Mariculture Committee

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REPORT OF THE

WORKING GROUP ON ENVIRONMENTAL INTERACTIONS OF MARICULTURE

Montpellier, France
15–20 March 1999

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1999 Meeting of the ICES Working Group on Environmental Interactions of Mariculture

Montpellier, 15-20 March 1999

1. Opening of the Meeting

The 1999 meeting of ICES WGEIM commenced at 0900 hours on 15 March 1999 at the offices of the Languedoc-Roussillon Region in Montpellier, France. The meeting was opened by M Madalle, Vice-president of the Region with responsibility for marine production, and head of the aquacultural unit (CEPRALMAR), who welcomed the WG to Montpellier on behalf of M Blanc, President of the Regional Council. On behalf of WGEIM, the Chairman, Ian Davies, thanked the Region for their hospitality.

The meeting was attended by members from six countries, with support from one other through fax and e-mail. Several other regular participants were unable to attend through illness or other engagements. Apologies were received from Harald Rosenthal, Ed Black, Timo Makinen, Hans Ackefore, Peter Burbridge, and Eva Roth.

The WG particularly regretted the absence of participants from Portugal, Spain and the Netherlands. Portugal has several nominated members but they have rarely attended. There is no member from Spain. WGEIM considered that it would be particularly beneficial to have participation from the Iberian peninsular where pond/tank culture was much more common then in N Europe and where some forms of co-cultivation occurred. It would also be valuable to have a member nominated from The Netherlands particularly in view of the important mussels production in The Netherlands. Mariculture Committee are asked to encourage both the nomination of members by Spain and The Netherlands, and the attendance by participants from as many countries as possible.

2. Adoption of the Draft Agenda

The draft agenda was accepted without alteration, although during the meeting some additional items were added to "Any Other Business".

3. Arrangements for the Preparation of the Report

The Chairman explained that, in common with all ICES WGs, WGEIM would be required to agree the recommendations and main points in their report by the end of the meeting. IFREMER and the Regional Council were thanked for providing word processing, fax, copying and Internet facilities to assist in this task.

4. Reports on:

4.1 National Production Trends

This section summarises some aspects of production trends. More complete information can be found for each country in Appendix 3.

4.1.1 Scotland: Shellfish production in Scotland (1997) is still on a relatively small scale, and dominated by mussels (1,307 tonnes) and oysters (2.8 million) and was increasing only slowly. Marine biotoxins were a serious hindrance to harvesting during the summer months.

Salmon production had increased by 19% to 99,197 tonnes in 1997. The input of smolts to sea increased from 32.9 million to 42.8 million, and it would be anticipated that this will be reflected in increased production in 1998 and 1999. However, the impact of Infectious Salmon Anaemia on production in 1998-99 has not yet been assessed.

4.1.2 Canada

a) Atlantic Canada

Production of fish is still dominated by salmon, but had decreased by 20% in 1998 as a consequence of ISA. Mussel production (1997) had increased by 10% to 13,000 tonnes, and American oyster production was now 4,500 tonnes. Scallop production was small (109 tonnes) but increasing.

b) Western Canada

The production of salmon in BC in 1997 was 40,500 tonnes, compared to 27,600 tonnes in 1996. Rainbow trout production had fallen to 150 tonnes from 800 tonnes in 1996. There had been little change in the production of shellfish (Pacific oyster, clams, scallops).

4.1.3 Ireland: Salmon production amounted to 15,400 tonnes, but would probably increase to 25,000 by 2002. Mussel cultivation by rope (6,700 tonnes) and bottom methods (10,000 tonnes) was also important. A particular difficulty had arisen over a new biotoxin which had been found in three areas and which persisted for up to eight months over the winter.

4.1.4 Norway: Salmon and rainbow trout production in 1997 was 36,4000 tonnes and in 1998 386,000 tonnes. Changes in quality of stock, feed quality, and other husbandry measures had greatly improved the productivity of the farms and reduced the production costs.

4.1.5 France: Molluscs continue to dominate French mariculture. 150,000 tonnes of oysters had been produced, although the growth rate had been poor in 1998. Mussel production had amounted to 60,000 tonnes and there was increasing use of long-line systems (now 15% of the total) despite difficulties with sea bream predation on rope mussels. Strains of flat oysters were being developed with resistance to Bonamia and Martellia. The production of sea bream and turbot in the sea was increasing, but that of trout had fallen. The total fish production in salt water was 6,000 tonnes, of which 650 tonnes were salmon.

4.1.6 Germany: Aquaculture remains a small activity in Germany. The main production of shellfish is mussels, and amounted to 16,000 tonnes in 1998. Production is expected to increase in the future in response to a good spatfall in 1998. Other species, including fish, are produced at a very low level.

4.1.7 Sweden: The overall trends in production in Sweden for the last five years have been for an increase in Arctic char production, decrease in rainbow trout, and little change in other species. In 1997, 75% of the total rainbow trout production (4,875 tonnes) was in fresh water, with 25% in the sea. 1,425 tonnes of mussels were produced in 1997.

4.2 Significant National and International Meetings

4.3 Significant New Research Results and Directions

The meeting did not separate these items from other areas of discussion, and relevant information will be found under other Agenda items and in the Appendices.

5. Development of a Programme of Work Related to the Objectives of the Mariculture Committee, the Marine Habitat Committee, ACFM and ACME

As introduction to this agenda item, Maurice Heral, Chairman of the ICES Mariculture Committee (MC), gave a presentation on the development of forward plans by ICES Committees. He listed the objectives of the MC as follows:

- increase of mariculture production;
- sustainable development of mariculture;
- breeding and reproduction techniques;
- diversification of the production (species and techniques);
- genetic improvements;
- international broodstock of cultivated species;
- disease control and epidemiology;
- introductions and transfers;
- ecological impacts (positive and negative), including inter-specific effects;
- interactions of mariculture with other users, and coastal zone management in relation to mariculture;
- environmental interactions.

These objectives would be addressed through:

- study groups;
- working groups;
- workshops;
- symposiums;
- the Annual Science Conference, including Theme Sessions;
- publications - ICES Journal, Cooperative Research Reports, reports, newsletters
- e-mail, website;
- cooperation with international organisations, such as EAS and WAS;
- European Union.

The current task before WGEIM was to clearly identify their fields of expertise which would contribute to these aims, and to develop a framework within which they could work for the next five years or so.

The reports of WGEIM were also considered by ACME and Marine Habitat Committee (MHC) in addition to the MC. In developing a proposed programme of work, it was necessary that WGEIM bear in mind the objectives of these Committees, particularly the MHC. The objectives of MHC are:

- Development of a toolbox to assess marine habitat quality.
- Development of a classification system for marine habitats of coastal areas, continental shelves and the open seas, including habitat mapping.

- Development of knowledge on the importance of biological diversity to the functioning of marine ecosystems.
- Development of knowledge on the effects of anthropogenic contaminants on habitats and dependent living resources.
- Enhance knowledge of marine monitoring methodology in relation to the well-being of marine habitats.

Following discussion of the presentation by Maurice Heral, the WG noted that the Objectives within the MC Five Year Plan could be considered in two groups, with two general aims and a series of Objectives which described how MC (and its WGs) would seek to meet the aims. The WG considered that the more general aims/objectives of MC were:

1. Increase of mariculture production.
2. Sustainable development of mariculture.

Within these aims/objectives, the main areas in which WGEIM considered that it could contribute to the work of MC were:

a) diversification of the production (in terms of the environmental interactions of new species or new technologies);
b) ecological interactions;
c) the interactions of mariculture with other users of the sea, and coastal zone management in the context of mariculture.

From this assessment, the WGEIM went on to develop a generalised series of topic areas within which it could work, and within which more specific items for Terms of Reference for individual meetings could be positioned to ensure that ICES maintains a source of information in these areas and progresses the Objectives of the MC and MHC (in particular).

1. **Collation of Information on Production Patterns**

This information is not currently available to ICES through any other route and describes the basic structure of resource utilisation on which the rest of the work of WGEIM (and MC) must be based.

2. **Meeting Specific Requests for Information From ICES or Other International Bodies**

The WG recognise this as a fundamental aspect of the work of ICES as a whole.

3. **Review of Information on Technological Change in Mariculture, Including the Utilisation of New Species, with Particular Emphasis on the Consequences for Production and the Environment**

This item meets the need to have adequate awareness in these areas of implications of current and likely new developments in the mariculture industries.

4. **Review of New Research and Monitoring Programmes**

The emphasis in this task would be making accessible to member countries the products of completed programmes which might not be readily available (eg in the Grey literature), and the review of the trends and directions in research and monitoring priorities to inform MC and member countries of developments in scientific opportunities and activities, and public attitudes and concerns.

5. **Review of Monitoring Activities**

The purpose of this item is to ensure awareness of new environmental concerns, new monitoring targets and new monitoring methods as an aid to ensuring that mariculture is undertaken in sustainable ways.

6. **Review Issues of Sustainability in Mariculture, Including Interactions Between Mariculture and Other Users of Resources in the Coastal Zone**

The aim in this item is again to support the development of mariculture in ecologically (in a broad sense to include other human activities) sustainable manner. One of the approaches that would be to incorporate mariculture in ICZM structures.

6. A Plan to Obtain Information on the Effects of Mariculture Activities in the Baltic Sea

The Working Group had been requested by MC to develop a plan to obtain information on the effects of mariculture activities in the Baltic Sea with the aim of producing material by April 2000 as a contribution to a chapter on "Baltic fish stocks, diseases and ecosystem effects" for the HELCOM Fourth Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1994-1998 [HELCOM 1999/3].

Anders Alanärä introduced the subject as follows:

From a physical perspective, the Baltic Sea offers great potential for aquaculture activities. However, other factors influencing the possibilities to run aquaculture are less encouraging. Large areas of the coastline are used for recreation and tourism, as well as by pleasure crafts and commercial shipping. In addition, many of the best areas for fish farming activities contain summer houses and permanent settlements, which often fight strongly against any new activity that may influence the surroundings. The biggest problem for aquaculture in the Baltic is, however, the eutrophication process that have escalated the last 20 years, with regular algal blooms in the most exposed areas and oxygen free deep-water areas. As a consequence, HELCOM declared in 1988 that the discharges of nutrients (and other pollutants such as heavy metals and toxic or persistent organic substances) should be reduced by 50% by the end of 1995. The implication of this, at least in Sweden, has been that the Swedish Environmental Protection Board and local environmental authorities became very restrictive towards any new activity that could add more nutrients to the sea. This was of course devastating for most new aquaculture initiatives along the Swedish coastline.

All this must, however, be put in the perspective that aquaculture activities account for an extremely small part of the total load of nutrients into the sea. The total aquaculture production of fish in the Baltic amounts about 20,000 tonnes per year, where Finland accounts for about 15,000 tonnes and Sweden for about 2,000 tonnes. If the nutrient load from fish farming is compared with the total load from all countries surrounding the Baltic, the load correspond to less than 1% of the total. Fish farming is, from an environmental point of view, a very small contributor compared to other sources. Despite the overall negative situation in the Baltic, there are many areas along the coastline that have good water quality and are very little influenced by eutrophication. In addition, in many of these areas, the unemployment rate is high and the population has declined. Politicians and other organisations have suggested aquaculture as one activity that could create working possibilities in such areas.

A big issue is if the Baltic can be restored from environmental pollution and, at the same time, be used as a resource for production, eg aquaculture. This is a very difficult question for local environmental authorities to handle, and that's probably why they often choose to protect instead of promoting licences (the "principle of precaution"). For example, the Swedish Environmental Protection Board has in an official publication from 1993 stated that the nutrient load from fish farming in the Baltic could reach 100 and 700 tonnes of phosphorus and nitrogen, respectively. This corresponds to a production of about 15,000 tonnes of fish per year. Problems occur, however, when this nutrient "allowance" is divided between counties, because of this protective attitude. One solution may be that politicians, both local and governmental, actively take part in the discussion and encourage the development of aquaculture in suitable areas.

Timo Makinen (Finland) provided some information on the use of feed in the Archipelago Sea and on the estimation of nutrient loads to the Baltic from fish farming in the Finnish Archipelago Sea. This information is given in Appendix 10.

The Working Group developed the following strategy and allocation of responsibilities to address the main concerns arising from aquaculture in the Baltic Sea. They were informed in advice received from ICES Secretariat that the production of juvenile salmonids (primarily salmon and brown trout) was to be considered in this exercise as a form of aquaculture. The "aquacultural period" of this operation would be considered to have ended when the fish were released to the open environment and could no longer be considered the property of the hatchery owner.

In preparing material for this task, contributors should bear in mind the need to present a balanced view of the problem. WGEIM noted that the proposed plan primarily addressed issues of the environmental effects of mariculture. WGEIM indicated that it was also necessary to take a range of socio-economic issues into account in coming to a balanced view of the consequences of mariculture in the Baltic Sea, and recommended that Mariculture Committee consider mechanisms whereby the scope could be expanded beyond environmental matters.

Effects of Mariculture in the Baltic Sea - the Plan

Issue	Approach	Responsible person
Location, scale and nature of fish farming	Approach national members of Mariculture Committee.	Ian Davies
Nutrient releases direct to sea water	Estimate from current production levels and reasonable values for FCR, and place in context with other inputs of nutrients (data from HELCOM PLC3 programme).	Anders Alanärä, using data from Ian Davies on production levels. Ed Black to assist. Ian Davies to approach HELCOM re: PLC3.
Nutrient releases in fresh water	Estimate from current production levels (FAO database) and reasonable values for FCR. Make allowances for the trapping of solid waste in lakes, and for losses of nutrients in estuaries, and place in context with other inputs of nutrients (data from HELCOM PLC3 programme.	Use method from Ackefors and Enell paper. Anders Alanärä and Timo Makinen, probably with assistance from Hans Ackefors.

Issue	Approach	Responsible person
Effects of re-stocking on: Stock size Population genetics Disease Other fish stocks Feeding competition	Seek advice from other ICES WG, or from the Fisheries Board of Sweden.	Ian Davies to approach ICES for advice.
Use and discharge of chemicals	Data on medicines use is available centrally in Sweden. Antifoulants - Contact fish farms direct for information.	Anders Alanärä to deal with data for Sweden. Ian Davies to approach Timo Makinen about Finland. Anders Alanärä and Timo Makinen to complete the task.
Scale of impact on the sea bed	Literature review and estimation by analogy with other marine sites.	Ian Davies to approach Timo Makinen as most of the work has been carried out at Finnish sites.
Transfer of diseases from farmed to wild fish	Results will be available from Anders Alanärä's project.	Anders Alanärä
Escapees: From Baltic farms From farms outside the Baltic	Results will be available from Anders Alanärä's project. Other information from NASCO.	Anders Alanärä Ed Black
Use of Baltic herring to make fish meal (protein) for the manufacture of fish feed. Effects on nutrient balance, eutrophication, other fisheries, etc	Results will be available from Anders Alanärä's project.	Anders Alanärä
Effects on marine mammals	Approach Chairman of ICES WGMMH.	Ian Davies
Effects on birds	Approach Chairman of relevant ICES WG.	Ian Davies

7. Update of the Section in the 1998 Report on Integrated Coastal Management (ICM)

Members of WGEIM undertook a revision of their 1998 text on ICM to reflect more closely the scope of expertise of the WG and to meet the needs of ICES. The revised text is included as Appendix 9. WGEIM emphasised the importance of ICM to the development of mariculture in new areas, and its growth and continuation in areas where it is already established. Sound decisions on resource allocation are essential to the progression of a suite of sustainable forms of mariculture in the ICES area. Mariculture, particularly intensive mariculture, is a relative newcomer to the coastal zone and interactions will inevitably occur between mariculture and pre-existing activities. There are many ways in which mariculture could potentially have negative interactions with other coastal activities, but equally other activities can adversely affect mariculture. The complexity of the web of scientific and socio-economic issues which can arise in coastal areas require a structured approach, such as that developing within the framework of integrated coastal management procedures.

In addition, the WG prepared a short Working Document as an initial exploration of ways in which their expertise on maricultural matters could be brought to bear on the process of incorporation of mariculture in ICZM. This Working Document is reproduced at Appendix 10.

8. A Plan for the Completion of the Cooperative Research Report on Chemicals in Mariculture

The completion of this report had been delayed by the inability of the member of WGEIM with primary responsibility for the drafting task to attend the 1998 and 1999 meetings of the WG. Discussions prior to the meeting revealed that the previous report had been extensively reviewed and that some new text had been prepared. "Raw materials" for other new text was made available to the WG.

It was agreed that the Chairman would work with Dave Alderman (UK) to ensure that the draft report is completed and approved by the WG during the current year, preferably before the ASC 1999.

9. Review of the Current State of Development of Predictive 2D and 3D Mathematical Models of Fish Farming which Integrate Environmental Physics, Husbandry Practice and Environmental Interactions

This item was introduced by Bill Silvert (Canada) who considered models at a series of different geographical scales, commencing with the whole bay/inlet scale. The primary target of modelling at this scale is the dispersion and effects of dissolved materials such as nutrients, and of material that behaves virtually as a dissolved substance. Inputs of these substances are combined with the flushing characteristics of the inlet. The main flushing mechanisms differ between areas. In some cases, tidal flushing was dominant, in others fresh water inputs had strong effects on the current pattern. In other areas, such as the Mediterranean Sea, water movements could be episodic in response to winds, etc. Modelling of mean conditions was relatively straightforward compared to the modelling of episodic or exceptional events which could greatly influence the environment. The main areas of development in "large" scale models are:

a) development of methods to take account of the proportion of the water which leaves the inlet on one tide and which returns on the next. One approach to the illustration of this process has been the use of virtual "floating tracers" in graphical computer simulations of flushing;

b) the recognition of the importance in some areas of bottom currents induced by wind/waves in the resuspension and redistribution of material from the sea bed.

Physical models of this general nature were now being integrated with models of ecosystem processes, particularly pelagic processes and nutrient regeneration from sediment (eg the ERSEM model). Such models could also incorporate the effects of sea lice treatment chemicals reducing the filtration activity of zooplankton, as is currently underway at Strathclyde University in Scotland. In areas where light limits the primary production processes, uptake of nutrients by macroalgae and benthic microalgae could account for a significant proportion of the nutrients released by fish farms.

On a smaller scale, say 200 m scale, the main target of modelling is the deposition of solid organic-rich waste on the sea bed. Most models were still based upon the fundamental approach initially described by Gowen in which particles of various properties are modelled settling through the water column and being advected away from the farm by water movements. The main development areas in these models are:

a) the recognition that fish faeces may not closely resemble coherent particles and may not obey Stoke's Law. Diver observations, particularly at sites using modern high energy, lipid-rich feeds have described fish faeces as having a mucus-like texture, to be present as strings which drift in the water and which can adhere to items such as cage nets until disturbed;

b) the importance of resuspension of bottom sediments in some locations, and the consequential redistribution of sedimented waste.

The combination of these two factors tends to distribute faecal waste over larger distances than the normal models predict. Some field observations of the distribution of sea lice treatments after use tend to support these suggestions. A new modelling approach may be necessary including horizontal diffusion coefficients, and probably combining structured and empirical models.

