddenzee, heavy storms swept a large portion of the mussel *(Mytilus edulis)* stock from the culture plots, as well as from the wild mussel beds. In combination with successive years of failing recruitment , this strongly decreased the national production of mussels in 1991/1992, which dropped to around 40.000 tons (provisional figure), almost exclusively originating from the Oosterschelde.

Also recruitment of cockles was very low during the last 3 years and consequently, the biomass of bivalves which can serve as food for overwintering birds dropped to very low levels. Increased mortality was observed among eider ducks and other bivalve- consuming birds like oystercatchers. Fishery for seedling mussels by the mussel growers and cockle fishery are blamed for contributing to this mortality.

Production of the European flat oyster *Ostrea edulis* has decreased to a level of about 1 Mio oysters in 1991 due to mortality after outbreak of bonamiasis in 1988.

Production of the Pacific oyster *(Crassostrea gigas)* is increasing slowly. The production in 1990 was about 1,000 tons or 9 millions of oysters. The development of *C. gigas* in the Oosterschelde, after its deliberate introduction for culture purposes in 1964 has, during the last few years, strongly been enhanced by a succession of warm summer periods, creating favourable conditions for recruitment. *C. gigas* now appears to have extended to sublittoral mussel culture plots, and this poses some problems to mussel growers.

The effort of the fishery for seedling mussels for the culture plots has grown considerably during the last 20 years as a result of increased size and engine power of the ships of the mussel growers and the additional deployment of shallow-drawing cockle dredgers for mussel seed fishery. This development has increased the fishing pressure on wild mussel beds in the tidal zone of the Waddenzee, which can be destroyed by dredging. This development has made nature and fishery management agencies to decide to temporal or permanent closure of areas in which seed mussels are regularly fished in the intertidal zone.

Finfish

Only one commercial project for rainbow trout culture in sea cages is in operation in the Oosterschelde, producing about 20 tons per year. There is one commercial, recirculating eel farm using salt ground-water, all other farms (about 20) use fresh water.

Research activities

Mussel culture

In the Netherlands, a study into the impact of the construction of a flood barrier on mussel culture in the Oosterschelde estuary was concluded. A mathematical model, "SMOES" (Simulation Model Oosterschelde Ecosystem), describing interactions between natural and cultivated mollusc stocks and the ecosystem has been validated and calibrated. Although the possibilities of the model for direct fisheries and ecosystem management are modest, it provides a basic view on the relations between primary production and food supply for filter feeders and their production in the situations before and after the completion of the barrier, which has caused a reduction of current speed and tidal exchange in the estuary. The total grazing pressure of the filter feeders in the ecosystem appeared to be limiting for bivalve production in the new situation, which means that, in periods in which large wild stocks of filter feeders, predominantly cockles *(Cerastoderma edule)* and mussels, *(Mytilus edulis)* coincide with large amounts of mussels sown on the culture plots, production and condition index (= meat yield) of borh wild and cultivated bivalves may decrease as a result of food competition. This is an argument not to increase the bottom surface area for mussel cultivation in the Oosterschelde.

Studies into new locations for mussel culture in the Waddenzee and the Oosterschelde, using experimental culture plots, have been concluded. The results have completed the information, necessary for relocation of a number of culture plots in these areas.

Culture of turbot in recirculating systems is still carried out at an experimental scale. Preparations are made for a pilot-scale experiment.

Ongoing research programmes

Molluscs

An ecosystem model for the Waddenzee: EMOWAD, which is, amongst others, aimed at describing the role of wild and cultivated mussel stocks in the area, is being updated.

Fish

At the Netherlands Institute for Fishery Research (RIVO) in IJmuiden, a program has started to study the composition of the rearing water and effluent of commercial recirculating systems for eel culture as a function of factors like stocking density, feeding, water treatment and farm management. The program is aimed at reducing the pollution load of the effluent, for which water authorities are increasing discharge charges. As this situation also applies to discharges into the coastal waters, the obtained information can be relevant for seawater aquaculture.

For the only cage-farm for rainbow trout in the country, located in a semi-enclosed area in the Oosterschelde, which has a yearly production of 20 tonnes, a study has been undertaken to assess its environmental impact. Organic waste and nutrient production as well as oxygen consumption are being monitored.

NORWAY

by
A.Ervik and J. Aure
Bergen

The Norwegian aquaculture production is about 60-70% of the world production of farmed Atlantic salmon.

The extremely fast growth rate in Atlantic salmon production during the last few years in Norway and internationally has led to a substantial over-production. This has resulted in marketing problems. Many farmers are accused to have responded with dumping sales, escalating the fall of prices, thereby contributing to the reduced profitability of the industry. As a result a number of bankeruptcies have occurred.

Production trends for Atlantic salmon and for rainbow trout are summarized for the period 1981-1991 in the following Table.

Year	Salmon	Rainbow trout	Total
1981	8.422	4.484	12.906
1982	10.265	4.689	14.954
1983	17.017	5.270	22.287
1984	22.300	3.636	25.936
1985	28.694	5.139	33.833
1986	45.452	4.288	49.740
1987	47.198	8.746	55.944
1988	80.522	9.352	89.874
1989	115.433	3.845	119.278
1990	158.147	3.528	161.675
1991	155.000	5.655	160.655

The prognosis for the production trends over the next few years indicate a decrease and a leveling out of the production. At the end of 1992 there might be an under-supply of fresh salmon in the market.

The production cycle for salmon ranges between 5 and 7 years from the production of brood stock until harvesting of market sized fish. This long lead time makes it difficult to predict and adjust the production level ahead of time in order to meet the marked demand.

The studies and management of the environmental impact of mariculture has focussed on key issues, espescially on the control of use of chemicals, on the genetic influence of cultured fish on wild stocks and on the spread of diseases.

In general, the opinion of the aquaculture industry regarding the environmental issues tends to be negative one. Environmental restrictions are expected to become one of the major regulating frameworks of the industry in the 1990`s .

UNITED KINGDOM

Scotland

by
Ian M. Davies, Aberdeen

Production trends

In 1991, salmon production was undertaken by 163 companies (171 in 1990), operating at 365 sites. The total production was 40,593 tonnes (32,350 in 1990). The overall survival of 1989 year class smolts was 57.9%, but this is predicted to rise to 67% for the 1991 year class.

20.2 million smolts were placed in the sea in 1991 (21,4 million in 1990, 24 million in 1989). There are trends within the industry to use reduced stocking densities, regional fish health management agreements, fallowing of sites, etc., for which preliminary indications suggest beneficial results in both reducing lice infestation and furunculosis outbreaks, and reducing the resistance of lice and the furunculosis bacterium to treatment chemicals. These, and other factors, suggest that production will remain around 40,000 tonnes until at least 1994.

The relatively small industry growing rainbow trout in salt water produced 178 tonnes (537 tonnes in 1990).

Shellfish cultivations was carried out by 310 registered businesses, of which 110 farms produced shellfish for sale, either for ongrowing or for consumption. The production for consumption in 1991 was 184 tonnes of Pacific oysters (115.3 in 1990), 9.8 tonnes of native oysters (0.1 tonnes in 1990), 1024.3 tonnes mussels (461.5 in 1990), 61.2 tonnes queen scallops (52.8 in 1990) and 37.9 tonnes scallops (8.2 in 1990).

A particular problem during 1991 was the occurrence over a wide area of algal toxins, which severely limited the freedom of businesses to market their product. As a result, a high proportion of active businesses reported zero production for the year.

Technology and Management Developments

Over the past year or so there have been a number of developments, mainly arising from the need to control problems of disease. There is a general tendancy towards lower stocking densities of salmon in cages - densities are now normally not above 15 kg/m^3. It is more common now for sites to be confined to single year classes of fish, which therefore requires a larger number of sites to be available. Larger companies may commonly have sufficient sites to undertake the rotations of stock, but a number of smaller companies have had to apply for additional sites to achieve saparation of year classes. A further advantage of single year class sites is that a site will naturally have a fallow period between the harvesting of one stock and the introduction of the next. This allows some degree of recovery of impacted sediment on the sea bed, and also may work to break the cycle of infection by diseases or parasites.

The advantages of breaking disease cycles has been extended into management agreements between companies which occupy sites in the same sea loch, and therefore have the potential for cross-infection. Such agreements commonly stipulate that all operators should introduce and harvest stock at the same time, and should exchange information and coordinate action to combat disease and sea lice. These agreements have been shown to be beneficial.

Environmental, social, and other pressures and conflicts with other interests, are all seen to be acting to limit further development of fish farming in the inner parts of sea lochs. The Crown Estate Commissioners, who issue sea bed leases for fish farms, have therefore identified 25 coastal areas (mainly sea lochs) which they classify as Very Sensitive Areas, within which there is a presumption against new finfish farms. The number of areas may be increased in the near future, and increases made in the requirements for formal Environmental Satements for new or expanded sites in these areas. A likely effect of these policies is that it will become much more difficult for farmers to find new or expandable sites in the very sheltered waters of sea lochs. This will force companies to look for potential sites in more open coastal waters.

England and Wales

by
Brian Spencer

Bivalves

Production trends

Cultivated *Crassostrea gigas* and *Tapes philippinarum* are produced solely from commercial hatcheries. The two commercial hatcheries together produce about 100 million juveniles per year of which about 75% are exported overseas.

Production of *C. gigas* is about 300 tonnes per year and expected to expand now that the industry is regaining its confidence since the ban on TBT for use on small boats was imposed. *T. philippinarum* production is less than about 50 tonnes per year with interest in its cultivation centered in the south coast.

Natural production of *Ostrea edulis* in the Solent, the main producing area, is about 200 tonnes per year. This source remains Bonamia-free and is used for relaying in other areas of the coast.

Natural production of Mytilis edulis is about 4000-5000 tonnes per year. The Wash, on the east coast remains the main producing area with smaller quantities coming fron the Menai Strait and other estuaries.

Research

Aspects of hatchery research contains some elements of investigation into nutritional requirements of juvenile and adult broodstock of *Crassostrea gigas, Tapes philippinarum, T. decussatus* and *Mercenaria mercenaria.* A large emphasis is directed towards the production of sterile non-native species, mainly *T. philippinarum* by inducing triploidy by treatment of the newly fertilized eggs with cytochalasine B. This is intended to reduce the potential for non-native species to establish themselves in England and Wales and to take advantage of the reported additional advantages of faster growth, improved meat quality and palatability, and greater heterozygosity.

A field programme has been started to measure the effect on the sea bed of *T. philippinarum* grown in intertidal ground lays covered with plastic netting. Changes in soil composition, and benthos are being compared with those in control plots.

A ten-year programme to assess the enhancement of a lobster fishery by the release of hatchery-reared juveniles is more than half-way through. About 50 000 micro-tagged lobsters have been released during a five-year period into a fishery on the north-east coast. A five-year monitoring programme has been established to detect the recovery of tagged adults caught by commercial potting.