Some progress was being made in linking the physics of particulate waste deposition with the response of the benthic community. Bill Silvert has carried out two studies of the changes of benthic communities over time in response to benthic enrichment from fish farms. A study of farm sites in Maine with J Sowles and L Churchill showed that sites exposed to constant carbon loading exhibit an asymptotic response and can take several years to reach maximum impact. Investigation of a site in the Red Sea with D Angel and P Krost confirmed that benthic response can be slow, and in particular suggested that recovery under an abandoned site can be biphasic - rapid initial improvement but persistent low-level degradation. In Scotland, Kenny Black and colleagues at Dunstaffnage Marine Laboratory were working on the adaptation and development of a model of the benthic effects of sewage disposal (BENOSS) for use at fish farms (DEPOMOD). The benthic community response was modelled in terms of an Infaunal Trophic Index. The project was due to be completed in mid 1999, and the final model would probably be adopted by the Scottish Environment Protection Agency as a tool to aid the establishment of appropriate biomass limits at fish farm sites. Further details are given in Appendix 4.

Jan Aure reported that models were available in Norway which computed the release of particulate waste, settlement on the sea bed and nutrient release, and could also be used to assess oxygen consumption in cages and the consequent effects on water quality in the cages.

The work to complete this simulation model of salmon farming has continued. A recent paper described the module for simulating the turnover of energy and matter due to metabolic processes in fish as an input to a model for simulating the water quality in fish farms.

The model conserves energy and matter, resolved in protein, fat and carbohydrates, and can be used for many purposes. Among other things, it can be used to find food compositions fulfilling different objectives, for instance, minimising the emission of plant nutrients or food costs. It happens that these two particular objectives may be combined since high protein content in the food (expensive) leads to large emissions of nitrogen and phosphorus and low protein retention by the fish. Here the main application of the model is to compute oxygen consumption and emissions of various biologically active substances from a fish farm given the fish stock, food composition, feeding rate and temperature. Fish respiration and emissions of dissolved substances are fed into a water quality model for net pen fish farms in natural water bodies. With known current statistics for the farm site, the minimum flushing of the net pens can be estimated for different physical configurations of the farm. From this the maximal fish production with satisfactory concentrations of oxygen and ammonia may be computed. The flux of particulate organic matter (uneaten food and faeces) estimated by the fish model is fed into another model computing the dispersion of negatively buoyant particles by currents and the loading of the sediment. That model (developed earlier) also computes the maximal allowable production with viable animals in the sediment beneath the fish farm.

The Coastal Oceanography for Sustainable Aquaculture Development (COSAD) project continues to provide a foundation for ongoing investigations of coastal circulation patters in bays and inlets, and relate this to carrying and holding capacity for fish and shellfish aquaculture in Atlantic Canada. A similar project is underway in Newfoundland.

B Hargrave and D Wildish have explored the identification of proxy indices to quantify benthic impacts and find that sulphide content and redox potential (Eh) are useful and economical indicators that can be used for cost-effective monitoring programmes.

Several members of the WG reported observations of fish feeding on excess pellets or faeces falling through the water column, thereby reducing the actual deposition of these materials on the sea bed. Bill Silvert reported episodic feeding on deposited waste by both fish and crabs at a fish farm site in Israel, which removed virtually all of the deposited waste at the site. Antoine Dosdat reported a similar occurrence at a French Mediterranean sea bream farm. Such processes were recognised as important, but reliable (realistic) modelling was not yet possible. A combination of modelling with empirical field data would probably be required and is recommended.

It was noted that the ideal was the balancing of waste production with the ability of the benthic ecosystem to accommodate the waste, thereby ensuring sustainability and also maximising production. Jan Aure suggested that forms of continuous monitoring of the benthic environment could assist in meeting this objective, provided that there was sufficient flexibility in the management of the farm to allow adjustments to be made during the production cycle. Patchiness in the distribution of waste on the sea bed presented a significant problem in this approach.

A report by Kempf and Merceron working in Cherbourg Bay showed that under the strong hydrodynamics of the bay, no significant organic deposition was noted on the sea bed. The current velocity was increased under the cage nets, decreasing the deposition of material immediately under the cages. Conversely, a slight but significant elevations of copper and zinc concentrations have been detected in the sediments, presumably derived from minerals in the fish feed.

Where sea grass beds (Posidonia) have been described, there is still a debate on the balance between the effects on growth by enrichment by organic matter, and shadowing by the cages. This could probably be modelled, but sound field monitoring has not yet been conducted.

In relation to shellfish production, Maurice Heral reported that it was now recognised that in some locations the flux of carbon to the sea bed led to increased availability of nutrients and stimulated the growth of micro-phyto benthos, such as benthic diatoms. Production took place at low tide, and the cells were suspended in the water as the tide rose and became available to the shellfish. Growth was limited by temperature, not by light. The process was important in intertidal areas and could also occur in the shallow sub-tidal within the photic zone. It was increased by shellfish biodeposition.

Studies on the benthic effects of suspended mussel culture were underway in Ireland and Scotland. Several reports had been published from Sweden (and earlier from Portugal).

The WG suggested that an ASC Theme session be organised on the linking of modelling of processes leading to effects on the benthic environment, and the temporal patterns of change (degradation and recovery) of the benthic fauna.

On the smallest scale, modelling was normally addressed to the effects of farms on hydrodynamics (and sediment accumulation at shellfish farms). The target was therefore primarily a husbandry matter, as current patterns through and round cages had direct impact on water quality in cages (dissolved oxygen levels for example). Relatively little was known about this although some observations had been made (eg by Mark Kempf of IFREMER). Martin Hevia has studied the current patterns around fish cages in Chile and G Bugden and P Keizer used dye tracers to study water movements within cages. Some new measuring instruments were available, eg ADCP which could examine current fields in great detail. It was also possible to measure the effects of mussel long lines and trestles on wave height, and current velocity, which would affect sediment accumulation and biodeposition patterns. Modelling in this area was not well advanced, and it was suggested that a combination of structural and empirical models would be needed.

The WGEIM recommended that a review be undertaken at its next meeting of the availability to the scientific community of mathematical models concerning the environmental interactions of mariculture.

10. Update on the Current State of the Art on General Environmental Issues Relating to Mariculture (eg Use of Chemicals, Husbandry Improvements, Modelling, etc)

10.1 Sea lice control, and the use of chemicals

Sea louse control remained a general problem in commercial and welfare problem in salmon cultivation. Additionally, declines in wild salmonid stocks noted in Ireland, Scotland, Norway and Canada have been linked by some people with sea lice populations at salmon farms. Ireland had instigated a compulsory sea louse monitoring programme at fish farms and had installed counters on many rivers. Louse control was largely through the use of chemicals including cypermethrin and ivermectin. Norway was undertaking additional studies of basic louse biology, and there were proposals to exclude fish farms from some fjords, close rivers to fishing and ban fish farming in some Regions (eg E Finmark). There is increasing pressure against the use of medicines as feed additives to prevent the possible transfer of medicine residues to wild fish eaten by consumers. There was particular pressure on diflubenzuron which has been reported to degrade to a carcinogen (p-chloro-aniline). In Canada there was no fishing for salmon in estuaries or on the high seas. There is pressure in Scotland for the introduction of an effective and environmentally acceptable approach to sea lice control.

The Working Group noted a general tendancy towards increased pressure against the use of chemicals (including therapeutants) at fish farms. Arne Ervik reported that in Norway, the use of in-feed treatments for disease or parasite infection was likely to become more difficult to sustain because of the possible transfer of such chemicals to wild fish feeding on excess pellets and faeces. Reports of antibiotics being found in wild fish at Norwegian fish farms about 10 years had been very influential.

In Scotland, a large new field programme of investigations (Post-authorisation Monitoring Programme, PAMP) into the possible community-level effects of sea lice treatment chemicals had been initiated. Sea lice treatment chemicals are categorised as medicines in UK (and EU) legislation. Before commercial preparations for the control of sea lice in mariculture can be presented to the market it is necessary for the manufacturer (normally) to obtain a Marketing Authorisation (MA) under UK and EU legislation.

Applications for MAs are assessed under the UK Medicines Act which the requires the licensing authority (Secretaries of State for Agriculture, acting on the advice of the independent Veterinary Products Committee, supported by the Veterinary Medicines Directorate of MAFF) to take into account factors relating to:

a) the pharmaceutical quality of the product;
b) the efficacy of the product;
c) the safety of the product to consumers, operators, and the environment.

Safety to the environment is assessed from data generated in a tiered series of tests ranging from simple determinations of physico-chemical properties to multi-species mesocosm studies and modelling of the behaviour and fate of the substance in the environment. In most cases, the data required by VPC/VMD stop short of experimental mesocosm studies, but include single species acute and chronic toxicity tests, and observations of the behaviour and biological effects of the product in field trials.

This information, together with the establishment of a Maximum Residue Level by the European Medicines Agency, forms the core of the safety package in an application for a MA.

Concern has been expressed by conservation organisations, and others, in the UK that the medicines assessment procedure cannot take account of possible longer term environmental effects, particularly at community and higher levels. There is very little, if any, scientific evidence to suggest that significant effects have arisen from the use of sea lice treatments (primarily dichlorvos and hydrogen peroxide) to date. However, studies at the community level are not easy to undertake, and only a few studies of the community effects of sea lice treatments have been attempted.

In recognition of this, a consortium of funding agencies have instigated a Post-Authorisation Monitoring Programme of the community level effects of the use of sea lice treatments at salmon farms in Scotland. The funding agencies include Government environment and fisheries Departments, conservation organisations, pollution control agency (SEPA), the Scottish Salmon Growers Association, individual salmon farming companies, with support from the relevant pharmaceutical companies. The project will begin shortly and will last three-five years. It is being carried out by a consortium of research institutes and consultants led by Dr Kenny Black, Dunstaffnage Marine Laboratory, Oban, Argyll. Further information is given in Appendix 5.

Again in Scotland, the Scottish Environment Protection Agency, which is responsible for water quality in the coastal zone has recently commissioned a report on possible new monitoring strategies to address the biological effects of sea lice treatments. The discharge of sea lice treatment chemicals from salmon farms in Scotland can only take place with the formal Consent of the Scottish Environment Protection Agency, under the Control of Pollution Act, 1974. This Consent normally requires that the fish farm undertake an approved programme of environmental monitoring covering such matters as the effect of organic matter deposition on the benthic environment, and of nutrient and oxygen levels in the water column.

SEPA have recognised that there is recurrent public concern over the discharge of sea lice treatment chemicals to the sea, in relation to both the products which are currently Authorised, and those which are presently progressing through the Authorisation process. SEPA considered that chemical monitoring for the substances was difficult and also did not directly address the main concern, namely the biological effects of the chemicals concerned. SEPA concluded that it was necessary to consider the feasibility of developing biomarker and bio-assay approaches to the assessment of the biological effects of sea lice treatment chemicals. Consequently, SEPA (through their research-sponsoring agency SNIFFER) have commissioned a review of the applicability of current, established biomarker and bio-assay procedures to detect biological effects arising from specific sea lie treatment chemicals, and of the potential for the development of new biomarker procedures for use in monitoring programmes. It is hoped that the report of this project will be available soon.

WGEIM considered that, while it was necessary to undertake appropriate monitoring activities at fish farms, the long-term solution to sea lice problems would lie in the area of control of the lice at levels which posed no direct or indirect threat to the environment. It was essential to continue basic biological etc research into sea lice to identify effective control strategies and techniques.

Some other cultivation systems had been shown, or were likely to, have the potential to reduce lice levels. Pump ashore tank sites generally did not have lice problems. Anders Alanärä suggested that closed cage systems with pumped water intakes from depth might avoid exposing the fish to "infective" life stages of lice. A few commercial scale systems were in use in Norway and under trial in Sweden. The main purpose of the systems was to control the temperature of the water in the cages (usually to increase temperatures in winter). The WG noted that such systems were normally rather expensive to install and operate, but that they might have application in particularly sensitive areas, and that they could offer the potential for the confinement and treating of effluents. Even with more traditional cage designs, there could be the possibility of retaining treatment chemicals in baths and using swim-over techniques to treat the cultured fish. WGEIM agreed to review reports on the success and usefulness of closed systems at its next meeting.

Wrasse were used at many fish farms in Norway, but were less common in Scotland. This difference was probably linked to the availability (and cost) of the wild-caught wrasse from limited stocks. It had been shown that wrasse were only effective on small fish, that they are largely ineffective in the winter and that they can carry salmonid pathogens.

10.2 Introduced species through aquaculture

Harald Rosenthal reported that near the island of Sylt in the North Sea, *Crassostrea gigas* had been grown on trestles for more than 10 years, and was reliant upon imported seed from certified hatcheries in Ireland. Seed was normally taken direct from the hatchery to Sylt. However, occasionally it has been necessary for the seed to be stored outside the hatchery for a few days before export. This led to some growth of fouling organisms and the importation to the Sylt area of the Wadden Sea of *Sargassum muticum*, *Ascophyllum nodosum*, *Aplidium nordmanni* (an ascidian) and *Styela clava* (which originated in the East Pacific).

Crassostrea gigas now seemed to be established (probably permanently) in the wild in the Wadden See. Spatfalls occurred ion 1991 and 1994, and the population was estimated at 1,000,000 in summer 1995, of which 66% survived the subsequent severe winter. The animals grew to 50-80 mm in two years, and the size structure of the population suggested survival of some animals from the 1991 spatfall. The animals were found as an epibiont on densely packed mussel beds, from which the normal common macro-algae were absent. Crassostrea therefore does not occupy the niche of the regionally extinct Ostrea edulis, but constitutes an r-selected species invading a crowded community in an undisturbed habitat.

Antoine Dosdat reported that more than 50% of the macro-algal species in the Thau lagoon had been introduced, almost certainly in association with imports of oysters for mariculture purposes.

Ed Black provided a report of the occurrence of juvenile Atlantic salmon in the Tsitika River, British Columbia. The presence of two age classes of juvenile Atlantic salmon in a river which hosts no hatcheries containing that species suggested that Atlantic salmon had successfully spawned in the river in 1996 and 1997. There was some doubt as to the numbers of juveniles present, the numbers of other salmonids present and the geographical distribution of the juveniles. The presence of these juveniles necessitated an evaluation of their ability to establish an endemic population and compete with local salmonid species. Concern was constrained by the fact that there had been numerous introductions of as many as half to one million eggs or fry to other river systems and no recorded returns from the smolts that went to sea (see WGEIM 1998 report). In addition, limited genetic evidence collected from this occurrence suggests that all the fish may have been the result of a single pair of fish mating in 1996 and another pair of fish in 1997. Further, even at the most extreme estimate of the abundance of Atlantic salmon fry they were very rare when compared to local salmonid species.

WGEIM noted that increasing recognition of the risk of inadvertent transfers of alien species when moving marine organisms from place to place. In some areas, aquaculture was dependent on the importation of juveniles, or other life stages. The development of local broodstocks and sources of juveniles is clearly a method of reducing this risk. While some introductions may present hazards to the wider environment in the receiving area, other importations can present direct hazards to aquaculture. Pests and diseases carried in the transferred organisms are a clear example. In addition, the transfer of toxic algae, with imported animals or by other means, such as ballast water are significant risk factors. Norway has recently experienced a bloom of Chatonella, thought to have been imported in ballast water, while there has been occurrences of a previously unknown toxin in Ireland. Antoine Dosdat reported a similar experience in the Thau lagoon.

10.3 Other pests

Oyster producers in some parts of Atlantic France were experiencing considerable increases in the populations of *Crepidula fornicata* (slipper limpet). Crepidula was introduced to the area from N America about 50 years ago, but had recently increased in numbers such that they now attained 30-40% of the standing stock of oysters in some areas. The Crepidula was expanding even in areas where oysters stocks were too high, and were competing for the energy resources. Growers were trying to remove them by trawling, but this was costly, and there was no significant market for the Crepidula.

Thomas Landry reported that in some locations on the west coast of America, a burrowing shrimp was altering the structure of shore areas (under-mining) and making the sediment unstable. Control was being attempted by chemical spraying.

11. Evaluation of Integrated Farming Systems in Coastal Habitats

The main advantages commonly stated for existing integrated aquaculture systems (mainly outside the ICES area) is that they are often traditional systems which have been shown by the passage of time to be sustainable, and which often make use of wastes from other forms of aquaculture or agriculture as energy inputs.

The WG briefly reviewed the status of integrated systems (essentially co-culture systems or systems which utilise waste heat) in countries represented by the members of WGEIM present at the meeting.

Members were not aware of any co-culture systems involving marine organisms in Scotland, Ireland or Norway. In France, there were some situations in which discharges from land-based farms led to concerns. One example was on the Atlantic coast of France in a marsh area protected under Natura 2000. Effluent from a 300-500 tonne sea bass farm was passed into a pond where silicate was added to stimulate diatom growth. After six-seven days, the effluent with phytoplankton was passed into an oyster pond. The oysters consumed the diatoms and grew to a good quality. At the moment, the oysters were not presented for sale, but could be once a system was in place to ensure that any pharmaceuticals used at the farm were not passed on to the consumer through the oysters. The plankton ponds also attracted large numbers of birds which could form the basis of an additional bird-watching activity.

A number of farms are using recirculating systems for sea bass and sea bream production. The rejected water is high in nitrogen and phosphorus and is also used to back-flush the filter systems. This effluent has been used in the production of Ulva lactuca (no commercial value) and experiments are underway on Gracilaria production which may have a commercial use. It was noted that there was interest in Spain and Denmark in this system for the production of turbot and eels respectively.

The main stimulus to the growth of co-culture integrated systems was for environmental protection purposes. In France, many complaints had been received from cockle fishermen, recreational users, etc about the growth of green algae which was attributed to the presence of a fish farm in the same waters. France was developing a zoning system for marine systems which would seek to define acceptable developments in various areas.

Dave Wildish reported that there was an experimental system in Canada in which macroalgae (Porphyra) was being produced in suspended culture at a salmon farm. The only current example of the use of waste heat of which the WG was aware was for the production of about 1,600 tonnes of sea bass in France near Dunkirk. Other experimental projects included the cultivation of sea urchins (*Strongylocentrotus*) in various structures associated with salmon cages. There was an unusual commercial activity in Canada which involved the capture of herring, their retention in cages, and the trapping of herring eggs on kelp added to the cages. The combined product of kelp and eggs was sold to Japan.

The WG briefly reviewed the conditions necessary for the development of co-culture systems. They noted that there was a long history of semi-extensive systems which had demonstrated sustainability. However, the current commercial pressure seemed to support co-culture on the grounds of more efficient (or complete) utilisation of the energy input (feed, etc), the opportunities for diversification to reduce the vulnerability of the enterprise to market changes or disease, and the possibility of improved effluent quality. In most cases, the confined effluent streams available from land-based farms were more amenable to use for shellfish of algal culture than were the effluents from cage culture systems.

A form of co-cultivation could be envisaged in open or semi-enclosed areas of relative nutrient deficiency where discharges from fish farming could increase the nutrient status of oligotrophic waters, encouraging the development of phytoplankton and providing new opportunities for the development of mariculture activities to take advantage of the enhanced primary productivity.

Significant factors mitigating against co-culture were currently fears over disease, either increased risks of transfer or increased difficulty of control, and economic factors. Currently, most co-culture systems based on current intensive systems are not economically advantageous. The main difficulty often seems to be either the availability of sufficient land close to the fish farm for the relatively large area of additional ponds, or the purchase cost of the land.