Design of artificial reefs (aperture sizes etc.) is receiving some attention in relation to stocking with hatchery-reared juvenile lobsters.

UNITED STATES

By

John B. Pearce and Carter Newell.

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

GULF OF MAINE (GOM)

Mussel bottom culture developed in Maine in the early 1980s, growing to a production of 1,000 tons of mussels/year by 1987. The growth of this industry has been hindered by a lack of knowledge of site-specific factors relating to mussel growth and yield. To address such issues, a model has been developed which considers tidal current speed, water depth, mussel seed size, time of year seeded, the annual food curve including phytoplankton and detrital carbon, seeding density, boundary layer mixing, mussel food ingestion, and basic physiological parameters to give an output of mussel final meat size, shell size, and shucked meat yield (e.g., pounds of meat/bushel). This will allow farmers to optimize yield and predict site production based on controllable parameters such as size of mussel seeded, seeding density, density distribution and time of year seeded.

To support the model, a variety of experiments have been performed to address estuary-scale (horizontal) and vertical scale (cm) distribution of food particles available to mussels. Time-series measurements during spring and autumn with underwater video showed tidal rhythms of mussel shell gape. Vertical particle profiles in the benthic boundary layer showed the importance of settled pelagic and resuspended benthic diatoms, as well as enriched organic carbon in the 5-10 cm above the bed region on the edge of the lease sites. Measurements of scope-for-growth in the field and investigations of mussel fieeding selectivity using a flow cytometer illustrated the sensitivity of mussel feeding to natural ranges in total particles, silt, and phytoplankton in relatively clear Maine waters. Finally, a particle depletion model was tested to predict seston depletion over a 1-km lease site, and different seeding strategies were investigated to improve mussel growth in inner-lease site locations.

Areas needing further investigation are:

The role of water stratification in limiting the effective water depth over the mussel beds from which food particles are obtained;

the role of the production of particle flocs in increasing the settling rate of particles which become available to the mussel bed; and

the role of resuspension in recycling near-bottom organic matter, increasing the food supply to mussels (for additional information contact C. Newell) .

Other shellfisheries/aquaculture activities in the GOM include the participation of several companies in model programs for seafood inspection and increased testing of products to encourage consumer confidence. The American oyster industry in the Damariscotta River area, Maine, using a combination of suspended tray culture of hatchery-reared seed, followed by one to two years on the bottom, has grown. Production may rise to five million oysters/year by 1997.

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

Net-pen salmon culture has reached near record levels for production per unit area. About five million smolts will be transferred to sea cages this year. There is some concern that production may now exceed the present market, resulting in depressed prices and profits. In spite of this the business continues to expand. The industry is the number two producer of revenue, on a dockside basis, of Maine fisheries. In 1990, salmon production in Washington State was 2,750 metric tons compared with 2,250 tons in Maine. A rapid increase in Maine production to 5,000 tons was achieved in 1991.

MIDDLE ATLANTIC BIGHT

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

Hard clam *(Mercenaria mercenaria)* culture has expanded in New York and New Jersey. One bay alone in New Jersey is producing 35 million clams per year. Towns on Long Island have constructed or are planning clam hatcheries, the major purpose of which is to augment <u>public</u> fisheries in town waters. Several of these hatcheries also are working with *C. virginica,* and bay scallops, *Argopecten irradians irradians.* Private clam culture is prevalent in New Jersey, where leasing of intertidal areas is allowed (Gregg Rivara, Cornell Cooperative extension, Riverhead, NY). Relaying of clams from uncertified waters to certified areas, with subsequent harvest after a depuration period, has also expanded.

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

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

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

CHESAPEAKE BAY

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

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

o Annual oyster survey to determine the level and prevalence of oyster diseases
o development of rapid diagnostic methods for studying prevalence and distribution of *Perkinsus marinus* and *Haplosporidium nelsoni*
o study of *in vitro* osmotic efects on "MSX" as a consequence of rapid salinity change and
o determination of whether non-indigenous species of oysters, as the Pacific oyster *(Crassostrea gigas),* are more resistant to MSX and "DERMO" than the American oyster. Preliminary results indicate that this is not the case.

SOUTH ATLANTIC

Mariculture companies have recently built extensive facilities (among the largest in the world) to culture hard clams in the Carolinas, Georgia, and Florida. Pond culture of shirmp is becoming more popular.

GULF COAST

Louisiana is the nation's leading producer of *Crassostrea virginica.* Most production is from private leases to oystermen from the state. The Louisiana Department of Wildlife and Fisheries (LDWF) manages public grounds and seed beds. Seed beds are public water bottoms upon which cultch is planted to encourage the attachment of spat. Typically, as spat grow to seed, seed oysters are transplanted to private leases and grown to commercial size.
The LDWF is the primary management agency for the resource. Most oyster research is conducted by universities. Recent research includes:

o Alternatives to clamshell as cultch for oysters,
o parasitological surveys,
o hatchery and deupration technology,
o remote setting of larvae,
o genetics and breeding,
o bioenergetics
o bioeconomic models, and
o new indicators of sewage pollution, including bacteriophages

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

Crayfish and alligator cultures are increasing in Louisiana.

WEST COAST

Washington State is the nation's leading producer of oysters *(Crassostrea gigas)* using remote setting and bottom culture. Production of Manila clams, and more recently mussels, continues to be an important part of hatchery production. Recent discovery of domoic acid in West Coast razor clams has stimulated increased monitoring activities by regulatory agencies. Mussel raft culture in Puget Sound produces about 250 metric tons per year. Nets hung from the rafts reduce duck predation.

Low meat yield in some oyster growing areas has stimulated interest in determinations of carrying capacity and the effects of expanding *spartina* populations on nutrients available for phytoplankton. Most oysters are triploid.

Production of abalone as well as that of a variety of fish species continues in California.

Appendix 5

Technical Report on
"Management of the Environmental Impact of Mariculture"
Draft Chapter on "Modelling"

Table of Contents: Chapter 5

5.0 Modelling

5.1 Definitions

An important management tool to assist in the limitation of the environmental change resulting from mariculture operations is the use of models to predict the impact. Such models can also be used to aid mariculture development. Thus, such models allow a potential impact to be compared with predefined standards; decisions may then be made of the proposed development made. Models may also be used to optimise farm productivity.

It is important to distinguish between large scale and site specific models. In the case of the former (see for example, Hakanson et al, 1986) the overall suitability of an area for mariculture is considered. Such models might provide an insight into the most important potential impacts in an area, but quantification of an impact requires a site specific model.

Since the severity of an environmental impact is dependent on the interaction between an operation and local environmental conditions (such as fish stocking densities and current speed), by their nature, site specific models require information on the physical, chemical and biological characteristics of the chosen site. The need to acquire site specific information might be viewed as a limitation of this type of model. However, at the present time there is no alternative.

A second important distinction is between models to predict the carrying capacity of a coastal area and models to predict holding or assimilative capacity. The carrying capacity of a coastal area refers to the potential maximum production a species or population can maintain in relation to the available natural food resource. An example would be the phytoplankton and detritus available to shellfish. In addition, such a model would provide an assessment of the impact of shellfish farming on the amount of phytoplankton and detritus available to other filter feeders and assist in managing the cultivated stocks of shellfish.

The holding capacity relates to the level at which production becomes directly limited by a resource such as oxygen availability. Eutrophication and benthic enrichment can also limit production and although these two effects may not be regarded as trophic resources, they are more appropriately considered as relating to holding capacity than carrying capacity.

In practice, it is unlikely that managers will wish production to increase until the carrying or holding capacities are exceeded. In both cases, the sustainability of the cultivation operations will be jeopardised. The carrying and holding capacities will therefore in most cases represent undesirable extreme levels of production.

In considering the acceptability of a mariculture operation, it is likely that managers will have other constraints in addition to the sustainability of the project. These may arise from other actual or potential uses of, or objectives for, the waterbody, which themselves may require certain environmental quality. The satisfaction of these other objectives may be sensitive to the recognised potential effects of mariculture. For example, managers may wish to limit nutrient release to ensure that algal production is not stimulated, or avoid releasing medicinal chemicals in such quantities that would cause unacceptable effects in the surrounding ecosystem. Modelling specifically directed at processes relating to these other constraints then becomes necessary. For such modelling to be useful, the managers must have quantified standards, targets, or guidelines for environmental parameters against which to assess the results of the models. The limits represented by these standards or targets define the assimilative capacity of an area.

5.2. Models to Predict Carrying Capacity

Carrying capacity models may be divided into global models concerned with production levels of populations, and analytical models concerned with growth rates of various stocks in relation to food availability. Both are mainly applied to mollusc populations.

5.2.1. Global Models

Global models are based on the population dynamics of the cultivated species. The production yield is permitted to follow the balance between the cultivated biomass and the available food. The relationships between annual production, cultivated biomass, growth rate and mortality rate are used for building a global dynamic model, utilising historical data. These models predict the maximum annual production that an area can support (Heral et al, 1986). This technique is readily applied, and can provide a method of management which prevents the stock exceeding the biomass which is necessary to reach the maximum potential production. Advantages of the use of such models include an improvement in seed to harvest yields and individual growth rates, and reductions in the length of the breeding cycle, in chronic mortalities and in the risk of disease. This empirical approach, however assumes that the the ecosystem is stable, ie that there is no long term temporal change. This type of model cannot, therefore, predict the response of the ecosystem to anthropogenic modification.

5.2.2. Analytical Models

The aims of analytical models are to predict the growth rate of molluscan populations as a function of the quantity of food available and the cultivated biomass. The study of trophic relationships can be classified in terms of the level of complexity of the coupling between physical and biological models and the number of biological compartments. Some models are multi-compartmental, designed with the residual fluxes between the compartments.

The transport of the particulate food is simulated by modelling advection and vertical diffusion. The time-scale can be in the order of a day and the spatial scale one hundred meters (Bacher 1990). As a starting condition, the amount of available food can be either be assigned arbitrarily or by a primary production model (Menesguen 1989). It is necessary to undertake a very intensive sampling programme to obtain field data of sufficiently high precision (Heral et al 1988), and particular attention must be paid to the large variability in the availability of food in coastal areas. The results of the models permit simulation of the evolution of the growth rate of mollusc populations of different biomasses. On the other hand, if a growth model is coupled with a phytoplankton model the combination can provide information on nutrient fluxes and their impact on the shellfish populations. In this way, sub-models can be developed (Raillard et al, 1991), such as primary production models, box models, energy budget, and hydrodynamic models. The validation of the whole model is of primary importance. The physical aspect of such models may be considered in general terms, with the ecosystem represented by a large box where residual fluxes and mean residence time are the main physical parameters (Incze et al, 1981, Heral et al, 1988, Bacher et al, 1990, Carver and Mallet 1989, Frechette, 1990, Rosenburg and Loo, 1983). In recent models (Newell and Campbell, 1992), physical model outputs are coupled with physiological models to predict spatial variations in growth rates within coastal embayments.