12. Assessment of Information on the Fate of Cysts of Toxic Algae in Erosional and Depositional Sedimentary Environments

Many species of dinoflagellates, as part of their life-cycle, produce non-motile resting cysts which sink from the water column to the sediment where they may remain viable for many years. Of relevance to the mariculture industry, and in particular the shellfish industry, are cysts of dinoflagellate species which produce toxins, eg *Alexandrium* spp. Initiation of toxic blooms of these species may be associated with the germination of cysts from "seed-beds", into motile cells under favourable environmental conditions. Blooms of toxic species can result in the accumulation of toxins in shellfish to a level which renders them unsafe for human consumption. This can lead to prolonged closures of shellfish production areas and significant economic losses for shellfish producers. Alternatively, blooms of species that produce ichthyotoxins, eg *Chatonella* spp., (*Heterosigma akashiwo*) may occur which can lead to mortalities of cultivated species, both finfish and shellfish. This species has caused losses of fish in France, Spain, Portugal, UK and Canada. It is believed to have been responsible for losses of juvenile oysters in BC and Washington state.

Studies carried out in many countries within the ICES area have revealed the presence of cysts of toxic species in sediments in aquaculture locations and in depositional areas in the coastal zone. Surveys carried out in Scotland in locations where Paralytic Shellfish Poisoning (PSP) toxins have been detected in shellfish have revealed the presence of varying concentrations of cysts of a number of genera, including *Alexandrium* (Appendix 12). Similar results have also been reported from Canada, Ireland, Norway and France. A study in Oslo fjord had used the distribution of cysts in sediment cores to describe the "history" of the occurrence of *Alexandrium* in the area.

Dave Wildish reported that *Alexandrium* cysts were an endemic problem in the Bay of Fundy area, and had been studied for some time. They tended to be concentrated in sediments in muddy depositional areas, and were largely absent in erosional areas of sand or glacial till. Canadian workers were satisfied that these cysts formed the basis of later blooms, and work in Canada and the US had been carried out to determine the conditions (temperature shock) necessary to induce the "hatching" of the cysts. Cysts had been shown to remain viable in sediment for up to nine years.

There are several mechanisms by which cysts can be resuspended into the water column and/or transported from one location to another. The potential transport in ship's ballast water has previously been discussed by the Working Group on Introductions and Transfers of Marine Organisms (WGITMO). *Heterosigma* is known to survive intercontinental transport in ballast water. Other mechanisms discussed by the WGEIM included:

- harrowing of sediments underneath fishfarm structures;
- maintenance/capital dredging of ports and navigation channels and the disposal of the dredge spoil at sea;
- transfer of cysts via the transfer and relaying of live bivalve shellfish.

Harrowing: The Working Group concluded that the practice of harrowing was inappropriate for a variety of reasons, including the potential resuspension of cysts, and that this practice should not be encouraged, even though field evidence suggests that the concentrations of cysts in sediment under cages is generally lower than in depositional areas away from the cages. Harrowing underneath fish farm structures is currently not permitted (or does not occur) in Scotland, Norway and Canada.

Dredging and dumping: The Working Group concluded that dredging operations in ports and navigation channels, and the dumping of the spoil at sea, could potentially result in the resuspension of cysts into the water column and the transfer of cysts into aquaculture locations by advective transport. Few studies, however, have been carried out on this issue. Recent work in BC suggests that many of the blooms affecting BC mariculture have been derived from excystment phenomena in Vancouver harbour, a major port receiving vessels from areas such as Japan where blooms of *Heterosigma* are known to be a problem.

Transfer of cysts via transfer and relaying of live bivalves: Studies carried out in The Netherlands and Ireland have shown that cysts can occur in the intervalvular fluid of live bivalves. The potential exists, therefore, for the transport of cysts, including cysts of toxic species, via transfers of live bivalves both within and between countries. While the Working Group recognised that cysts could be transferred by this mechanism it also recognised that it would be very difficult, if not impossible, to introduce realistic mechanisms for its regulation and control.

13. Any Other Business

13.1 Recent literature on the sustainability of mariculture

A recent publication in the journal *Science* (Naylor *et al.*, 1998, Nature's subsidies to shrimp and salmon farming, *Science*, **282**, 883-884) had suggested that the environmental consequences of shrimp and salmon were an unacceptable price to pay for the products, and that steps should be taken to reform World Trade Agreements to permit restrictions on the process of production and to restrict the trade in intensively-produced shrimp and salmon. The main arguments against salmon farming were:

a) Salmon are carnivorous and too high in the food web to permit efficient utilisation of marine (fish meal) resources.
b) Salmon farming uses the sea as a receptacle for nutrients and other wastes.
c) Poor husbandry has led to the use of antibiotics and pesticides in salmon production.
d) Escapees present a genetic hazard to natural stocks.
e) The full environmental costs of salmon production are not internalised and is leading to the demise of fisheries and biological diversity in ocean ecosystems.

A limited set of correspondence on the paper is included in *Science*, **283**, pp 639-640.

The Working Group noted that many of the arguments in Naylor *et al.*, are similar to those in a previous publication which included some of the same authors (Folke *et al.*, 1994, The costs of eutrophication from salmon farming: Implications for Policy, *J. Envir. Management*, **40**, 173-182) A group of members of WGEIM had published a comment on this paper (Black *et al.*, 1997, The costs of eutrophication from salmon farming: Implications for Policy - A comment, *J. Environ. Management*, **50**, 105-109).

The Working Group discussed the paper Naylor *et al.*, at some length, recognising that such publications can present distorted or incomplete views of the position of intensive mariculture in the global food production system. WGEIM agreed that in many areas shrimp production had not been performed in a sustainable manner, but that the exploitation of inappropriate sites (or by inappropriate husbandry methods) had never been so widespread in salmon farming, and was now largely absent in the ICES area.

The WG felt that the paper was very incomplete in that it treated the salmon (and shrimp) industries in isolation from other food production sectors. The proposals put forward for far-reaching reforms of the global trading and economic structures without attempting any analysis of the wider consequences of their proposals. The main points made during discussion, and in contributions received by fax from Harald Rosenthal were:

1. The "trophic level" argument put forward by Naylor *et al.*, is incomplete. It would be possible to fully replace fish meal in salmon diet by vegetable protein, but currently fish meal is economically preferable to vegetable products. Salmon farming uses a small proportion of the global fish meal production (perhaps around 15%) and therefore has little influence on the price.

2. In discussions over feed sources and composition it is necessary to distinguish between protein and oil, which Naylor *et al.*, fail to do.

3. Environmental improvements are being progressively made in the rather young industry of salmon farming. Feed technology, waste production, chemical usage, and other aspects of environmental effect are coming under increasing levels of control and improvement.

4. The term subsidy implies a diversion of food resources from other, more beneficial places. It is not clear what these might be. The fish used for fish meal are often not usable as human dietary components in the quantity available from the fisheries. It is not clear how any surplus production of the fish meal industry might be used.

5. Sustainability in the environmental sense cannot be separated from due consideration of markets, market demands and product acceptance.

6. Aquaculture animal products are obtained at all trophic levels, from filter feeding bivalves to fish at higher trophic levels. All can have limitations, for example mussel production can be limited by predation, food limitation, impact on the benthos, etc. Production is modulated by the environment and by market restrictions. Production needs to be diverse to meet market demands.

7. There may be other routes to sustainability in terms of feed utilisation that involve the use of wastes in recycling or integrated farming processes, a subject not addressed at all by Naylor *et al.* Such utilisation of wastes is the basis of integrated systems in Asia and some parts of Europe, and offers considerable potential for sustainable development, and may well incorporate the production of carnivorous fish.

8. The implied comparability between shrimp and salmon farming is seriously misleading. A comparison between salmon and chicken production might be more appropriate.

The WG noted that a reply to Naylor *et al.*, was being prepared by a group of scientists from ICES countries. WGEIM also noted that sustainability of mariculture production was a primary objective of ICES Mariculture Committee. In particular, economic and socio-economic aspects need to be considered, identifiying those externalities that could be internalised and those which already capture environmental costs from other resource users. It was therefore recommended that WGEIM should work inter-sessionally to prepare material for an assessment of the progress towards sustainability in mariculture in the ICES area. A working title could be "Towards sustainability in mariculture in the ICES area". WGEIM would address itself primarily to ecological issues, but a full assessment of this question would require contributions from other WGs with expertise in other areas related to mariculture. The proposed content of the report, and persons responsible for progressing elements of it, are as follows. Subject areas outside the expertise of WGEIM are referred to MC for support, with the recommendation that the relevant tasks are allocated to appropriate Working Groups.

Report: "Towards Sustainability in Mariculture in the ICES Area"

Topic area	Responsible persons	ICES group
Environmental - Fish	Antoine Dosdat Ian Davies	WGEIM
Environmental - Shellfish	Maurice Heral	WGEIM
Inter-specific interactions. The trophic argument (cf Naylor *et al.*). Fish meal and oil utilisation.	Thomas Landry (+ Harald Rosenthal)	WGEIM
Interactions with other activities, emphasising ecological matters, and encompassing procedures such as LENKA and MOMS.	Peter Burbridge Dave Wildish	WGEIM
Economic aspects Socio-economic aspects	Eva Roth Bernard Glaesser? Several members of the WG to seek out national reports.	WGEIM
Coastal management issues, including: ICM Resource management structures Access Property rights Opportunity costs Time averaged benefits, etc	Eva Roth Peter Burbridge Bernard Glaesser? Ed Black and others	WGEIM
Genetic matters including escapees.		MC to refer to appropriate WG
Disease aspects, including transfer to and from wild populations.		MC to refer to appropriate WG

Topic area	Responsible persons	ICES group
Other interactions with wild stocks, including the sea lice/sea trout issue.		MC to refer to appropriate WG
Other issues as may be identified by MC.		MC to refer to appropriate WG

13.2 Plans for ICES symposium in Canada

Dave Wildish outlined the plans for the ICES Symposium on Environmental Effects of Mariculture to be held from 13-16 September in St Andrews, New Brunswick, Canada. The basic structure of sessions, chairmen and scientific panel members was as follows:

Session	Chair	Scientific panel member
Harmful algal blooms and mariculture	P Lassus	H Rosenthal
Sediment biogeochemistry and mariculture	M Holmer	I Davies
Disease/environmental factors in mariculture	J Stewart	A Figuras
Environmental monitoring in mariculture	D Wildish	A Ervik
Mariculture and production/carrying or holding capacity	J Grant	B Bayne
Other ecological issues in relation to mariculture	M Heral	H Ackefors

The proceedings of the Symposium would be published, and members were encourage to both submit papers and attend the symposium.

13.3 Access to natural resources for aquaculture

The WG was addressed by M Jean-Paul Troadec, one time Director of Fisheries and Aquaculture for IFREMER. He described the mechanisms whereby the development of many forms of economic activity is dependent upon the presence of a developed and appropriate system of property rights. He applied these concepts to the utilisation of renewable natural resources, and in particular to the transition from capture fisheries to aquaculture. He used a box model consisting of resource units, production systems, exploitation systems and management (regulatory) systems to demonstrate the poorly developed state of property systems in the sea, and how such led directly to over-exploitation of resources. He indicated some areas of difficulty that needed to be addressed to improve the property rights system in the sea to aid the development of aquaculture and simultaneous conservation of natural resources. The text of his presentation is given in Appendix 6.

13.4 Artificial reefs in the Languedoc-Roussillon region

The WG was addressed by Mme Beatrice Pary of the Centre for the study and promotion of aquatic activity in the Region. She described two artificial reef projects in the local coastal waters, and the development of off-shore mussel rope culture. It was not clear whether the reefs had increased marine production of harvestable material. However, the reefs had excluded trawlers and re-directed the catch towards local small boats. The reefs provided new opportunities, for example for bottom cultivation of molluscs or crustaceans in the protected areas behind the reefs, or for recreational fishing or diving to the benefit of the local economy. A summary of her presentation is available at Appendix 7.

13.5 Environmental aspects of Infectious Salmon Anaemia in Scotland

Much of the attention of both the Scottish salmon cultivation industry and the regulatory authorities over the last 10 months or so has been directed at the control of a serious outbreak of Infectious Salmon Anaemia at sea sites. There are currently approximately 10 sites where ISA has been confirmed, and a similar number where there is some suspicion that it may be present. A Joint Government/Industry Working Group has been established, and has recently published its first report (January 1999). Primary concern has been over the diagnosis and control of the outbreak, but a number of issues relating to the interaction of salmon cultivation with the environment have also arisen, some of which are outlined below:

1. **Disposal of mortalities and slaughtered fish**

The rapid disposal of hundreds of tonnes of fish, sometimes in remote areas, has proved to be a difficult problem. The normal facilities for the disposal of routine mortalities were unable to cope with such large quantities. Processing through fish meal plants was often not appropriate as some plants did not have licences which permitted them to handle salmonids, and in others the processing was not rigorous enough to fully destroy virus in the fish. Destruction through acidification and formation of silage has been a useful method of disposal.

2. **Disinfection**

The increased attention of the industry to disinfection procedures for personnel, equipment and boats has led to increased need to dispose of used disinfectant, and increased use of slips for sterilisation of the hulls of vessels.

3. **Waste discharges**

Discharges from harvesting stations and processing plants have been identified as particular risk factors, and this has emphasises the need for elimination or disinfection of effluents.

4. **Compulsory fallowing**

An important element in the strategy being adopted for the eradication of the disease is the imposition of compulsory fallowing periods. The infected area has been divided into a number of "Fallowing Zones" close to infected farms, "High Risk Zones" around these, and "Surveillance Areas" at greater distance from infected farms. In Fallowing Zones, all the farms will be required to fallow simultaneously for a period of six months. This period will commence when all farms in the Fallowing Zone are empty of fish. The comparable period for High Risk Zones is three months.

5. **Requirement for new or expanded sites**

The above requirements have led to some companies predicting considerable financial difficulty over the next one/two years. In attempts to mitigate these problems, immediate requirements for new sites have arisen. These requirements cover a variety of circumstances, from temporary accommodation for the 1999 year class of smolts until other sites emerge from compulsory fallowing periods, to long/medium term new production sites where 1999 smolts would be grown out.

In the longer term, it is likely that the movement of fish between sites during the marine on-growing phase will be much less frequent than in the past, and that there may be a general presumption against SW to SW movements. This will mean that many sites will operate below their maximum Consented biomass for much of the production cycle. If current levels of production are to be maintained, companies will have to request additional tonnage at existing sites, or request Leases and Consents for new sites.

6. Draft proposals for new fish farm location management strategies

Experience in handling the current outbreak of ISA in Scotland has emphasised the importance of separation between farms as an element in a disease control strategy. It has been recognised for some years that fish suffering from a range of diseases can shed large numbers of infective particles (eg bacteria or viruses). These particles will be diluted and dispersed by the normal hydrographic processes in coastal waters such as sea lochs. Many of these particles can remain viable in sea water for significant lengths of time, can be carried to other farms and may infect other fish. Consequently, it is generally recognised that farms which share the same body of water will commonly share the same disease problems. With specific reference to ISA, the inclusion of other farms within the Fallowing and High Risk Zones around infected farms has brought about a reconsideration of possible strategies designed to limit the spread of diseases.

The current distribution of fish farms in Scotland is such that farms are often located within less than one tidal excursion of each other. Such small separation distances give little opportunity for control of diseases for which infective agents have even a moderate survival time (hours to days) in sea water. Larger separation distances would give more time for the infectivity bacteria/viruses to reduce, and natural hydrographic processes would result in greater dilution and dispersion of the infective agents.

However, it was noted that fish farms tended to be located in groups, separated by less than one tidal excursion, but groups of farms were often separated by rather greater distances (geographically and hydrographically) from adjacent groups. It has therefore been suggested that this existing grouping of farms could be used as the basis for regional and local management strategies, and that preservation of the separations (fire breaks) between groups of farms might be a useful criterion in the assessment of applications for new sites.

Reference

Interim Report of the Joint Government/Industry Working Group on Infectious Salmon Anaemia (ISA), January 1999, 26 pp. Available from the Librarian, FRS Marine Laboratory, PO Box 101, Victoria Road, Aberdeen, UK, AB11 9DB.

13.6 Offshore mussel cultivation in Languedoc-Roussillon, France

Claudine L'Hoste of CEPRALMAR described the processes which had led to the development of a off-shore mussel cultivation industry using submerged long-lines. Her overheads are included in Appendix 7. The Region had been very pro-active in the early stages in supporting both scientific and economic aspects of the project (field trials) and also in facilitating negociations between other users of the areas, such as fishermen. Large (10 km x 4 km) blocks of sea bed had been allocated to mussel farming, and within these blocks producers were allocated (leased) one or more concessions, each of which could hold up to two long-lines. Growth of mussels (*M. galloprovincialis*) was rapid and complete in 6-12 months, depending on season. Harvesting was seasonal, but growers maintained continuity of supply by seasonal importation of fattened mussels from the Atlantic coast of Spain and France.

13.7 Cultivation of fish in closed systems

Jean-Paul Blancheton of IFREMER Palavas described the development of closed system cultivation technologies for Mediterranean fish, primarily sea bass (and sea bream). The systems had developed from poorly controlled hatcheries with very mixed success, to enclosed and controlled hatcheries, and were now concentrating on closed on-growing systems.

The current systems consisted of a primary circulation through the growing tanks with a turn-over of about once per hour (and 100% daily replacement) which included adjustment of pH and mechanical filtration, and a secondary effluent treatment system with high activity algal ponds. A system with a capacity of 2-3 tonnes of fish would require 300 m^2 of algal ponds, and would produce one tonne dry weight of Ulva lactuca.

The outstanding problems areas were:

a) The need to improve mechanical filtration to remove smaller particles;
b) Improved control of bacterial populations to either reduce the formation of dissolved organic matter, or aid the oxidation of DOM;
c) Valorisation of the macro-algae produced in the polishing pond. Ulva was very effective at removing nutrients, but had no significant value. Alternative algal species were being considered.

Significant improvement over many existing systems was the efficient and reliable removal of ammonia (mainly through transformation to nitrate) obtained in the biological filters. These continued to work satisfactorily even in winter. The fish were fed through demand feeders and feed wastage was minimal. The system was explained during a visit to the IFREMER Palavas station. Copies the illustrative material used by M Blancheton were circulated to WG participants after the meeting.

14. Consideration and Approval of Recommendations, Including Proposals for a Further Meeting

WGEIM agreed the report of the meeting (subject to editing by the Chairman) and recommendations listed in Appendix 13, including the proposal for a further meeting in 2000.

15. Closure of the Meeting

The formal sessions of the meeting closed at 1635 hours on 19 March 1999. On the following day, the members of the WG visited a number of mariculture facilities in the area of the Salse-Laucate lagoon. The facilities visited included an established shrimp (*P. japonicus*) hatchery, a new oyster hatchery, and a closed system sea bass farm producing 100 tonnes of fish. The sea bass farm utilised scaled-up versions of the systems previously seen at IFREMER Palavas station. Advantage was taken of a reliable supply of underground water at 17°C which meant that it was possible to keep the temperature in the tanks relatively constant (17-23°C) all year round. The farm had been created under an EU demonstration project to bridge the gap between experimental two tonne units and the target fully commercial 300 tonne units.

The oyster hatchery had been constructed in association with oyster on-growing in the adjacent lagoon. The local authority, through CEPRALMAR had been instrumental in creating structures and facilitating negotiations between competing interests which lead to the establishment of 30 small oyster business on a block of concessions in the lagoon, with harbour, processing and retail facilities along the more sheltered channel which joined the lagoon with the open sea.