The analytical models of growth rate are generally based on equations of the energetic budget (Bayne 1976) . All the different terms (consumption, respiration, assimilation, dissolved and particulate excretion) are deterministic, that is, measured as functions of the temperature, the allometric relation with the weight, and the quality and the quantity of the food (Bacher 1989). Short term variations in feeding rate provide uncertainties in these models in areas where tidal transport of food is important, and have been recently sampled by underwater time lapse video

(Newell and Gallagher, 1992). Wildish and Kristmanson 1979, Verhagen (1986) Small et al (1986) and Frechette et al (1989) have all drawn isodepletion curves of the system as functions of the biomass, food concentration and the current velocity. The model of Frechette et al (1990) has been recently developed to simulate growing conditions at lower density mussel culture sites. The particulate food supply was found to be most sensitive to changes in water depth and a dimensionless parameter obtained by dividing bed filtration rate by the bottom shear velocity, U^* (Geyer, Sankar and Newell, 1992).

Another approach is to model predator-prey relationships, and this has been applied to mussel rafts by Wiegeit and Perras-Ludo (1982). These models, however, can only be applied in enclosed areas where there are no pulsed inputs of allochthonous material. Furthermore, the ecosystem must be in an equilibrium.

Models of carrying capacity for molluscs can also provide an assessment of the impacts of the culture on the environment. For example, the filtration activity of cultivated molluscs can cause a decrease in the phytoplankton population. Some molluscs have the ability to sort particles, for example by size, and could bring about changes in the species composition of the phytoplankton. Selection of algal particles over inorganic particles may result in a decrease in food quality to downstream populations (Newell et al, 1989). The recycling of dissolved substances excreted by shellfish could also contribute to the selection of particular species (Vincendeau,1987). Finally, large scale intensive molluscan culture has been shown in some circumstances to compete with and depress zooplankton populations. (Tenore et al, 1985).
Figure represents the interactions between the differents models in the way to manage this man built ecosystem.

5.3. HOLDING AND ASSIMILATIVE CAPACITY MODELS

Holding or assimilative capacity models have been developed with the aim of minimizing adverse interactions between the cultivated species and the waterbody or bottom sediments in the area.

5.3.1. Introduction

Holding capacity models for finfish cultivation usually involve two distinct stages. Firstly, models of a mainly physical nature are used to describe the distribution and dispersion of waste materials such as feed, faeces, nutrients, parasiticides and antibiotics arising from the farm. The second stage is concerned with modelling the response of the ecosystem to the inputs from the farm. The responses may be described in chemical terms (eg changes in dissolved oxygen levels) or biologically (eg changes in benthic faunal characteristics or phytoplankton populations). The significance of the responses may be assessed in relation to the effects of the predicted changes on the farmed species (holding capacity) or effects on the surrounding ecosystem (assimilative capacity). Models may be constructed on various scales, from small scale models concerned with processes and effects within the fish cage, to intermediate scale models covering perhaps a few tens or hundreds of metres round the farm (for example, decribing the distribution of solid waste in a low energy environment). On larger scales, models may address effects on whole inlets or bays, or even be concerned with the wider influences of aquaculture on coastal systems.

The first stage models are usually essentially mass balance models, driven by some function describing the release (or consumption) of material from the fish within a cage or farm, and normally rely heavily on hydrographic modelling to describe advective and dispersive processes within the waterbody. The first objective is normally the estimation of the distribution of specific waste materials such as nutrients or particulate organic matter.

Mass balance models coupled to a simple dilution term have been successfully used as management tools in freshwater (both for aquaculture and other industrial development) (Dillon and Rigler, 1975). The Dillon and Rigler type mass balance model has been successfully applied to some coastal estuaries (Lee and Jones, 1976). However, it should be borne in mind that the models were used in river estuaries in which strong salinity stratification and the net out-flow of the surface brackish layer equate with summer thermal stratification of, and river out-flow from limnic waters and with the river out flow. It is clear that such narrow requirements do not often match the environments used for mariculture, for example fjordic inlets, or more open coastal embayments. In many situations, therefore, this relatively simple approach is not applicable. It may also be noted that simple mass balance models fail to take into account the possibility of incomplete dispersion in large limnic waters (Chapra, 1979).

5.3.2. Modelling of hydrographic processes in large tidal embayments

The development of finfish culture in less protected areas, such as large coastal embayments, requires the adaptation of modelling tools for the assessment of the proposed maricultural activities. Such modelling tools already exist, and can be applied relatively easily. The assessments are based on the necessary hydrodynamic specifications for the site of the activity. Complications of the effects of sills on hydrodynamic models are not considered here.

Regions of poor water quality due to accumulation of wastes can be assessed in this way, and consequently the best areas for fish farm development identified. The resuspension of sedimented material cannot yet be well predicted in the longer term.