Appendix 1

AGENDA

The ICES Working Group on Environmental Interactions of Mariculture will meet in Montpellier, France from 15-20 March 1999, commencing at 0930 hours on 15 March.

1. Opening of the Meeting.

2. Adoption of the Agenda.

3. Arrangements for the Preparation of the Report.

4. Receive Reports on:

   National Production Trends.
   Significant National and International Meetings.
   Significant New Research Results and Directions .

5. Develop a Programme of Work Related to the Objectives of the Mariculture Committee, the Marine Habitat Committee, ACFM and ACME.

6. Develop a Plan to Obtain Information on the Effects of Mariculture Activities in the Baltic Sea.

7. Update the Section in the 1998 Report on ICZM.

8. Develop a Plan for the Completion of the CRR on Chemicals in Mariculture.

9. To Review the Current State of Development of Predictive 2D and 3D Mathematical Models of Fish Farming which Integrate Environmental Physics, Husbandry Practice and Environmental Interactions.

10. To Update the State of the Art on General Environmental Issues Relating to Mariculture (eg Use of Chemicals, Husbandry Improvements, Modelling, etc).

11. To Define and Evaluate Integrated Farming Systems in Coastal Habitats.

12. To Assess Information on the Fate of Cysts of Toxic Algae in Erosional and Depositional Sedimentary Environments.

13. Any Other Business.

    13.1 Recent literature on the sustainability of mariculture.
    13.2 Plans for ICES Symposium in Canada.

14. Consideration and Approval of Recommendations, Including Proposals for a Further Meeting.

15. Closure of the Meeting.

Appendix 2

LIST OF PARTICIPANTS

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Appendix 3

COUNTRY REPORTS

Atlantic Canada
Western Canada
Finland
France
Germany
Ireland
Norway
Scotland
Sweden

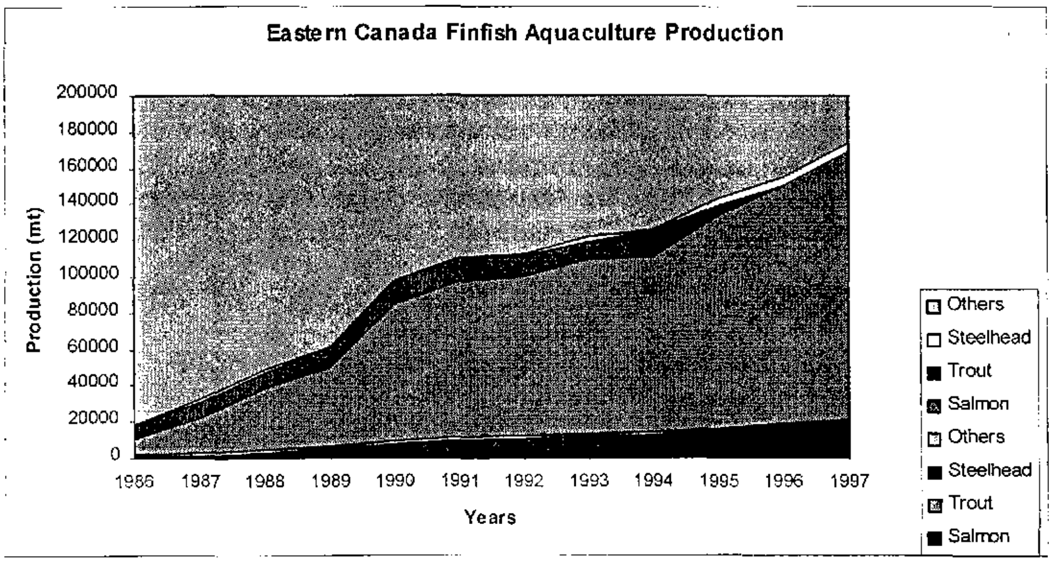
Canada (Atlantic)

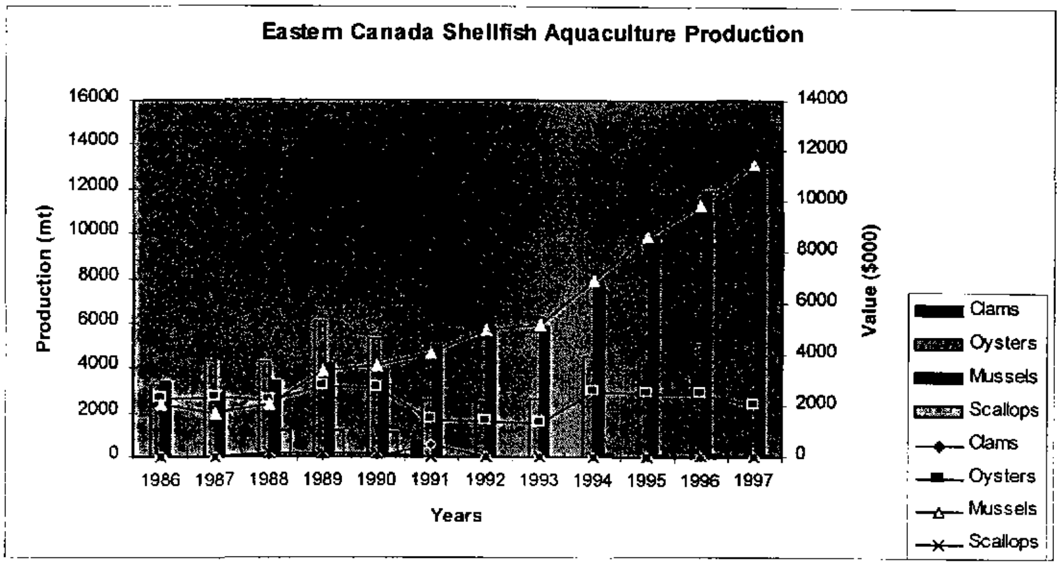
T Landry

Production

The Atlantic salmon still dominates aquaculture production in Atlantic Canada despite the losses associated with ISA over the past two years. The preliminary information for 1998 is projecting a decrease in production of about 20% from the 20,000 mt produced in 1997. This problem has been addressed by extensive management strategies including destruction of infected stocks, site relocation, new husbandry practices and development and implementation of a vaccine program. Although this is clearly a disease situation, it has raised considerable discussion on the impact of aquaculture on the environment and the perceived link between the salmon health and the environmental health. There is no scientific evidence of this link, although proposals have been prepared to investigate it. Meanwhile, the perception remains and is spreading to other aquaculture debates.

The 1997 production level for steelhead, in Atlantic Canada, is 946 mt with the bulk of the production coming from Nova Scotia and Newfoundland. This industry is only a decade old and is expected to continue its rapid growth.



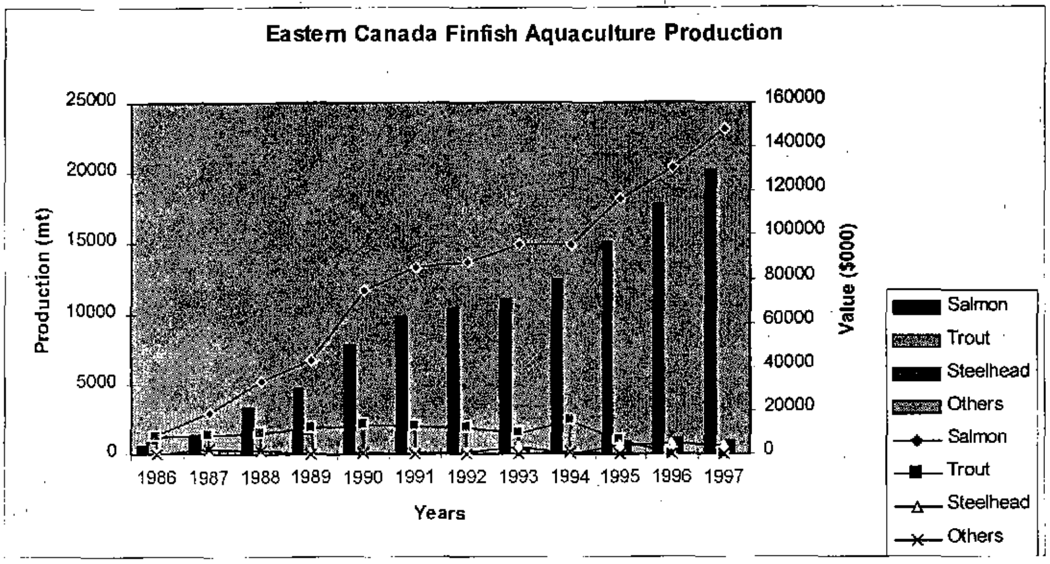


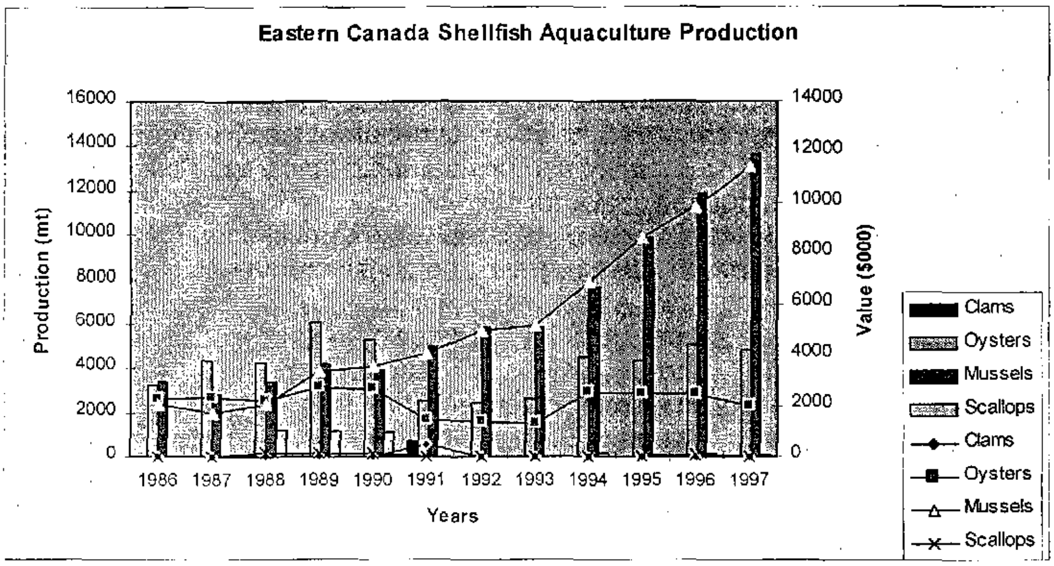
Mussel (*Mytilus edulis*) is the most important species for the shellfish aquaculture industry in Atlantic Canada and continues to grow with a 12% increase in production from 1996-1997. The growth for 1997-1998 is expected to increase again by 10%. Prince Edward Island accounts for over 70% of the 13,658 mt produced in Atlantic Canada and Canada in 1997. The growth of this industry and expansion into new areas, however, is not always well received by the coastal community. Concerns on over capacity and disease epidemics and their perceived link to environmental degradation due to aquaculture activities seems to be growing faster than the aquaculture industry itself. In Nova Scotia, for example, the establishment of a mussel farm has been debated for over a year with little progress and considerable negative press attention.

Oyster production in Atlantic Canada is mainly dominated by the American oysters (*Crassostrea virginica*), although the production and interest in European oysters (*Ostrea edulis*) is still considered as a great potential for species diversification. The overall production levels have remained stable over the past five years between 4,000 -5,000 mt, which represents about 50% of the total Canadian production. Prince Edward Island and New Brunswick are the two biggest oyster producing provinces. European oyster production in Nova Scotia, accounts for 2% of the 4,778 mt produced in 1997.

The giant scallop is the only other species that contributes significantly to the shellfish aquaculture production in Atlantic Canada, with 109 mt produced in 1997. Nova Scotia and Newfoundland are the dominant provinces in scallop production in Atlantic Canada.

Developmental work is continuing on soft shell clam, bar clam and quahaug aquaculture in New Brunswick and Prince Edward Island.





Meetings

NSA. The Annual Meeting of the National Shellfisheries Association will be held in Halifax, NS on 18-22 April 1999. A special session on the modeling of shellfish ecosystems will be included in the program.

ICSR. The Third International Conference on Shellfish Restoration is being planned for the fall of 1999 in Ireland. This will be the first European location for this conference which features sessions on shellfish habitat assessment and restoration as well as habitat remediation through watershed management and pollution abatement. Final dates will be announced during the summer.

Aquatech '99. The 1999 meeting of Aquatech will be held in Fredericton, NB, 27-30 July 1999. It will be integrated with the larger BioAtlantec 1999 and bring together an international audience focussing on the development of genomics and pharmaceuticals for agriculture, aquaculture and forestry.

ICES Symposium, Environmental Effects of Mariculture. St Andrews, NB, 13-16 September 1999.

AAC. Annual meeting of the Aquaculture Association of Canada will be held in Victoria, BC, 26-29 October 1999.

AAC2000. Annual Meeting of the Aquaculture Association of Canada will be held in Moncton, NB, 28-31 May 2000.

CZC2000. The Coastal Zone Canada meeting will take place in St John, NB, 17-22 September 2000. The theme will be Coastal Stewardship: Lessons learned and paths ahead.

Research and Publications

COSAD. F H Page, S Robinson, T W Sephton. The Coastal Oceanography for Sustainable Aquaculture Development project is continuing in Atlantic Canada. The main objective of this two-three year project is to develop a foundation for ongoing investigations on the coastal circulation of nearshore bays and inlets and relate this to carrying and holding capacity for aquaculture activities, for both shellfish and finfish. The project will be completed in 2000. A similar project (NAIA environmental monitoring program) is being conducted in Newfoundland by C Couturier, J Parsons and T Clements.

Sustainable Salmonid Aquaculture in Bay D'Espoire , Newfoundland. M Tlusty, C Diamond, M R Anderson , V Pepper. A systematic environmental monitoring program has been establish to evaluate the potential effects of salmon aquaculture. The main objective of the program will be to assess changes in nutrient loading as a result of Salmonid farming in the Bay D'Espoire.

Sea Lettuce. The objective of this project is to document changes in the abundance of the sea lettuce and determine the factors associated to a perceived increasing abundance.

Quantitative Environmental Monitoring Methods. D Wildish and NBDFA. Introduction of a monitoring method for the Bay of Fundy salmonid culture industry. The geochemical measures proposed, Eh and sulphide levels, indicate the microbial status of sediments.

Tunicate Fouling: Results of a world wide search. AANS. 1997. A mussel farm in Nova Scotia was devastated by the infestation of the tunicate *Ciona intestinalis*. The entire 1997 crop was lost and the future of the farm was in jeopardy. This was the first reported case of the sort in Atlantic Canada. Similar infestation problems with this tunicate has been reported in other parts of the world, namely, South Africa, United States, Ireland, Spain, Scotland. It appears that this problem can worsen with the expansion of the mussel industry.

PEI Benthic Survey. K R Shaw. 1998. Evaluation and comparison of benthic characteristics from mussel culture sites, reference sites and non-culture (mussel) sites in Prince Edward Island. Results showed lower Eh and BEI values in references sites compared to culture sites and lower values in water content, organic matter content and total sulfides in culture-free site compared to lease sites. The differences between culture-free and lease sites, however, are not directly attributed to mussel culture activities.

L'impacte de l'activite mytilicole sur la capacite de production du milieu lagunaire des Iles-de-la-Madelaine. P Mayzaud, V G Koutitonsky, P Souchu, S Roy, N Navarro, E Gomez-Reyez. 1992. This study looked at the impact of mussel culture on a lagoon ecosystem to determine the carrying capacity for mussel culture.

Canada (Western)

British Columbia Aquaculture Production 1995-1997

	Wholesale value ($ Million)			Farmgate value ($ Million)			Harvest ('000 Tonnes)		
	1997	1996	1995	1997	1996	1995	1997	1996	1995
Salmon	195.0	172.0	172.8	175.5	158.9	170.4	40.5	27.6	27.3
Rainbow trout	0.7	0.5	0.5	0.7	0.5	0.5	0.15	0.8	0.1
Pacific oyster	6.2	8.3	7.7	4.9	6.3	5.4	4.7	5.4	5.3
Clams	5.4	5.3	4.9	4.5	4.5	3.9	1.0	1.0	0.9
Scallops	0.7	1.0	0.3	0.6	0.9	0.2	0.09	0.14	0.02
Total	208.0	187.1	186.2	186.2	171.1	180.4	46.5	34.9	33.6

*All figures are estimates.

Source: The 1997 British Columbia Seafood Industry Year in Review.

Other species currently being cultured in limited or experimental quantities include: Arctic char, sablefish, white sturgeon, geoduck clam, sea cucumbers and the green sea urchin.

Links to data on Seafood, Marine Plants, Canned Salmon Pack Bulletin.

Return to Aquaculture and Commercial Fisheries Home Page.

Return to BC Fisheries Home Page.

France

A Dosdat, M Héral and C de La Pomélie

1. Figures

Production remains stable (production and turnover) compared to 1996 figures given in the previous report of WGEIM. These are summarised in the following tables:

1997: Production (Metric Tons) by Ongrowing Farms, and Turnover (MF)

Species	Production	% 97/96	Turn over	% 97/96
Molluscs				
Cupped oyster	147,150	0	1,398	0
Blue mussel	63,350	0	507	0
Flat oyster	2,500	0	87	0
Cockle	2,400		17	
Manilla clam	650	62	29	63
Scallop	150		3	
Cultured pearl	6		850	
Total	213,806		2,891	
Fresh Water Fish				
Rainbow trout	45,000	-10	675	-9
Fish in ponds	10,000	0	100	0
Silurid	215		4	
Eel	180	0	11	8
Sturgeon	150		5	
Sturgeon caviar	0.4		1	
Tilapia	80		3	
Total	55,625		799	
Sea Water Fish				
Sea-bass	2,173	-4	113	-9
Sea-bream	1,312	27	66	22
Turbot	980	21	49	20
Atlantic salmon	650	32	15	15
Sea water trout	589	-57	13	-62
Other fish	71	20	4	17
Total	5,775	-5	260	-8
Crustaceans				
Macrobrachium	69	0	8.3	0
Tropical shrimp	1,160	11	61	9
Japanese shrimp	24	0	2.4	0
Total	1,253	10	71.7	9
Algae				
Undaria	54	0	0.2	0
Asparagopsis	8		<0.1	
Total	62		0.2	
Overall Total	266,521		4,022	

1997: Hatchery Production (Millions of Units), and Turnover (MF)

Species	Number
Cupped oyster (3 mm)	260
Trout (2 g)	455
Tropical shrimp (12 days PL)	182
Manilla clam	43
Other fresh water fish	62
Sea-bass (2 g)	14
Sea-bream (2 g)	16
Flat oyster (3 mm)	10
Macrobrachium	6
Scallop (30 mm)	6
Turbot (5 g)	2.5

2. Comments on Species

For the **cupped oyster** production,1998 has been characterised by a general decrease of growth rate on the Atlantic coast (20%) in relation to the cold spring and summer. Another consequence of the bad meteorological conditions was the lack of spat collection which traditionally occurs on the South West Atlantic coast. This has happened in only one of the last 20 years. Advice has been issued by IFREMER and the administration to control illegal importation of spat from countries where diseases are declared, and the requirements from domestic hatcheries will probably increase in 1999.

During summer time, in Thau lagoon, a distrophic event killed 2,500 tons of oysters and mussels. The Agriculture Ministry did not allow French producers to integrate innovative tetraploids strains in the field. Conversely, triploids are produced by private hatcheries (with the objective of avoiding summer maturation). Off shore projects in deep water on the Atlantic coast failed because of opposition from local fishermen.

Flat oyster selective breeding programmes are in progress at experimental level to produce strains resistant to parasites (*Bonamia* and *Martellia*). Mortality rates have been reduced by 25%. Negotiations are in progress with private hatcheries to produce these strains.

Mussels suffered from unexpected predation by wild sea bream in long line offshore production, endangering the economic return from Mediterranean production. This is a good example of interaction between mariculture and fishery.

For **turbot, sea bass and sea bream**, private hatcheries decided to implement breeding programmes with the aid of public research bodies. First results indicates a genetic gain of 10% per generation for growth rate. Sexual dimorphism in size appeared important in sea bass, amounting 40% in favour of females. Projects on sea bass viral encephalopathy have been launched to propose vaccination procedure and improved diagnostics. These nodaviruses have been found on halibut, turbot, sea bream. New land based farming system have been designed to treat wastes, either by lagooning using phytoplancton and bivalves (Atlantic coast) or by recycling using recirculating systems (Mediterranean coast, Channel). French production is expected to increase in forthcoming years by a factor 2 in the Mediterranean region.

For **salmonids**, attempts to produced Atlantic salmon in Cherbourg Bay faced the so called "summer syndrom" that had consequences on mortality and growth rates. Brown trout farming still develops in Western Brittany.

For **red drum** in French West Indies, a development plan has been proposed in 1997. First farms begin now to operate, the objective of which is to export on European markets.

3. Others

French government decided to undertake the zoning of the coastal area in order to determine its potential for aquaculture (both shellfish and fish). This study, contracted with IFREMER, will be pursued by a development scheme to enable aquaculture to develop in French marine waters. The major problem relies on the capacity to dispose of hydrodynamics model in every location.

Administration has to face now importation of foreign species. Sounded regulation is lacking in the French law on this topic, ICES recommendations being not incorporated yet.

Finland

Table 1: Active fish farms

	Baltic Sea nr	Fresh water nr	Total nr
Total[1]	207[1]	463[1]	670[1]
Fish farms edible fish	200	87	287
Fish farms fingerlings	19	115	134
Natural rearing pond farmers	-	322	322

[1]Because some farms have more than one production type the numbers are not to be summed

Table 2: Production facilities of the active fish farms

	Baltic Sea	Fresh water	Total
Net cages 1,000 m^3	1,275	372[1]	1,647
Earthen ponds 1,000 m^2	21	799	820
Tanks 1,000 m^2	3	72	75
Natural rearing ponds ha	-	8,261	8,261

[1]including enclosures

Table 3: Production (1,000 kg) ungutted weight and the value of the production, (MEur). The VAT (17%) not included

Production	Baltic Sea 1,000 kg	Fresh water 1,000 kg	Total 1,000 kg	Value MEur
Rainbow trout	12,965	3,350	16,315	36,66
Whitefish	33	3	36	0,17
Brown trout	-	25	25	0
Other species[1]	9	41	50	0,17
Total	13,007	3,419	16,426	37,00

[1]for example, vendace and the char species

Table 4: Value of the rainbow trout fingerling production (MEur). The VAT (22%) not included

Rainbow trout	8,58 MEur

Table 5: Poikastoimitukset istutuksiin ja jatkoviljelyyn (1,000 kpl) sekä kalamäärät (1,000 kpl) vuoden lopussa (ei sisällä vastakuoriutuneita)

Yngelleveranser till utplantering och fortsatt odling (1,000 st) och mängder i odlingar (1,000 st) i slutet av året (nykläckta ingår ej)

Species/group and size class		Deliveries for restocking	Deliveries for ongrowing	Amount of fish at the fam at the end of the year
Rainbow trout	under 20 g	9	13,475	2,240
	20-200 g	4	4,633	7,767
	over 200 g	227	1,864	7,417
Salmon	under 20 g	1,512	694	3,943
	20-200 g	2,647	109	2,668
	over 200 g	0	-	18
Landlocked salmon	under 20 g	53	-	491
	20-200 g	379	-	640
	over 200 g	117	-	37
Brown trout	under 50 g	862	555	3,317
Fresh water	50-200 g	749	121	1,581
	over 200 g	418	30	474
Brown trout	under 50 g	448	249	2,703
Baltic Sea	50-200 g	1,549	80	1,351
	over 200 g	20	7	10
Char species	under 50 g	210	26	846
	over 50 g	78	85	270
Whitefish	under 20 g	23,103	24	457
	20-100 g	146	-	165
	over 100 g	0	-	67
Pike-perc[1]	All sizes	9,843	3	36
Grayling[1]	All sizes	1,666	83	201
Pike[1]	All sizes	928	-	-
Cyprinidae[1]	All sizes	291	8	100
Signal crayfish	All sizes	203	8	. .
Crayfish	All sizes	44	-	. .
Others[2]	All sizes	69	0	6

[1]Usually one-summer-old fingerlings with a weight of under 10 g
[2]For example vendace and burbot

The names of regions used in Tables 6 and 7

1. Uusimaa - Nyland
2. Varsinais-Suomi - Egentliga Finland
3. Häme - Tavastland
4. Kymi - Kymmene
5. Etelä-Savo - Södra Savolax
6. Pohjois-Karjala - Norra Karelen
7. Pohjois-SAvo - Norra Savolax
8. Keski-Suomi - Mellersta Finland
9. Pohjanmaa - Österbotten
10. Kainuu - Kajanaland
11. Lappi - Lappland
12. Ahvenanmaa - Åland

Table 6: Production (1,000 kg) by regions in 1997 (ungutted fish).

Region	Baltic Sea 1,000 kg	Fresh water 1,000 kg
Uusimaa - Nyland	295	-
Varsinais-Suomi - Egentliga Finland	5,046	..
Häme - Tavastland	-	..
Kymi - Kymmene	531	..
Etelä-Savo - Södra Savolax	-	304
Pohjois-Karjala - Norra Karelen	-	189
Pohjois-Savo - Norra Savolax	-	271
Keski-Suomi - Mellersta Finland	-	319
Pohjanmaa - Österbotten	1,333	22
Kainuu - Kajanaland	219	1,442
Lappi - Lappland	-	712
Ahvenanmaa - Åland	5,582	-

Table 7: Production of fingerlings for restocking and ongrowing (1,000) by regions (newly hatched not included)

Species/group and size class		Uusimaa - Nyland	Varsinais-Suomi - Egentliga Finland	Häme - Tavastland	Kymi - Kymmene	Etelä-Savo - Södra Savolax	Pohjois-Karjala - Norra Karelen	Pohjois-Savo - Norra Savolax	Keski-Suomi - Mellersta Finland	Pohjanmaa - Österbotten	Kainuu - Kajanaland	Lappi - Lappland	Ahvenanmaa - Åland	Yhteensä - Total
Rainbow trout	under 20 g	3,696	1,697	1,374	-	734	-	2,568	623	70	2,643	79	-	13,484
	20-200 g	-	59	67	-	213	197	2,150	706	280	86	36	43	4,637
	over 200 g	102	389	144	-	24	32	219	90	42	531	107	411	2,091
Salmon	under 20 g	-	-	-	-	-	-	-	283	-	380	1,543	-	2,206
	20-200 g	. .	101	. .	-	. .	-	135	314	-	1,080	837	. .	2,756
	over 200 g	-	-	-	-	-	-	-	-	-	0	-	-	0
Landlocked salmon	under 20 g	-	-	-	-	3	19	-	1	-	6	. .	-	53
	20-200 g	-	-	-	-	48	211	. .	66	-	22	. .	-	379
	over 200 g	-	-	-	-	1	63	. .	31	-	7	-	-	117
Brown trout	all under 50 g	. .	14	. . .	-	. .	-	-	194	28	78	187	-	697
Sea water	50-200 g	. .	124	-	-	. .	-	. .	182	168	208	93	. .	1,629
	over 200 g	-	13	-	-	-	-	. .	. .	7	1	1	-	27
Salmon and brown trout, Total		237	252	. .	-	311	293	603	1,072	203	1,782	2,700	368	7,864
Brown trout -	under 50 g	6	-	40	-	130	165	-	387	3	184	502	-	1,417
Fresh water	50-200 g	-	-	1	-	151	120	68	18	31	118	363	-	870
	over 200 g	-	-	1	-	20	147	89	107	-	66	18	-	448
Char species	under 50 g	-	-	32	-	. .	. .	-	-	-	7	132	-	236
	over 50 g	-	-	78	-	. .	-	-	. .	-	11	53	-	163
Whitefish	under 20 g	20	288	461	444	493	505	375	2,053	419	7,184	10,885	-	23,127
	20-100 g	-	-	-	30	20	-	-	95	-	1	-	-	146
	over 100 g	-	-	-	-	0	-	-	-	-	-	-	-	0
Pike-perch	All sizes	121	1,932	1,431	523	861	380	1,788	1,870	73	867	-	-	9,846
Grayling	All sizes	-	48	67	95	152	81	-	93	22	733	458	-	1,749
Pike	All sizes	144	198	165	41	25	-	149	33	-	173	-	-	928
Cyprinidae	All sizes	8	109	17	14	130	-	10	11	-	-	-	-	299
Signal crayfish	All sizes	37	67	47	53	-	-	-	7	-	-	-	-	211
Crayfish	All sizes	-	32	7	4	1	-	-	-	-	-	-	-	44
Others	All sizes	-	-	-	-	0	-	-	15	-	-	54	-	69

Germany

ICES Working Group on "Environmental Interactions of Mariculture, 1999"

Harald Rosenthal

Aquaculture in marine and brackish waters remains to be a very small activity in Germany. The few specialised farms along the coast of Schleswig-Holstein continue to produce at the same level. While the cage farm site in the inner Kiel Bight consistently produces 20-30 tonnes of rainbow trout, the turbot hatchery continues at previous production levels with juveniles of turbot while also picking up on the production of seabass. Several sturgeon specimens (white sturgeon and other species), are maintained for scientific studies at the Bülk turbot hatchery near Kiel as well as at the brackish water station near Rostock (Mecklenburg-Vorpommern). A few small-scale trout farms operate along the Baltic Coast of Mecklenburg-Vorpommern.

Restocking of the so-called "Ostsee-Schnäpel" (Coregonus oxirhynchus) along the backwaters of Mecklenburg-Vorpommern has continued in 1998.

Mussel farming is mainly performed along the coast of Lower Saxony and Schleswig-Holstein, partly on leases located nearby or within the Wadden Sea Marine Protected Area. Table 1 summarises the production figures over the past three years. The production varies greatly within years, depending on patfall success. It is anticipated, that total production will recover because of reasonable spatfall last year. A small fishery on Spisula solida existed in 1996 on leases temporarily given to a few fishers.

Table 1: *Mytilus edulis* production on mussel plots in the German Wadden Sea during the period 1996-1998

	Mytilus edulis production		Spisula solida production	
Year	Tonnes (wet weight)	Value (Mio DM)	Tonnes (wet weight)	Value (Mio DM)
1996	32874	14.4		
1997	16569	16.1		
1998	15582	7.8		

Additionally, a small oyster farm, employing rack or thresthle culture, continues to produce 50 tonnes for a specialised market of the Pacific oyster (*Crassostrea gigas*). Seed oysters are regularly received from a certified hatchery in Ireland. This however, has not prevented that seed oysters acted as vectors for the transmission of other invertebrate species which have become established along the coast of the German Wadden Sea.

Ireland

T McMahon

The available statistics for the main species produced in Ireland in 1995 and 1997 are given in Table 1 below. With the exception of *O. edulis*, for which there was a small decrease in production tonnage, there were significant increases in the production tonnage of the other main species. It is expected that the trend of increased production will continue for at least the next three-five years.

Table 1: Aquaculture Production (Metric Tonnes) in Ireland 1995 and 1997

Species	1995	1997	% change
Atlantic salmon	11,811	15,411	30.5
Sea reared rainbow trout		698	
Fresh water rainbow trout		1,101	
Rope mussels (*M. edulis*)	5,501	6,776	23.2
Bottom mussels (*M. edulis)*	5,501	10,208	85.5
Oysters (*C. gigas*)	2,539	3,819	+50.4
Oysters (*O. edulis*)	397	360	-9.3
Clams (*T. semidecussata*)	103	304	195

New Legislation

Aquaculture operations, both on land and in the marine area, are now governed by the Fisheries (Amendment) Act, 1997. The Act obliges any person wishing to engage in aquaculture activities in Ireland to be licensed; unlicensed operations could entail a fine of up to £100,000 and/or imprisonment for up to two years.

Under the Act two types of licences are defined:

Aquaculture licence: This is a licence to engage fully in a clearly defined type of aquaculture for a specified period of time which ordinarily cannot exceed 20 years; the duration of the Licence will be determined by reference to the nature and production cycle of the aquaculture in question and the business plan of the applicant.

Trial licence: This is a licence to engage in aquaculture in an investigative or experimental manner. The period of validity of a trial licence will depend on the nature and merit of the specific projects proposed but cannot exceed one year in the case of salmon farming or three years in any other case.

An Environmental Impact Statement (EIS) must accompany all applications for Aquaculture Licences in respect of sea water salmonid breeding installations. An EIS may also be required in other cases if the proposed aquaculture operation is likely to have significant effects on the environment.

The Fisheries (Amendment) Act 1997 requires public advertisement of all licence applications in order to give interested parties and the public generally the opportunity to comment on those applications and to have those comments duly considered before a licensing decision is made. A decision by the licensing authority to grant an Aquaculture Licence will have effect one month after the decision is published unless, in the meantime, an appeal is duly lodged against the decision. Any person aggrieved by a decision made by the licensing authority under the Fisheries (Amendment) Act 1997 in relation to an application for an Aquaculture Licence may appeal the decision to the Aquaculture Licences Appeals Board. An appeal must be made within one month after the date of publication of the decision. The appeal procedures do not cover applications for Trial Licences.

Aquaculture in Relation to Coastal Zone Management

In December 1998 a new initiative called the Coordinated Local Aquaculture Management Systems (CLAMS) was established. The CLAMS programme, which is coordinated jointly by the Marine Institute and Board Iascaigh Mhara (Irish Sea Fisheries Board) is designed not to try to solve or take responsibility for all issues but to highlight issues that the relevant bodies (Government and private) need to deal with. The various aspects that will be involved in CLAMS include:

- Integration of the various sectors, such as intensive and extensive aquaculture, as well as sections of the inshore fishing fleet.
- Accurate and up-to-date base line data which will incorporate accurate maps and positions of aquaculture operations, production data, fishing areas, and other activities impacting on and being impacted by aquaculture. Much of this is already being addressed by BIM (The Irish Sea Fisheries Board) via its existing GIS/production database.
- Commercial development plans.
- Codes of practice.
- Carrying capacity.
- Single bay management plans for salmon farms

Sea Lice Monitoring

The control of sea lice remains an important issue in Ireland and an extensive sealice monitoring programme, carried out by the Marine Institute, is in place. All salmon farms are monitored 14 times per year with two inspections/month during the critical months of March, April and May. During each inspection two cages of fish are sampled; a standard cage which is sampled at each inspection and another cage selected at random at each inspection. A sample of 30 fish are taken from each cage, the fish anaesthetised and all mobile lice removed and preserved in alcohol. All lice remaining in the anaesthetic after the sample is processed are retained. All lice are identified and development stages determined.

The introduction of single generation sites and minimum fallowing periods and single bay management has resulted in an overall reduction of lice loadings on farms.

Fish Counters

The Marine Institute has a comprehensive programme of installation, operation and maintenance of fish counters on the main salmon rivers in Ireland. Table 2 below gives details of the location, counter type and current status the programme at each of the locations. The programme is ongoing.

Table 2: Summary table of the current progress of the installation and operation of fish counters in Ireland

Location	Counter type	Status
Ballynachinch	Logie	Under construction
Ballysodare		Under construction
Boyne	Logie	Under construction
Casla	Logie	Operational
Corrib	Logie	Under construction
Dee		Under construction
Deele		Under construction
Eaney	Logie	Under construction
Feale	Logie	Operational
Erriff	Logie	Operational
Eske		Under construction
Fermoyle	Logie	Operational
Garavogue	VAKI	Under construction
Gowla	VAKI	Operational
Invermore	VAKI	Operational
Island Bridge	Logie	Operational
Kerry Blackwater	Logie	Operational
Leixlip	Logie	Operational
Moy	HTI	Operational
Slaney	Logie + VAKI	Operational
Suir		Under construction
Waterville	Logie	Operational

Research Programmes

The Marine Institute has been appointed as the agency responsible for implementing the Marine Research Measure of Ireland's Operational Programme for Fisheries 1994-1999.

The Operational Programme for Fisheries is part-financed by the European Union's European Regional Development Fund (ERDF) and its objectives are to maintain and strengthen the contribution of the fisheries sector to the national economy to support economic development and long term employment creation in coastal communities. In particular, the Marine Research Measure is directed at deficiencies in the infrastructure and capacity required to improve marine

RTD (research and technology development) and to develop public-private sector RTD partnerships. Projects relevant to the aquaculture industry, funded under this programme in 1997/98 include:

A Socio-Economic Evaluation of the Impact of Fisheries and Aquaculture in Counties Donegal, Galway, Kerry and Cork

Project partners: Tralee Regional Technical College and Aqua-Fact International Services, Galway.

This project will identify the nature and extent to which coastal communities in the north-west, west and south-west of Ireland rely on fisheries and aquaculture in order to survive. It will profile the likely impact of different fishery policy measures on the viability and quality of coastal/rural communities and regional development in these marginal areas. The study will be driven by the fishing industry, with the emphasis on generating a realistic model of the socio-economic status of the coastal communities, with research expertise provided by Tralee Regional Technical College and Aqua-Fact International Services Ltd.

Environmental Management of Mulroy Bay in Relation to Aquaculture Production

Project partners: C-Mar, The Queen's University of Belfast; Mulroy Bay Aquaculture Producers; and Martin Ryan Marine Science Institute, Galway.

Mulroy Bay is a fully marine inlet on the North coast of Ireland and supports an extensive aquaculture industry, predominantly aimed at salmon, mussel and scallop production. The bay is also the major site for scallop seed collection in Ireland and, as such, is unique. Concern now exists among producers within the bay that expansion cannot continue without a structured plan for sustainable use. The overall objective of the project is to establish an environmental monitoring programme within the bay that can be maintained and managed by those working in the area.

A Remote Sensor to Measure Food Loss From Salmon Farm Cages

Project partners: Sea Sense Ltd, Galway and Aqua-Fact International Services, Galway.

This project seeks to develop a technology, which will assist in the management of feeding in salmon farms to optimise economic returns and ensure the minimum possible fall out of waste food into the environment. The project is a joint venture between two SMEs in the west of Ireland supported by a fish farm operator. The study is led by an acoustic technology specialist in association with an environmental management company and a fish farm - Muir Geal Teo. The product, if successfully developed, has the capacity to offer economic benefits to the fish farmers and environmental management benefits to the regulatory agencies.

Development of a Submersible Finfish Rearing Cage System for Inshore and Offshore Use Using Floating Hose Technology

Project partners: Bonnar Engineering, Co Donegal; Centre for Natural Resources, Tralee Regional Technical College; and Ferim Farraige Oilean Chliara Teo, Mayo.