5.3.3. Modelling of hydrographic processes in fjordic inlets

Finfish cultivation is practised in fjordic inlets in several ICES membe states . Although to some extent estuarine in character, fjordic inlets are characterised by an entrance sill and one or more internal sills. The presence of one or more sills is the essential distinguishing feature separating fjords from other coastal inlets or embayments. The presence of an entrance sill acts as a barrier to the penetration of saline water into the inlet from the more open coastal areas, and this has a major effect on the hydrography of the inlet. The deep water in the inlet may become partially isolated from the water outside the sill, and have relatively long residence times, and therefore have the potential to accumulate nutrients and develop reduced oxygen levels. The degree to which such isolation occurs, and the susceptibility of the bottom water to deoxygenation, is of particular significance in the suitability of fjord basins for aquaculture. Dillon and Rigler type models cannot readily be applied to such situations, and the now common models of circulation used in pollution control in non-fjordic estuaries normally cannot take account of the influence of the dramatic bottom topography of fjordic inlets.

5.3.4. Sub-models

A family of models, developed by Canada's DFO and BIO, to represent environmental impacts adjacent to fish cages provides evidence for the use of integrated submodels. A model representing the physiology of a single fish (FISH) calculates oxygen consumption, ammonia generation, feces production and wasted food. The sum of processes at a particular farm comprise another model (SITE) which passes to a sedimentation model (SETTLE), and finally to a water quality model called FARM (Silvert, 1992).

5.3.4.1. Hydrodynamics

In hydrodynamics, mathematical models are sequences of calculations solving the Navier-Stokes equation, using the finite element method. Detailed knowledge of the bathymetry is necessary. Two-dimensional models are at pesent an essential tool in marine studies, and are generally sufficient in areas where mixing is good. Three dimensional models are appropriate to studies concerned with vertical movement and the influence of wind stress. In this particular case, even if 3-dimensional models appear to be necessary, 2D models can give reasonable results when limited to short periods. For good precision, reliable and accurate meteorological data are necessary. Another possible way forward towards depth discrimination is the development of layered finite difference models, in which the water column is considered in (usually) 2 - 4 homogeneous depth intervals.
The types of 2D and 3D models outlined above give very precise information on current speeds, water levels, and concentrations of dissolved substances. As these models provide Lagrangian flows and instantaneous speeds, they may be coupled with other interacting submodels.

Working in Scotland, Turrell and Gillibrand (1992) noted that while it is possible to develop complex two-dimensional numerical models of the depth-dependent circulation in Scottish sea lochs, the effort required to establish such models for individual sea lochs is considerable, and that routine advisory work on potential aquaculture developments requires simpler approaches. They therefore developed a series of simplified models of advection and diffusion to address particular aspects of the required advice. In doing so, it was necessary to make certain assumptions, the most significnt of which were that each sea loch system could be described by a characteristic flushing time. These can be calculated for any fjordic inlet using information on low water volume, surface area at high and low water, and the tidal range, all of which can normally be obtained from hydrographic charts, and applying methods described by Edwards and

Sharples (1986). The results of such calculations have been confirmed to be applicable to near-surface non-stagnant water in several sea lochs. A second assumption is of the existence of a surface mixed layer with a distinct lower interface, and that contaminants released into this surface layer do not mix with the water below. In practice, some limited exchange with deeper water will occur. Turrell and Gillibrand normally select a mixed layer depth of 5 metres, and note that Edwards and Sharples (1986) found that 88% of the sea lochs that they studied had mixed layer depths of less than 10 metres. The majority of the soluble material released from fish farms will enter this surface mixed layer, particularly sea lice treatments (dichlorvos). Finally, an advanced two-dimensional research model is under development which avoids the assumptions noted above, but derives these parameters from wind and tidal forcing, freshwater input, and salt input from outside the loch. The model calculates surface elevation, current velocity, salinity, vertical velocity and density. The model has been found to adequately simulate observed vertical structure of tidal currents under various conditions in Loch Sunart.

Aure and Stigebrandt (1990) decribed general principles underlying circulation in fjordic inlets. They recognised three main forcing mechanisms. Firstly, an estuarine mechanism is found which is driven by the input of freshwater at the head of the fjord. This forms a discrete surface brackish layer which moves out of the fjord, and a compensatory inflow of saline water occurs below this. The magnitude of the estuarine circulation is governed by various factors including the freshwater discharge, wind stress, the surface area and width at the mouth of the fjord. Secondly, the rise and fall of the tide in the adjacent coastal area "pumps" water in an out of the fjord. The volume of water concerned again depends upon various factors, including the tidal range and the topography. This mechanisms causes the greatest input of turbulent energy to the fjord. In some cases, water which leaves a fjord or sea loch on the ebb tide may partially return with the following flood tide. This has the effect of increasing the actaul flushing time, and thereby increasing the potential for the accumulation of contaminants in the water. Thirdly, circulation can arise from variations in the density field of the coastal water. In Norway, such changes result from the combination of strong vertical stratification and variable upwelling or downwelling driven by wind stress. Observations indicate that this mechanism can efficiently force water exchange between coastal waters and water at intermediate depths in adjacent fjords.

5.3.4.2. Dissolved matter

5.3.4.2.1. Nutrients

Models of the dispersion of dissolved substances (eg nutrients, dissolved chemicals). Resolution of the St Venant advection-dispersion equation permits calculation of the dispersion (Salomon et al, 1988). The relative importance of advection and dispersion may differ between sites types. In particular, information has been provided on the potential increases in ammonia levels in Cherbourg Rade (Salomon and Breton, 1990) over a tidal or seasonal cycle.

Turrell and Gillibrand (1992) describe models addressing the equilibrium enhancement of nutrient (ammonia) levels in a sea loch that would result from continuous release of nutrient into water of constant flushing rate, treating the nutrient as conservative. This approaches the assessment of the potential for hypernutrification, and can rank lochs on this criterion. It does not go on further to consider the potential for these nutrients to be converted into algal biomass and possible eutrophication, a question that needs to be addressed through more complex ecosystem models.