Ireland has developed a leading position in the area of farming salmon off shore in high seas cages. In this project, a Donegal company in association with the Regional Technical College in Tralee and a fish farming company in Mayo will consider the development of a new type of off shore floating cage, capable of submersion, below the main area of wave activity. The approach offers a number of benefits including; a reduction in susceptibility to wave damage and a reduction of the visual impact of cages as most of the structure will be below water level.

Marine Biotoxins

In Ireland the monitoring programme for the detection of Diarrhetic Shellfish Poisoning (DSP) toxins is now carried out on a weekly basis throughout the year. The number of closures of shellfish production areas, due to the presence of DSP toxins at a level unsafe for human consumption, was very low in 1996, 1997 and 1998. A significant feature, however, was the detection of a previously unknown toxin, azaspiracid, in mussels from two production areas, Killary Harbour and Arranmore Island, on the West Coast. The toxin, which causes severe gastrointestinal illness in consumers, persisted in the shellfish for up to eight months and the production areas were closed for this period. The source of the toxin is as yet unknown.

Effects of Salmon Farming on Water Quality

Kilkieran Bay, on the west coast of Ireland supports 12 licensed salmon farm operators with a combined annual production of approximately 4,000 tonnes. The Marine Institute commissioned AquaFact International Services Ltd to collate the available data on inorganic nutrient concentrations in the bay and to statistically examine the data to determine if there were any significant trends that could be related to salmon farming activities. Data were available from surveys carried out in the bay prior to the establishment of any salmon farms as well as from monitoring programmes carried out at the salmon farm locations. The report, "*An assessment of water quality data from Kilkieran Bay, Co Galway,*" which will be published later this year, concluded that there was no statistically significant increase in nutrient concentrations in the bay as a result of salmon farming activities.

Recent Publications

Costelloe, M., Costelloe, J., O'Donoghue, G., Coghlan, N.J., Oonk, M. and Van der Heijden, Y. 1998. Planktonic distribution of sea lice larvae, *Lepeophtheirus salmonis*, in Killary Harbour, West coast of Ireland. *Journal of the Marine Biological Association of the UK*, **78**, 853 - 874.

Jackson, D., Deady, S., Leahy, Y. and Hasset, D. 1997. Variations in parasitic caligid infestations on farmed salmonids and implications for their management. *ICES Journal of Marine Science*, **54**, 1104 - 1112.

Satake, M., Ofuji, K., Naoki, H., James, K.J., Furey, A., McMahon, T., Silke, J. and Yasumoto, T. 1998. Azaspiracid, a new marine toxin having unique spiro ring assemblies, isolated from Irish mussels, *Mytilus edulis*. *Journal of the American Chemical Society*, 9967 - 9968.

Norway

Arne Ervik, Jan Aure, Anders Stigebrandt and Johan Glette

Introduction

The report gives a short presentation of Norwegian aquaculture and its regulations. It is mainly based on "Statistics from the activities in the field of aquaculture", Directorate of Fisheries, 1998. In addition it addresses the environmental aspects of the aquaculture industry.

Statistics

Licences, approval of fish farm sites, slaughter and processing plants.

The Norwegian aquaculture is concentrated along the coast form Rogaland to Finnmark (Fig. 1).

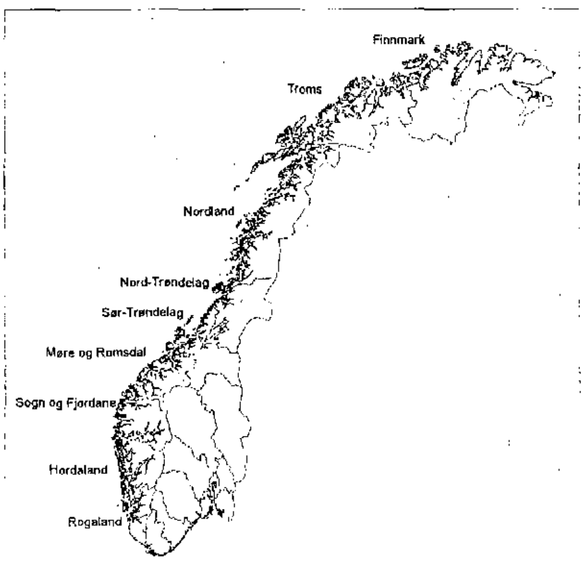


Figure 1: The main aquaculture counties of Norway.

All aquaculture activity requires a licences issued by the Directorate of Fisheries (Table 1). Most grow out licences are issued form Rogaland to Troms, with the greatest numbers in Hordaland and Nordland.

Table 1: The number of licences for salmon and rainbow trout in Norway per 31 December 1997, and the number of licences for other species

Licences for salmon and trout per 31 December 1997 Grow-out farms, juvenile fish and brood stock							Various licences			
Country	Juvenile		Grow out		Brood stock		R&D		Others	Shellfish
	Licence	Cap 1 mill	Licence	Vol 1,000 m^3	Licence	Vol 1,000 m^3	Licence	Vol 1,000 m^3	Number	Number
Finnmark	3	2,30	46	503,40	1	8,00	2	12,01	18	4
Troms	23	9,51	66	788,00	1	12,00	2	10,04	25	5
Nordland	33	20,38	129	1.579,00	2	24,00	7	29,00	64	42
N -Trøndelag	18	8,91	56	661,50	1	3,00	3	19,00	8	23
S -Trøndelag	26	10,98	76	924,60	2	24,00	2	0,50	19	33
M & Romsdal	48	21,34	95	1.142,00	7	34,00	4	15,00	44	26
Sogn & Fj	33	14,33	73	865,00	2	15,00	2	4,00	28	29
Hordaland	75	30,72	136	1.688,30	6	41,00	8	47,50	76	40
Rogaland	25	11,03	51	567,30	3	13,05	3	9,00	36	22
Vest-Agder	5	0,75	12	144,00	0	0,00	0	0,00	7	1
Aust-Agder	1	0,30	4	25,00	0	0,00	0	0,00	3	5
Telemark	5	1,06	4	6,00	0	0,00	0	0,00	3	0
Buskerud	5	0,20	6	12,94	0	0,00	0	0,00	0	2
Akershus	0	0,00	1	0,10	0	0,00	1	0,30	0	1
Oslo	0	0,00	0	0,00	0	0,00	2	0,55	0	2
Vestfold	0	0,00	0	0,00	0	0,00	0	0,00	0	2
Østfold	0	0,00	0	0,00	0	0,00	0	0,00	0	5
Hedmark	13	0,39	33	55,39	2	0,00	0	0,00	6	1
Oppland	3	0,62	32	17,86	2	0,00	0	0,00	0	0
Total 1997	316	132,80	820	8.980,39	29	174,05	36	146,89	337	243
Total 1996	330	132,79	817	8.806,29	37	172,40	32	139,89	340	220
Change	-4,2%	0,01%	0,37%	1,98%	-21,6%	0,96%	12,5%	5,0%	-0,88%	10,45%

The aquaculture is dominated by Atlantic salmon and rainbow trout, but licences are issued for other species as well (Table 2). These licences have a small production or are used for experimental purposes.

Table 2: Licences for the cultivation of other species than salmon and trout in 1996 and 1997. Please notice that marine and flatfish are combined licences

	1996	1997	Changes
Cod	152	122	-20%
Halibut	48	68	42%
Marine	66	68	3%
Char	46	43	-7%
Eel	19	24	26%
Turbot	2	3	50%
Saithe	2	3	50%
Wrasse	1	2	100%
Flatfish	1	1	0%
Greyling	1	1	0%
Mackerel	1	1	0%
Catfish	0	1	
Perch	1	0	-100%
Total	340	337	-1%

The fish farms must be minimum 1,000 m apart to prevent transfer of disease, and each licence should have at least three separate sites. In areas with many licences this may difficult to achieve. The sites are used by rotation to separate the year classes of fish for hygienic reasons, and to reduce the risk of over loading. The fee for an application for a aquaculture site is 8,000 NOK. New application forms that request site specific information required to access the environmental impact of the fish farm (depth profiles and water current in different strata) are now being introduced.

The number of approved sites for salmon and trout are high, especially in the counties Nordland and Sør-Trøndelag where potential sites are abundant (Table 3). In other counties like Hordaland there is a deficiency of sites. The high number of sites in some counties is partly because each site in cooperative location is counted as one site. The actual number of sites in operation for grow out of salmon and trout is about 1,850 (Directorate of Fisheries).

Table 3: Approved sites for aquaculture activity in the different counties

County	Salmon and trout[1]	Other species	Shellfish
Finnmark	150	19	4
Troms	291	30	5
Nordland	894	91	52
Nord-Trøndelag	376	15	23
Sør-Trøndelag	530	18	34
Møre og Romsdal	363	48	36
Sogn og Fjordane	267	31	65
Hordaland	399	82	83
Rogaland	139	39	36
Vest-Agder	22	7	1
Aust-Agder	5	3	7
Telemark	2	2	0
Buskerud	1	0	4
Akershus	2	0	1
Oslo	0	0	1
Vestfold	0	0	1
Østfold	0	0	5
Hedmark	0	4	1
Total	3,441	389	359

[1]Locations in sea and brackish water only.

Each license on a cooperative locations is counted as one location.

According to the guidelines given by the Directorate of Fisheries slaughter and packing plants must be approved as a mean of securing a high hygienic standard of the industry and the quality of the product. These regulations also include plants for further processing of the fish. Registering is also acquired to be allowed to export cultured fish. Table 4 gives an overview of approved slaughter and packing plants and registered exporters.

Table 4: Approved slaughter and packing plants and registered exporters in Norwegian aquaculture industry

County	Slaughter- and packing plants	Plant in work	Registered exporters[1]
Finnmark	8	8	10
Troms	22	22	12
Nordland	29	29	21
N-Trøndelag	13	10	5
S-Trøndelag	22	15	16
Møre og Romsdal	32	21	51
Sogn og Fjordane	17	15	9
Hordaland	30	22	34
Rogaland	12	6	12
Agder	7	3	6
Others	8		22
Total	200	151	198

[1]Source: Norwegian seafood export council

Production

The production of salmon is regulated by feed quota. The quota for 1998 was 650 tonnes dry feed per licence, for 1999 the quota is set to 680 tonnes. The reason for this regulation is an agreement with EU to regulate the export of salmon. Rainbow trout is not included in this regulation, and the production of this species is regulated by a maximum volume of 12,000 m^3 of net pen per licence and a maximum density of 25 kgm^{-3} of fish in this volume.

Table 5 presents the statistics for the production of salmon and rainbow trout in the period 1993 to 1997, and in the different counties in 1997. The production and sale of juveniles is shown Table 6. The main production takes place along the western and northern coast form Hordaland to Nordland (Fig. 1). This part of the coast is little influenced by pollution or euthrophication. In 1998 the production of salmon and rainbow trout was respectively 345,595 and 41,267 tonnes round weight. The value of this production was 7,925 and 836 million NOK.

Table 5: Production and sale of salmon and trout in Norwegian culture 1993-1997

Weight thousand metric ton round weight. Value million NOK. Average price with sale NOK

County	Salmon			Trout			Changes (weight)	
	Weight	Value	Price	Weight	Value	Price	Salmon	Trout
Finnmark	9,13	182,00	19,93					
Troms	21,69	457,65	21,10	0,01	0,15	14,82		
Nordland	62,06	1.289,88	20,79	0,10	1,95	20,07		
Nord-Trøndelag	26,07	518,20	19,88	0,51	9,48	18,71		
Sør-Trøndelag	40,29	815,51	20,24	4,91	95,01	19,36		
Møre og Romsdal	45,57	913,82	20,05	12,17	233,57	19,19		
Sogn og Fjordane	34,67	671,26	19,36	5,82	107,42	18,46		
Hordaland	66,54	1.333,13	20,03	8,07	147,50	18,27		
Rogaland	20,13	411,15	20,42	1,66	30,45	18,39		
Agder/Østlandet	5,24	117,65	22,47	0,25	4,47	18,23		
Total 1997	331,37	6.710,25	20,25	33,49	629,99	18,81	11,4%	45,8%
Total 1996	297,56	5.916,01	19,88	22,97	479,60	20,88	13,8%	56,2%
Total 1995	261,52	6.109,66	23,36	14,70	362,51	24,65	27,9%	0,9%
Total 1994	204,47	5.638,99	27,58	14,57	343,78	23,59	25,0%	62,5%
Total 1993	163,58	4.516,45	27,61	8,97	216,09	24,10		

Table 6: Production and sale of juvenile salmon and trout in 1995-1997, and at county level in 1997

Quantities mill numbers. Value mill NOK

County	Salmon						Trout	
	0 year old		1 year old		2 year old		All ages	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Finnmark	0,27	1,88	0,98	8,10	1,14	9,15		
Troms	0,16	1,41	6,30	51,11	0,89	8,18		
Nordland	6,35	42,84	13,94	111,60	0,34	3,18		
Nord-Trøndelag	2,76	21,37	5,43	37,39	2,90	25,31	0,04	0,23
Sør-Trøndelag	1,42	7,82	7,37	55,31	0,56	7,20	1,69	11,62
Møre og Romsdal	1,87	13,39	11,65	98,51	1,21	11,09	3,51	25,79
Sogn og Fjordane	0,90	5,84	8,23	67,62	1,06	10,40	1,35	10,17
Hordaland	6,13	48,34	18,50	171,05	0,72	7,05	3,76	19,83
Rogaland	1,76	12,39	4,88	33,52	0,89	5,22	1,00	6,73
Agder/Østlandet	0,58	4,87	1,17	13,54			0,05	0,10
Total 1997	22,21	160,14	78,44	647,76	9,71	86,78	11,41	74,48
Total 1996	18,01	139,94	68,77	653,51	11,73	120,69	12,14	85,85
Total 1995	18,97	168,44	72,19	811,88	6,28	82,34	10,63	82,29

Million		1995	1996	1997
	Salmon	97,44	98,51	110,36
	Change		1,10%	12,03%
	Trout	10,63	12,14	11,41
	Change		14,25%	-6,08%

Other Species

Compared to salmon and rainbow trout the production of cod, arctic char and halibut is small and have been relatively stable for the last years (Table 7). The cod is produced from both wild caught and produced fry, while the production of char and the halibut are completely based on produced fry. The slow increase in the production of halibut from is caused by the nodavirus (VER) which set back the production of fry. In 1998 one produced about 250 tonnes of halibut, in 1999 the production is expected to be above 600 tonnes.

Table 7: Production of cod, arctic char, halibut and other species in the different Norwegian counties and in the period 1994-1997

Quantities metric tons

County	Cod	Char	Halibut	Other Species[1]
Finnmark	63			
Troms	144			73
Nordland	11	217		
Nord-Trøndelag	6	10		
Sør-Trøndelag	14			
Møre og Romsdal	21	114	55	
Sogn og Fjordane	16			1
Hordaland	30	1	3	26
Rogaland	8	2		3
Agder/Østlandet	4	45	54	
Total 1997	307	344	113	157
Total 1996	198	200	138	299
Total 1995	289	289	134	310
Total 1994	561	241	63	224

[1]Other species are turbot, mackerel, eel and wrasse

Productivity

The productivity of the aquaculture industry have increased significantly, which is also reflected in the cost of production (Fig. 2, Table 8). The most important factors are improved fish feed and feeding routines, use of artificial light, production of smolt all the year, reduced decease losses, improved breeding programmes and environmental conditions. All this have reduced the time of production in the sea from 22 months in 1987 to 13 months in 1995. This increased turn over accounts for a substantial part of the reduced cost of production.

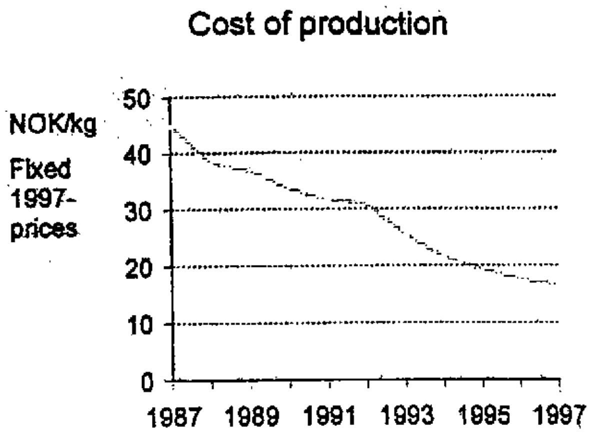


Figure 2: Cost of production in Norwegian aquaculture in the period 1987 to 1997.

Table 8: The elements of the cost of production in Norwegian aquaculture in 1996 and 1997. Source: Examination of profitability of grow out farms. Directorate of Fisheries 1997

Cost of production

Costs, NOK per kg	1996	1997
Smolt	3,00	2,64
Feed	8,60	8,94
Insurance	0,35	0,23
Wages	1,66	1,58
Other working costs	2,72	2,51
Interest	0,88	0,73
Cost of production	17,21	16,63
Compensation	-0,07	-0,12
Loss on claim	-0,01	0,03
Calc wages to owner	0,01	0,01
Calc Interest on own capital	0,43	0,34
Calc Discount (mixed prize)	0,57	0,58
Slaughtering and packing	1,97	2,19
Transport	0,18	0,18
Total cost pr kg	20,29	19,84

Environmental Impact

Environmental quality objectives

The environmental quality objectives (EQO) set in 1993 have been audited and new ones have been formulated for the period 1997-1999. The EQO covers obligations through international organisations like NASCO (1994) and The North Sea Declarations (1990 and 1995) as well as national objectives. The main areas of concern are escapees, transfer of decease, the use of chemicals and medicine and organic load.

Escapees

Norway is considered a core area for Atlantic salmon, and Norway has obliged herself to contribute to protection, rebuilding of the wild strains and a sustainable management of the species. Despite the effort to prevent fish from escaping, the number of reported escapees is still high, although the relative number of escapees seems to be decreasing (Fig. 3).

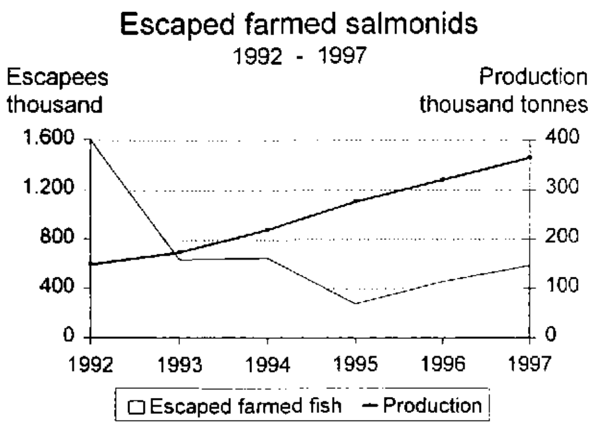


Figure 3: Reported escaped framed salmonids in the period 1992 to 1997. The figure also shows the production of Norwegian aquaculture.

As can be seen form Table 9, escapees contribute just 3% to the total losses, while diseases and losses of unknown reasons together contribute to 75%.

Table 9: Losses in Norwegian aquaculture in 1997

Quantities: 1000; S = Salmon; T = Trout

	Diseases		Escapees		Maturity		Mortality 1.mnd in sea water		Predator		Wound damage		Defects		Unknown reasons		Total waste	
County	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T
F	1	0	4	0	0	0	108	0	5	0	41	0	0	0	419	0	576	0
T	161	0	115	0	7	0	319	0	71	0	67	0	17	0	826	4	1.583	4
N	550	0	63	30	50	0	235	12	254	7	63	0	87	0	1.306	34	2.607	83
Trø	1.053	11	92	78	48	3	268	4	96	26	54	0	66	0	1.700	159	3.377	281
M & R	695	11	11	0	231	108	209	17	62	16	47	0	17	20	1.332	285	2.603	456
S & Fj	299	0	23	32	137	15	65	11	38	5	44	0	58	1	793	167	1.456	231
H	1.261	76	6	5	146	12	323	72	15	3	49	8	38	0	1.672	123	3.509	298
R	270	0	93	0	57	9	206	8	40	4	10	8	3	0	304	82	983	110
A	214	0	28	7	72	2	17	1	0	0	8	0	3	0	294	5	636	15
Total	4.503	98	434	152	748	149	1.748	125	581	60	382	16	287	22	8.645	858	17.329	1.478
Total	4.601		586		897		1.873		641		398		309		9.503		18.807	
%	24%		3%		5%		10%		3%		2%		2%		51%		100%	

Investigations in the period 1989 to 1996 showed a frequency of 34 to 54% escapees in salmon catches at the coast. The frequency has been significantly higher at the coast than in the fjords, where the escapees contributed to 10 to 21% of the catch. In the rivers 4-7% of the catch taken by anglers was escapees, while the frequency in the brood stock in the rivers was as high as 21 to 38%. The short term objective to reduce the frequency of escapees in the brood stocks are thus not fulfilled. There seems to be a trend that the frequency of escapees are highest in areas with much fish farming, but the variation between the different areas are great.

We have little information on the effect of escapees have on the wild strains of salmon. The ICES "Working Group on the application of genetics in fisheries and aquaculture" concluded in 1994 that escapees from aquaculture must be kept at a minimum or stop completely, until one have other means that can reduce the negative consequences escaped cultivated fish have on the wild populations of Atlantic salmon.

Disease

The disease situation in Norwegian fish farming is at present good. The bacterial diseases is almost absent due to the use of effective vaccines, vaccination strategies and hygienic means. The most serious disease problems are caused by the IPN virus after sea transfer of Atlantic salmon and by infections with salmon lice. Vaccines against IPN exist, but they are less effective than the vaccines to bacterial diseases. To control the lice infections, wrasse together with use of chemicals seems to be the most used strategy (Table 10).

Table 10: Sale of endo- and ecto-parasite drugs used in Norwegian aquaculture. Source NMD

The numbers are given in kg active substance

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Endo-/ectoparasitt drugs Metrifonat (Neguvon ®)[1]	3,300	2,408	2,144	1,946	1,779	1,227	281	138	0	0
Diklorvos (Nuvan ®)	3,488	3,416	3,588	3,115	2,470	1,147	395	161	36	0
Azametifos (Salmosan®)						389	738	606	315	182
Cypermethrin (Excis®)								23	28	2,5
Pyretrum (Py-Sal 25®)						32	26	9	18	0
Hydrogenperoksid[2]					*ca* 710 tonnes	290 tonnes	340 tonnes	160 tonnes	20 tonnes	0 tonne
aziquantel[3]	72	177	188	86	79	119	110	130	225	195
Fenbendazol[3]	104	60	56	10	2,2	1,5	0	0	15	16
Malakittgreent (oxalat)	26	39	114	69	56	63	47	35	36	23
Diflubenzuron[3]								160	361	437
Teflubenzuron[3]								610	1,510	1,334
Deltamethrin (Alpha Max®)										18,5

[1]Neguvon powder is also used for the treatment of pig and chicken. The numbers include only 2.5 kg packages used for aquaculture.

[2]Hydrodenperoksid for treatment of salmon lice was made reseptpliktig in 1993. One dealer of hydrogenperoksid did not report the sale for 1993, but this sale is considered to make a minor contribution to the total sale. The numbers for the later years are complete.

[3]The number include mainly sale of medicated feed from feed producers.

NMD 11 February 1999

Even though many of the potential diseases are controlled by vaccination and other prophylactic treatment, cultured fish is a potential reservoir of pathogens (bacteria, virus and parasites) which may be transferred to wild fish stocks. Spreading of salmon lice from farmed fish to wild fish is one of the most serious problems connected to fish farming today. A national action plan is being made which includes objectives, action plans and research priorities.

Due to low occurrence of bacterial diseases among farmed fish in Norway the last five years, the usage of antibiotics in the industry has been low (Table 11). In 1987 the industry used about 48 tonnes to control such diseases. In 1998 about 680 kilos were used. In the same period the salmon production increased from 60.000 tons to close to 400.000 tons. The improved disease situation has decreased the environmental problems caused by the usage of antibiotics in fish farms.

Table 11: The sale of antibacterial agents in Norwegian aquaculture in the period 1987 to 1998. The numbers are given in active substance, and include medicine sold by medicine wholesalers and feed companies. The numbers are worked out by NMD in cooperation with Norges veterinærhøgskole, Seksjon for farmakologi og toksikologi. Source NMD

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Florfenikol							56	14	64	64	123	135
Flumequin			329	1,959	3,837	9,833	2,177	227	182	105	74	53
Nifurazolidon	15,840	4,190	1,345	118	131	0	78	0	0	0	0	0
Oxolinic acid	3,700	9,390	12,630	27,659	11,400	7,687	2,554	811	2,800	841	507	436
Oxytetracline-chloride	27,130	18,220	5,014	6,257	5,751	4,113	583	341	70	27	42	55
Trimetoprim + sulfadiazin (Tribrissen)	1,900	670	32	1,439	5,679	5,852	696	3	0[1]	0[1]	0[1]	0[1]
Total	48,570	32,470	19,350	37,432	26,798	27,485	6,144	1,396	3,116	1,037	746	679

[1]The last four years there have been very little sale the via the feed producers. The sale of Tribrissen from medicine "grosister" can not be distinguished with regard to use at farmed fish and other animals.

No systematic mapping of diseases on the wild fish stocks in Norwegian waters has been carried out. Accordingly, no statistics on prevalence of diseases on wild fish populations is available. However, no and then separate cases of diseases have been reported. Among bacterial diseases the most common one seems to be vibriosis caused by various serotypes of *Vibrio anguillarum*. This disease has been detected on coalfish and Atlantic cod caught in Norwegian waters. Little is known concerning viral diseases on wild fish stocks mainly due to lack of systematic studies. However, Infectious Pancreatic Necrosis (IPN) virus has been detected on fish and shellfish. This virus is not species specific and can be transferred from one species to another. As it is detected on shellfish without causing any disease problems it is not unlikely the such organisms acts as vectors for transmission of the virus. Also, fungus infections have been reported on wild fish stocks in the Norwegian waters. The best known case is infections with *Ichtyophonus hoferi* on herring caught in Norwegian fjords. Such infections may contribute to a decrease in the population of this species. Infections with *Ichtyophonus hoferi* may also be transmitted from one species to another and is reported on different flat fish species.

Parasites, exoparasites as well as endoparasites, may cause problems on wild fish stocks. Various species of lice is reported on Atlantic cod and other white fish species. The salmon lice has been detected on wild Atlantic salmon and on sea trout. Especially sea trout populations seams to be heavily infected and may be one reasons for the observed decrease in the populations of sea trout and salmon in Norwegian waters.

Regulating Environmental Impact

The regulations of Norwegian aquaculture is under revision, and an important part of this work is to implement regulations that safeguard good environmental conditions inside and in the vicinity of the fish farms. A system to prevent overloading of fish farm sites has therefore been developed, and is now taken into use. The system is called MOM, and consists of a monitoring programme, a set of environmental quality standards and a simulation model. One of the principles in MOM is that the extent of monitoring is determined by the environmental impact, so that the more severe the impact, the more intensive the monitoring.

The use of MOM is shown at Figure 4. For new farms the environmental impact and an tentative monitoring is simulated. When the monitoring is carried out, final level of monitoring is determined. For sites in operation the level of monitoring is determined form the results of the monitoring.

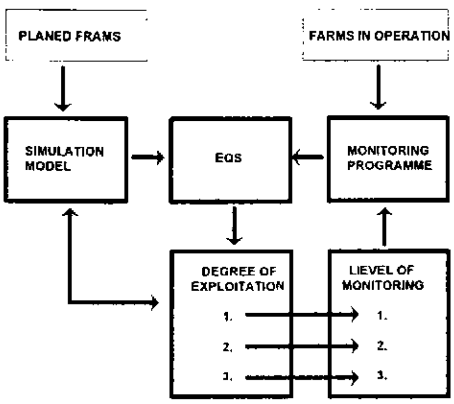


Figure 4: The application of the MOM system.

Modelling

The work to complete the simulation model has continued. Below is presented an abstract by Anders Stigebrandt of a paper describing the module for simulating the turnover of energy and matter by fish as an input to a model for simulating the water quality in fish farms.

Abstract

This paper describes a model of the turnover of energy and matter due to metabolic processes in fish. The model conserves energy and matter, resolved in protein, fat and carbohydrates, and can be used for many purposes. Among other things, it can be used to find food compositions fulfilling different objectives, for instance, minimising the emission of plant nutrients or food costs. It happens that these two particular objectives may be combined since high protein content in the food (expensive) leads to large emissions of nitrogen and phosphorus and low protein retention by the fish. Here the main application of the model is to compute oxygen consumption and emissions of various biologically active substances from a fish farm given the fish stock, food composition, feeding rate and temperature. Fish respiration and emissions of dissolved substances are fed into a water quality model for net pen fish farms in natural water bodies. With known current statistics for the farm site, the minimum flushing of the net pens can be estimated for different physical configurations of the farm. From this the maximal fish production with satisfactory concentrations of oxygen and ammonia may be computed. The flux of particulate organic matter (uneaten food and faeces) estimated by the fish model is fed into

another model computing the dispersion of negatively buoyant particles by currents and the loading of the sediment. That model (developed earlier) also computes the maximal allowable production with viable animals in the sediment beneath the fish farm.

Scotland

SOAEFD Annual Survey of Fish and Shellfish Farming for 1997

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Part 1: Shellfish

This report is based on an annual survey questionnaire of all registered Scottish shellfish farming companies. The cooperation of the shellfish farming industry is gratefully acknowledged.

The survey showed that 105 companies produced shellfish for sale for the table and 19 for ongrowing. The remaining 102 companies remained in operation but for various reasons had no sales during 1997. The number of active companies decreased from 187 to 170 since 1996 (from a peak of 229 in 1990). These companies consisted of 265 active sites, of which 158 produced shellfish, a 10% decrease from 1996. Most active sites and areas of greatest employment were focussed in the Strathclyde, Highland, Western Isles, Orkney and Shetland regions.

Production

The shellfish species cultivated in Scottish waters and for which production returns were received were:

Common mussel	*Mytilus edulis*
Pacific oyster	*Crassostrea gigas*
Flat oyster	*Ostrea edulis*
Scallop	*Pecten maximus*
Queen	*Chlamys opercularis*

Oysters

Pacific oysters: 2.8 million oysters were produced for the table, very similar to the 1996 figure. A further 1.2 million were produced for on-growing, a decrease of around 60% on the 1996 figure Most productive companies were sited in the Strathclyde and Highland Regions.

Native oysters: Only 11,000 native oysters were produced for the table in 1997, compared to 96,000 in 1996.

Pectinids

Scallops and queens: Production of scallops for the table fell from 302,000 in 1996 to 223,000 in 1997. The production of queen scallops was relatively constant at 1,207,000 in 1997 compared to 1,271,000 in 1996. Most productive companies were sited in the Strathclyde and Highland Regions.

Mussels

Mussel production increased by about 12% during 1995, as 1,307tonnes were produced. No mussels were produced for ongrowing. Most productive companies were sited in the Strathclyde and Highland Regions, and also in the Western Isles. The figures for mussels do not include dredge caught, market size animals from wild fisheries.

Although prices fluctuated throughout the year, the value at first sale of the species cultivated can be estimated as follows: Pacific oysters varied between 12 and 25 pence per shell; native oysters 50 pence per shell; scallops and queens 50 and 5 pence per shell respectively; and mussels £750-£1,200 per tonne.

General Comments

Marine biotoxin monitoring in Scotland continued during 1997. Examination of more than 1,700 shellfish and phytoplankton samples from 40 sites revealed the presence of paralytic (PSP) and diarrhetic (DSP) shellfish poisons in all important shellfish growing areas. Voluntary Closure Agreements were agreed where appropriate, and Closure Orders under the Food and Environment Protection Act (1985) were imposed in Orkney. The effects were seasonal, from spring to early autumn.

Classification of bivalve production areas under the Food Safety (Live Bivalve Molluscs and Other Shellfish) Regulations 1992 covered 163 areas, of which only seven were classified as C. There are currently 19 approved depuration systems. In an attempt to meet End Product Standards at all times, there is an increased demand from buyers that all marketed stocks are depurated, including those classified as A (where purification is not essential).

The steady growth in shellfish production over the last 11 years has tended to slow. The industry is still dominated by small producers, presumably representing the crofting communities, although production of all species is dominated by a few large producers. The number of companies and manpower employed in the industry remain stable. It is predicted that the production of all species will increase steadily over the next few years.

Part 2: Salmon

This report is based on an annual survey questionnaire of all registered Scottish fish farming companies. The cooperation of the fish farming industry is gratefully acknowledged. Annual return forms were sent to 65 companies covering 171 farms engaged in ova and smolt production, and 101 companies covering 340 active on-growing sites. Returns received were 100% of these companies.

The survey showed that 98 companies produced fish for sale; the remaining three companies remained in operation but for various reasons had no sales during 1997. The number of active companies decreased from 106 to 98 since 1994. These companies consisted of 340 active sites, of which 275 produced fish, a 1% decrease from 1996. Most active sites and areas of greatest employment were focused in the Strathclyde, Highland, Western Isles, and Shetland regions.

The Scottish salmon industry increased its production by 19% in 1997, to 99,197 tonnes. Mean weights of grilse and pre-salmon were 3.3 kg and 3.8 kg. It appears that market requirements dictate the size at harvest.

The trend to increasingly harvest fish in the same year as smolt input (fish under one year old) halted in 1995 and in 1997 amounted to only 0.7% of the total harvest. Since 1992, mean fish weight has generally increased, which reflects the effectiveness of vaccines, enhanced growth rates due to improved feeds and feeding methods (eg high protein diets, automatic feeding systems) and continuing improvements in husbandry practices, particularly those aimed at reducing stress in the fish (eg air lift mortalities removal, swim through at net changes). Other important factors have been the application of management schemes to avoid the introduction of infections, eg fallowing of sites, group agreements on single age group stocking over extended areas, stocking with smolts of common health status, and continuing efforts to control sea lice.

The general pattern of improved survival of smolts to harvest from the minimum in 1989, when survival was at a minimum of 58% due largely to the bacterial disease furunculosis, seems to have ceased. Overall survival of the 1995 year class was 87.8% compared to 90.7% and 91.5% for the two preceding year classes. This decrease may be attributable to a number of factors, including disease, jellyfish, algal blooms, escapes, predation by seals, and poor husbandry.

Sea water cages continue to be the only significant system of production. The number of tank sites remained static and in 1997 contributed less than 0.6% of production. The volume of sea cages increased from 8,433 to 10,587 million cubic metres. The trend towards the use of cages of larger sizes continues.

The numbers of smolts put to sea continues to increase, from 32.9 million in 1996 to 42.8 million in 1997. It is estimated that this should result in a increase of production to over 115,000 tonnes in 1998. Some 8.9 and 0.2 million were, respectively, S0.5 and S1.5 "out of season" smolts, each showing an increase over 1996. The number of sites producing more than 500 tonnes (71 sites) had again increased, and contributed 71% of the overall production. The average production density was 9.3 kg per cubic metre of cage net capacity, and was less than the 1996 value of 9.8 kg per cubic metre. This suggests that the industry had paid heed to SOAEFD warnings not to allow increased production at the expense of increased stocking density. Productivity per man at the largest sites has attained 100 tonnes, compared to 80 tonnes per man in 1996. The averages for the industry were 77 tonnes and 60 tonnes respectively.

Ova production and ova laid down to hatch in 1997 increased by 63.8 million (50%) and 7.4 million (10%) respectively. This should result in increased smolt production in 1998. Exports of salmon ova fell by 0.8 million (2%) and imports by 4.5 million (55%). Some 10 million additional smolts (30%) were put to sea in 1997 and these should contribute to higher production tonnages in 1998 and 1999.

Part 3: Rainbow Trout

The activity in the rainbow trout industry has been rather stable for several years. Production in 1997 amounted to 4,653 tonnes, compared to 4,630 tonnes in 1996. This may indicate that current market demands are being met and that production will only increase if new market demands or outlets can be established.

Sweden

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Production Trends

The available statistics for the main species produced in Sweden in 1996 and 1997 are given in Table 1. The overall trend (for the last five years) is that rainbow trout production decrease, Arctic charr increase, and other produced species remains relatively stable.

About 75% of the rainbow trout production in 1997 occurred in fresh water, and the remaining 25% in the sea.

The number of companies producing fish for consumption in 1997 was 183, which can be compared with the figures for 1989, where 314 companies were active.

Table 1: Aquaculture production (metric tonnes) in Sweden 1996 and 1997

Species	1996	1997	% change
Rainbow trout	5778	4875	-156
Eel	184	215	168
Arctic charr	100	183	830
Blue mussels	1821	1425	-217
Cray fish	10	8	-200

Trends in the Industry

A relatively small number (about 18) of larger fish farms (mean production of about 200 tonnes) clearly dominates the total production of rainbow trout in Sweden. The general trend for these companies is that they aim to increase the production to at least 400 tonnes per year in order to take advantage of large-scale benefits. However, in many cases, such planes are hindered by local environmental concerns.

Research Activities

A three year long research programme on the environmental effects of fish farming started in 1997. The aim of this project is to 1) establish the nutrient load from Swedish fish-farming activities; 2) create new models for evaluation of ecological effects of nutrient discharge; and 3) create a toolbox for handling of environmental issues related to fish farming, ie handbook in Environmental Consequence Analysis, identification of water resources suitable for fish farming, genetically hazards of escapees, the risk of disease transfer from farmed to wild fish, and a sectored view of the nutrient balance between fisheries and fish farming.

International Meetings

The 2nd COST 827 Workshop on "The behaviour of fish in culture" held in Umeå, Sweden 18-20 of August 1998. The workshop attracted 93 people from 11 different countries.

Workshop on the theme "Man and coastal areas: impact of aquaculture" to be held in Kristineberg Marine Research Station, Fiskebäckskil, Sweden 28-30 June 1999. The workshop is a joint activity between the Scandinavian countries and France.

Appendix 4

INFORMATION ON DEPOMOD (SCOTLAND)

Economic Site Assessment Through Modelling the Effects of Carbon Deposition to the Benthos From Large Scale Salmon Mariculture (DEPOMOD)

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Increasingly regulators find themselves seeking better predictive capability for large fish farms and improved objectivity in the decision making process. This decision frequently adopts the precautionary approach implicit in environmental protection. Similarly, fish farmers need methods for assessing the suitability of new sites, or the potential for expansion at existing sites, so as to concentrate their efforts on sites which are likely to have good husbandry characteristics and minimise the costs of future monitoring of impact on the sea bed. It would be of considerable value to both the industry and the regulator if there was some agreed tool available, based on objective science, which could be used by both sides to determine the optimum carrying capacity of a site or proposed site.