5.3.4.2.2. Parasiticides

A model which calculates the maximum amount of dichlorvos that might be used per year in each sea loch, such that the concentration of dichlorvos does not exceed an annual mean environmental quality standard. This EQS value has been derived from a wide range of ecotoxicological data, and is designed to prevent the occurrence of chronic toxic effects on the natural fauna of the sea loch. This is directly applicable to the management of aquaculture development, and can result in constraints upon the farmers in their use of this medicine. The reported current usage of dichlorvos in each loch may then be compared with the quantity derived from the model, and assessment made of those lochs where reductions in usage would be particularly desirable, and those where dichlorvos usage should not present a limitation to further development.

The above two models were concerned with the effects of the farm on a loch-wide scale. On a smaller scale, it is necessary to consider the short-term concentrations of, particularly, dichlorvos, around fish farms, so as to ensure that short-term acute toxic effects do not occur. This requires a different modelling approach, which considers both the dispersive processes leading to dilution of the patches of dichlorvos released after sea lice treatments, and the advective (mainly tidal) forces moving the patches about the inlet. Advection is simulated by a particle-tracking approach representing both residual sea-ward drift and oscillatory tidal movements, and diffusion using standard two-dimensional Gaussian equations. This model has been applied to field studies of the movement of dichlorvos away from fish farms (eg Davies et al, 1991).

5.3.4.2.3. Oxygen

In Norway, research projects have been investigating the effects of fish farming in fjords on eutrophication of the upper water layer (above the sill depth), and on the increased oxygen consumption in basin water (deep water dammed in the fjord below sill depth) (Aure and Stigebrandt 1990). The study was based upon measurements from a large number of Norwegian fjords as well as upon recent theoretical developments (mathematical/empirical fjord models). A framework for the computation of the environmental loading of nutrients, and oxygen demand caused by farm sediments, was also developed.

Aure and Stigebrand concluded, based both on direct field observations and from modelling, that fish farming in Norwegian fjords results in only small elevations of nutrient levels in the upper water layers. The reason for this is that the intensive water exchange between the coastal water and the fjords tends to equalize the conditions in the two regions.

On the other hand, if a fish farm is located over a sill basin, the farm sediment will increase the oxygen consumption in the basin water. They also developed a method to compute the response of the minimum oxygen concentration in water in sill basins to fish farming (The "R-method").

Stigebrandt and Aure (1989), on the basis of the same measurements, demonstrated how to model the vertical turbulent energy from information about the tidal amplitude, the topography of the fjord and the vertical stratification. The vertical turbulent exchange is vital factor influencing the diffusive supply of oxygen to the basin water, and determines the rate of density decrease in the basin water, which in turn determines the frequence of water renewal in fjord basins.

Oxygen consumption of sediment has been modelled by Wildish et al (1990).

5.3.4.3. Particulate matter

For shellfish cultivation purposes, mass balance models have been developed to quantify the flux of phosphorus and nitrogen between the water column, cultivated oysters and the sediment (Sornin et al. 1986; Feuillet et al. 1988). The quantity of sedimenting faeces and pseudo-faeces can be modelled as a function of the concentration of the available food, and dispersion can be simulated as a function of the settling velocity of particulate waste and current speed. However, such models commonly neglect the possible resuspension of biodeposits under the suspension cultures, which will both redistribute the waste material, and contribute to the availability of food. Resuspension is governed by a number of factors including critical erosion velocities, current speed, wind-induced turbulence and other water movement. These processes have only recently been successfully modelled. They have been shown to be an important part of the food supply to bottom cultured mussels (Campbell and Newell, 1992).

A general model of the dispersion of particles and suspended matter has recently been developed (Salomon and Pommepuy, 1990). This model shows that the rate of death of bacteria and viruses can be altered, and it was possible to demonstrate very long survival times (14 to 40 days, Le Hir et al, 1989). The settling rate of particles, the deposition rate and resuspension must also be taken into account. At depths of less than 20 metres, resuspension caused by swell could occur.

The uneven flocculation of fine particles make further improvements in the model difficult, because of the great variations in the settling velocities of the resultant compound particles. However, rough estimates can be made based upon the calculation of the particle distributions and natures over one or more tidal cycles, and the surface of the envelope enclosing them, so that the thickness of the deposit can be assessed.

Applied to finfish culture, factors that are important in modelling the sedimentation of particulate feed waste and faecal material below fish cages include:

a) the rates of waste production
b) the water depth, which may vary with tidal state
c) the current velocity, and its variation with time
d) the spectrum of settling velocities of waste particles

Organic loadings are generally high below fish pens in relation to background levels but are restricted to the general vicinity of the farms. Some comments have already been made above on the application of finite difference models to the prediction of the pattern of distribution and settlement of particulate waste. In addition, Gowen et al (1989) developed and tested a model of the horizontal displacement, and therefore distribution on the sea bed, of waste particles in a Scottish sea loch. Recent studies in Maine and Canada have recorded slower rates of accumulation of organic matter due to:

a) the need to take into account lower rates of waste feed pellet production, and accumulation, due to hand feeding resulting in less wastage, and consumption of pellets at or near the sea bed by fish and crabs;

b) resuspension and transportation of particulate organic material by tidal currents in areas of erosional sea beds;

c) resuspension and transportation of settled particles during storms in areas open to wave swell.

Although successful as an initial approach to particle modelling, improvements to the simple model of Gowen et al (1989) may be possible to take into account factors such as:

a) the range of settling velocities present in fish farm waste, and the distribution of the waste by weight within that range

b) vertical variations in the water current velocity field

c) effects of the cages themselves in altering the velocity field

d) the significance of wave action in the dispersion of waste.

The use of two-dimensional flow models, a simple model of vertical variations in horizontal currents (Lardner and Cerkinge, 1988), a Lagrangian particle tracking model, full 3-dimensional models and wave models will be compared in order to improve predictions of the sedimentation under fish pens at culture sites (Panchang, Richardson and Newell, 1992).

Arising from field and modelling studies of the types mentioned above, environmental managers in Maine, USA, have established criteria for the minimisation of the biological effects of sedimentation. In order to minimise organic enrichment of the benthic environment, they require that the minimum separation distance between the bottom of the fish pen and the sea bed at mean low water is at least 3 metres, and shall equal or exceed Z, where

$$Z = 0.0003(P) - 0.425 (V) + 31$$

where P = production in pounds weight per year
V = current speed (cm/sec) between the net pen bottom and the sea floor.

5.3.4.4. Modelling the effects of nutrient enhancement on primary production and the wider ecosystem

Several of the modelling strategies discussed above are able to predict the distribution of nutrients (mainly ammonia) released from fish farms. While the degree of nutrient enhancement has been used as a criterion for management decisions regarding fish farm operations, the main cause for concern over nutrients is their potential to lead to enhanced phytoplankton growth (eutrophication) of benign or harmful species.

Numerous models of primary production now exist (eg Billen and Lancelot, 1988; Fransz, 1985; Jorgensen, 1986). In the Netherlands, the SMOES (Simulation Model Oosterschelde Ecosystem) was used to predict the effects of changes in riverine nutrient input and tidal current velocities on phytoplankton and benthic filter feeder production (Scholten, 1991). The DUCHESS two-dimensional physical model (Delft Hydraulic Laboratory, Netherlands) and the SENECA ecosystem simulation model (Delta Institute, Netherlands) provide easy to use models with user's manuals.

The simplest models attempt to reproduce the nitrogen cycle without considering remineralisationin the sediment. More sophisticated models simulate nirogen, phosphorus, and silicon cycles, taking into account exchange with the sediment. Most models deal with chlorophyll biomass coupled with a Lagrangian model of residual circulation. There is little field evidence to indicate that fish farming has resulted in increased production of phytoplankton or macroalgae. Gowen and Ezzi (1992) clearly demonstrated nutrient enrichment around a fish farm in Loch Hourn, Scotland, but did not find that it was converted into plant biomass. However, primary production in an area has been modelled, it is possible to predict the oxygen content of the waterbody, in relation to consumption by the fish and benthic activity. Other modellers seek to develop primary production models to aid in understanding the causes underlying the species successions seen in pelagic ecosystems. As yet, it is not possible to predict this succession in detail, or, more particularly, to predict the occurrence of blooms of harmful species.

In some areas, complex models of primary production are not necessary to investigate the impact of nutrient release on, say, the oxygen consumption in bottom water. In such cases, it is sufficient to assume that all nitrogen added to the system is converted into phytoplankton biomass, whioch later settles towards the sea bed. However, in other situations, such as that described by Gowen and Ezzi (1992), such an assumption is evidently unrealistic, and alternative approaches must be considered.

Research in hand (SOAFD, Aberdeen) aims to combine models of physical processes and of biological processes to describe to nitrogen cycle in a large Scottish sea loch system (Loch Linnhe). The model takes into account advective fluxes of water, and associated nitrogen, into and out of the system, and of exchanges between water masses and sediment within it. Onto this physical model, a biological model has been built which considers phytoplankton, zooplankton, and carnivores, and the fluxes of nitrogen and carbon between them, the water, and the sediment. The programme is designed to provide a combined physical and biological model, which can be adapted to other sea lochs, and which can be used to explore the effects of introducing various amounts of ammonia (in simulation of nutrient release from fish farms) at various new farm slocations in the loch under consideration.

5.3.4.5. IMPACTS ON THE MACROBENTHIC COMMUNITY

While there have been numerous studies of the flux of carbon and nitrogen through salmonid farms to the benthos (e.g. Gowen and Bradbury, 1987), and numerous studies of the effects of organic enrichment on the benthos (Pearson and Rosenberg, 1978; Weston, 1990), there is a need to couple models of the flux of organic matter to quantitative changes in community structure. Trends observed along increasing gradients in rates of organic enrichment include:

a. decreases in species richness
b. general reductions in biomass
c. some biomass increases in opportunists (e.g. Capitella)
d. body size decreases of individuals
e. reduction in the depth of habitation of the infauna
f. changes in trophic guilds

Weston (1990) quantified changes in mean areal species richness, total community biomass and total community abundance with distance from a large salmon farm in Puget Sound, Washington. Work in progress (Watling and Findlay, Univ. of Maine) is examining changes in community structure at contrasting sites:

a. erosional, high current sites
b. sites impacted by wave-induced resuspension
c. sites where organic accumulation occurs

Coupling of models of the production of particulate waste feed and feces, waste transport to the bottom, and benthic community responses should be a research priority in future studies.

More complete models of secondary benthic production are under development (Chardy, 1988). In coastal areas, secondary production is largely dependent on the organic input, and models of population dynamics can provide production/biomass relationships. Recent models seek to introduce the bacterial compartment both as a trophic source, and as a component in the remineralisation of organic material.