Although models have been developed on fjordic ecosystem dynamics (Ross *et al.*, 1993, 1994), these are on a much broader scale than required for this purpose and provide no information at high resolution. Gowen *et al.* (1989) described a simple model for predicting carbon deposition rates from marine fish farms based on a current meter record and the production of a site. This model, although a useful starting point, only provides limited information regarding the deposition of carbon and includes none of the physical and biological parameters which determine the fate of organic material once it has reached the seabed, nor does it include fish husbandry factors affecting variation of input over time.

Ten years ago farms with biomass consents of 200 tonnes were considered large and it was on such sites that much of the basic science regarding impacts to the benthos was established (Hall and Holby, 1986; Weston, 1986; Brown *et al.*, 1987; Kaspar *et al.*, 1988; Ritz *et al.*, 1989). Applications being prepared at present typically relate to much larger operations where consents are being sought for biomasses in the range of 1,000 to 2,000 tonnes. These sites are often located in highly dispersive areas exposed to strong tidal currents although there is still considerable demand for sites in more sheltered sea lochs. In this project we are making detailed investigations on the hydrography and biological effects of two large sites, both in relatively exposed locations, and comparing the results with historic and other available data for the purposes of developing and validating a computer model of the dispersal of organic material and consequent effects on the benthic community.

This project takes as a starting point the model (BenOss) developed by Dunstaffnage as a commission from SEPA, UK Water Industry Research Ltd and the EA (Cromey *et al.*, in press) for predicting benthic community response to varying the treatment level from long sea sewage outfalls. This model, which essentially tracks particles of organic solids in a current field, follows their incorporation and degradation in sediments, and predicts indicators (indices) of community response, has been validated for long sea outfalls and is now in wide use in the water industry.

A number of modifications are being made to allow this model to be used at fish farms: the level of organic loading on the sediment is approximately two orders of magnitude greater around fish farms compared with long-sea sewage outfalls, consequently the biological communities present are quite different; the gradients of organic input are extremely steep with very large changes occurring in relatively short distances making sampling station selection critical; fish food and faeces have quite different behaviours in sea water relative to sewage solids and are of different composition with unknown degradation rates; waste food pellets quickly break down into smaller particles of unknown size distribution which are then susceptible to resuspension at varying rates. In addition fish farm sites are generally more stratified than sites for sewage outfalls requiring a greater appreciation of vertical current shear and its effects on particle dispersion. Whereas sewage outfalls can be described in terms of mean flows and concentrations, the output from fish farms varies dramatically over the growing cycle requiring modelling of typical fish growth. Food wastage is generally believed to be at a lower level than in the past: Gowen *et al.* (1989) assumed a 20% loss; more recently (1992) this has been estimated at 12% from sediment trap studies (Black, unpublished), however further study is required to accurately assess this important contribution.

Objectives

The objective of the research is to produce a flexible, user friendly computer model of the effects of carbon deposition from large scale mariculture on the benthos in dynamic coastal environments to assist assessment of applications for new, or increased, discharge consents. This model will be validated using existing and new field data.

In order to meet this primary objective several secondary objectives must be achieved:

- modification of the existing model to allow for variations in carbon input over the growing cycle;
- model validation against benthic, hydrographic and husbandry data from several sites;
- determination of degradation rates of fish food and faeces;
- improved estimation of the% food wasted;
- estimation of the particle size distribution of waste food and faeces at various states of decay.

Developments of the model have been validated against the field data gained during the detailed benthic surveys and from historic data provided by Marine Harvest McConnell, SEAS Ltd, and SEPA. The model is developed as a Windows 95 application entitled DEPOMOD.

The model has been made "user friendly" allowing its use directly by fish farmers on the basis of a current meter record and site specific parameters. The farmer will therefore have an inexpensive and rapid method for determining whether or not to proceed with an application and the level of biomass likely to be consented. Support for the industry will be in the form of a workshop planned for the end of the project to which the industry will be invited. The model will be made available to the fish farm industry in the form of an executable file and associated report and user manual.

Using this model as an agreed tool for determining consents, and knowing that this is also freely accessible to the industry, the regulator should have to deal with fewer applications as those likely to fail will not be submitted. The regulator will have an additional validated method for determining consents thus reducing disputes and may use the data requirements of this model as a benchmark for the integration of regulatory requirements across all SEPA regions.

Appendix 5

INFORMATION ON POST-AUTHORISATION MONITORING PROGRAMME (PAMP) FROM SCOTLAND

The Ecological Effects of Sea Lice Treatment Agents

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The toxic effects of all new sea lice treatments have been examined during the product licensing and discharge consenting processes but these studies have been limited to a few sentinel species and there is currently little information on the wider ecological consequences of the use of these products. This project seeks to address the widely perceived research need in this area by conducting long term, broad scale BACI (Before After Control Impact) studies at a range of low energy fish farm sites and encompassing all the currently available or presently proposed sea lice treatment chemicals. The results of this research will answer commonly asked questions on the ecological significance of these chemicals under realistic treatment regimes with respect to macrofauna, zooplankton, meiofauna, benthic diatoms, phytoplankton and macroalgae. This proposal has been developed and costed on a three year basis but it is assumed that the study will require five years to deliver the results at a sufficiently high level of statistical certainty. The experimental design of the final two years of the five will be informed by the initial results and it may be possible within the first three years to discontinue study of those taxonomic groups which can be proven to show no response to particular treatment agents.

1. There have been several published studies on the effects of sea lice treatment chemicals on sentinel taxa and on certain species assemblages (see for example refs 2-27). While the proposer is aware of many other such studies carried out on behalf of pharmaceutical companies for regulatory purposes which are "commercial in confidence", there have not yet been ecosystem based studies which would seek to determine the wider ecological relevance of these compounds. The reasons for this dearth of research are simple: experiments are difficult to design requiring a fundamental understanding of the multi-variate statistics necessary to test for effect and of the many possible sources of variance within the marine environment, they are necessarily expensive requiring a large number of experimental stations, reference stations and sites and they require to be of sufficiently long duration to account for temporal variance. Most importantly they require the cooperation and collaboration of fish farmers whose principle objective must be the health of the fish under culture. Also, they require expertise levels not currently available within one institution.

   The results of the study proposed here, using the methodology briefly outlined below, will aid regulators in setting discharge limits based on robust statistics, while identifying key taxonomic components which should be targeted for regulatory monitoring. In addition, the number and range of samples required will provide key information of the natural functioning of sea loch systems, the natural variability of the communities found therein and the response of these communities to stress from organic and chemical pollutants. This information will be used to further develop impact models (Ref 29) which relate the input of contaminants to the spatial and temporal biological response. Such models are currently being tested for specific treatment chemicals by the proposer for SEPA.

Scientific Objective(s)

1. To determine the effects of each of several sea lice treatment chemicals on macrofaunal assemblages.

2. To determine the effects of each of several sea lice treatment chemicals on zooplankton assemblages.

3. To determine the effects of each of several sea lice treatment chemicals on meiofaunal assemblages.

4. To determine the effects of each of several sea lice treatment chemicals on benthic diatom assemblages.

5. To determine the effects of each of several sea lice treatment chemicals on phytoplankton assemblages.

6. To determine the effects of each of several sea lice treatment chemicals on macroalgal and littoral assemblages.

7. To measure the concentrations of each of several sea lice treatment chemicals in the environment post-treatment.

8. To determine the significant correlations between ecosystem responses, time, and therapeutant concentration to determine the proportion of the observed environmental variance attributable to the treatments against a background of responses due to other parameters such as waste organic materials and nutrients.

9. To model the dispersion and or deposition of farm wastes including of each of several sea lice treatment chemicals in the marine environment post-treatment and to incorporate terms relating to the toxicity of these chemicals to certain parts of the ecosystem (eg the macrofauna).

Interdependence of Objective(s)

Objectives 1 to 6 could be viewed as separate projects but, independently, they are not capable of achieving the primary objective (8). In reality much of the fieldwork which will address these objectives will be undertaken simultaneously to maximise efficiency. Objective 7 addresses the need to measure the primary contaminant as, without these data, significant correlations between the effects of any treatment and ecosystem response are likely to be made much more difficult. Objective 9, which includes dispersion studies and a preliminary acoustic survey at each site, is essential to inform efficient experimental design. All of the objectives are essential to the success of the project but it may be possible, especially in the third year of the project, to reduce effort in some areas and concentrate resources in others but this will depend on an evaluation of results and is more likely to be a statistically justifiable option in the 4 and 5th years.

The main risk to the project lies in the fact that the experimental sites are necessarily operating fish farms where the primary concern will be animal welfare and therefore the experiments cannot be planned well in advance with any great certainty. At the time of writing the study sites are unknown but are assumed to be within reasonable proximity of the coordinating institute (G Rae, pers comm.) and will therefore probably already be well known to the proposer in terms of background biology and physics. The approach proposed will minimise the likely uncertainty in farm management by assuming the worst case scenario ie that the study sites have previously been used, have previously had sea lice treatment agents used at them (ie beyond Entry Level 3) and that the farmers may wish to use a variety of agents at each site through the course of the study. Should sites at Entry Levels 1 or 2 be available then initial work will be modified to more closely determine patterns of natural variance prior to treatment.

Approaches and Research Plan

Scientific Rationale

The specification puts forward an outline strategy for the project together with a fairly detailed framework based on the Phase 1 report commissioned previously. This application follows the framework closely, but for cogent and practical scientific reasons and because of economic constraints it does not propose that all the recommendations in the Phase1 report should be implemented immediately. Thus it develops a tiered strategy based on an initial emphasis of assessing those elements of the marine ecosystem around each of the selected treatment sites deemed most likely to be vulnerable to the specific treatments being imposed. Not all the ecosystem elements suggested for study will be monitored intensively if, after an initial inspection survey of a chosen site, it appears that some elements are unlikely to be impacted. It is probable, for example, that sub-tidal hard substrates may be absent from the vicinity of some or all of the chosen areas. It will not be possible to decide definitively on priorities until the chosen sites are assessed in a preliminary survey phase at the start of the project.

Certain scientific pre-judgements as to the probable elements to be emphasised can be made however. It is suggested that the most sensitive elements to contamination from bath treatments will be zooplanktonic organisms. These will include members of the permanent zooplankton, which will be monitored directly, and benthic larvae and post-larvae. These latter will be monitored by the quantitative assessment of recruitment to settlement panels suspended at appropriate points along transects through the contaminant dispersion plume and placed in the littoral zone across areas of plume impingement. These settlement panels will be used simultaneously to assess effects on benthic diatoms. The most vulnerable fauna to contaminants from in-feed treatments are thought to be the adult infaunal macro- and meiobenthos and epifaunal predatory decapod crustaceans. Thus quantitative surveys of these elements will also be prioritized during the initial part of phase two of the project. Assessment of impacts on the macroflora and microflora will be based, at least initially, on qualitative surveys of both quadrats and settlement plates. These proposed priorities will be reassessed on completion of the pre- and post-treatment surveys in the first year of the project.

Appendix 6

THE REGULATION OF ACCESS TO NATURAL RESOURCES IN MARINE AQUACULTURE

J-P TROADEC

The regulation of access to natural resources in marine aquaculture

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Abstract. Fishing, aquaculture and pollution illustrate the role of institutions in economic development and conservation of natural renewable resources. Institutions that were developed for regulating access to marine living and environmental resources when those were not globally binding have become inadequate for sustaining the expansion of new farming systems in areas where competition for environment and space is significant, as well as for adjusting fully-developed farming systems that are bound by the natural capacity of environment. Despite the historic change in the Ocean regime, in a number of national legislations, the legal status of living and environmental resources does not adequately reflect their economic state characterized by commercial exploitation and scarcity. Comparison of farming systems indicates that stock ownership is more critical than technological innovation for the expansion of new systems. Institutions that have to be adjusted for rationalizing mature systems include property systems of natural resources, mechanisms for allocating use rights, and the resource management structures. Adjustment requirements differ with the nature of use systems and their stage of development but, in all cases, ecosystem fluidity and stock mobility impose particular constraints to adjustments. Articulation of institutional and ecological structures, and of mechanisms used for allocating use rights and human inputs in commercial activities, is an essential requisite.

1. Introduction

In uses of the environment, institutions are the *'rules that assign control of resources - through rights and duties - to individual persons or associations of persons'* [1]. So far, in aquaculture R&D programs, this topic has received less attention than the biological, technological or economic dimensions of this activity. Still, agricultural history [2], farming systems analysis [3, 4, 5], economics of institutions [6, 1], or studies on institutions for environment conservation [7], all emphasize the role of institutions in economic development and natural resource conservation. Considering the lesser development of property regimes in the ocean, one would expect that controls on access to natural resources play a critical role in the development and rationalization of marine farming systems.

The existence of clear links between technological intensification, economic and social organization of primary producers' groups, and land tenure systems is a constant in the history of agriculture. If technological intensification reduces the role of natural resources in production, the extension and diversification of technical controls that characterize the process leads to a specialization and segmentation of work which, with the capital and labor intensification that comes along the same process, contribute to the individualization and formalization of property systems. Trends towards the allotment and appropriation of land to secure producers' investments and harvests can be observed both in space and time [2]. In space, land appropriation relates to the degree of land artificialization: from the *outfield* (marshes, forests and natural pastures) and fallows, used collectively for productions (fishing, hunting, gathering and grazing) which do not involve technology nor capital inputs and, consequently, no artificial enhancement of natural productivity, to the cultivated *infield* (artificial meadows, fields cultivated between two fallows or permanently, gardens).

Through time, the formalization (occupation, possession, property) and segmentation (clan, lineage, family, individuals) of land tenure took place as major farming systems (slash and burn, light and heavy plough farming systems, modern agriculture based on mechanization, mineral fertilizing, genetic selection and specialization) succeeded in the history of agriculture.

Economics of institutions generalizes these observations to make the development of property systems the foundation of economic growth: '*... innovation, economies of scale, education, capital accumulation, ... are not causes of growth. ... Growth will simply not occur unless the economic organization is efficient. Individuals must be lured to undertake the socially desirable activities. Some mechanisms must be devised to bring social and private rates of return into closer parity ... A discrepancy between private and social benefits or costs means that some third party or parties, without their consent, will receive some of the benefits, or incur some of the costs. Such a difference occurs whenever property rights are poorly defined, or are not enforced*' [8].

Investigations on the formation of property systems are less advanced in marine aquaculture. Likely, this is related to the lesser development of technological intensification in the ocean. Still, scattered works show that the processes taking place in the sea and on land are similar, but with differences related to the greater complexity of domestication and institutional adjustment in aquatic environments [9, for a world review; 10, for aquaculture in sub-Saharan Africa].

As long as marine living resources and environment were not globally binding [11, 12], access to these resources remained largely open and free, except within a thin stripe along the shore. In the 70s and 80s, the extension of national jurisdictions gave coastal states the authority to adjust exploitation rates to the productivity of natural resources. Initially, revisions of national legislations focused on the control of foreign activities - fishing fleets in particular - for which the property of natural resources has been clarified. The revision of institutions is much less advanced with respect to the regulation of domestic activities, but the number of countries that are addressing the issue is increasing steadily.

So far, investigations on access regulation in marine primary activities have focused on three situations:

- open access: Hardin's parable[1] on the tragedy of the commons has been criticized for ignoring the social controls that pre-merchant societies were able to exert collectively on the natural resources within the territories they occupied or possessed, and for the subsequent confusion between communal property and open access; still, the current state of fisheries characterized by overcapacities, overfishing and conflicts shows that Hardin's diagnosis applies also to public property regimes where mechanisms of use rights allocation have not been adjusted to the new conditions of commercial exploitation of natural resources;
- communal property: social scientists see in the formal recognition of communal systems an option for promoting the development of rural communities that have been deprived from their use privileges by the establishment of public or private property regimes [14, 15, 15]; customary systems of communal property can also provide useful references for the design of regulatory schemes for the exploitation of resources which, owing to their geographic extension, cannot be rationalized by individual approaches, or may require new forms of international cooperation (transboundary resources) [17, 18].
- private use: economists analyze the advantages and the application conditions of systems of private use rights for the commercial exploitation of common resources (fisheries and environment).

Comparatively, the effects of technological intensification on the formation of property systems in the ocean have received less attention. In addition to a new examination of

[1] - Under open access, '*each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of commons. Freedom of the commons brings ruin to all*' [13].

development theories, this approach of the issue can improve our understanding of the expansion conditions of new aquaculture systems, as well as for the rationalization of mature systems - i.e. those whose expansion is bound by the resources.

The first part of this paper reviews the institutional constraints that compel the development of new farming systems. This review identifies links between the property of cultivated stocks and technological intensification. The second part examines the conditions for balancing mature farming systems with the capacity of cultivated ecosystems. Institutional adjustments that would facilitate the rationalization of farming systems are presented.

2 - Technological intensification and cultivated stock ownership

2.1 - Access to sites

The taking off of new farming systems is frequently constrained by the competition for sites with activities formerly established in coastal zones. The development of traditional systems, such as shellfish culture, took place initially in areas which were lightly occupied. Similarly, the development of new systems is concentrated in regions where space is not binding (e.g. Norway, Scotland, Chile, ... for salmon farming; Greece, ... for sea bass and sea bream farming; shrimp culture in mangrove areas in developing countries, ...).

Occupiers of densely-occupied areas (coastal dwellers, tourists, land farmers, commercial and sport fishermen, ...) oppose frequently to the settlement of new farming operations. To limit conflicts, administrations tend sometimes to oppose environment conservation considerations to requests for farm settlement, giving preference to uses that benefit from an anteriority in space occupation. National legislations limit the density and distribution of farms, and the amounts of offalls by individual farms, but, when assessments of environment assimilation capacities are outstanding or not accurate enough, such limitations are necessarily arbitrary. The command mode (administrative norms and decisions) that is commonly used for allocating leases may weight differently the conservation requirements for new farming systems and for long-established activities, even though the former are using marginally the natural capacity of water bodies and the later are significantly exceeding it. This weakness of the command mode is doomed to become more acute as uses of the coastal environment intensify and diversify.

2.2 - Technological intensification

Limits of natural productivity can be outstripped by extending technical controls over new physiological functions of cultivated stocks and water bodies. The domestication process develops by discrete steps. From fishing to fully-controlled systems, there is a full range of production systems which can be regrouped schematically into six sets:

- fishing of wild stocks;
- attraction and forage enhancement in open waters: in the simplest and less productive forms, man modifies the distribution and enhances the production of stocks by providing artificial shelters, by cutting migration routes, and by enhancing food production through simple practices (artificial reefs, Mediterranean valliculture, *acadjas* in Benin, ...);
- extensive systems: in more sophisticated and productive forms, man acts on the reproductive strategies of stocks (transplantation of wild juveniles, seeding of artificially-reared fingerlings in ranching, spat collection in shellfish and seaweed cultures); interventions on population strategies does not necessarily require the control of reproduction;
- semi-intensive systems in which production of forage is stimulated by fertilizing the rearing environment, as in fishculture in ponds, lagoons and lakes;

- intensive systems in which stocks are artificially fed, as in fish culture in cages, raceways and ponds;
- fully-controlled systems in which the offalls are recycled: rearing of African catfish *(Clarias gariepinus)* in the Netherlands, and tilapia in heated water in Belgium; fishculture in ponds in which water is recycled.

No statistics are available on the production by major farming systems. In the aquaculture statistics published by FAO, the production of simplest extensive systems in which cultivated stocks are harvested collectively, generally together with wild stocks, is not distinguished from the catches of fisheries [1]. However, except for the later, the relative importance of major farming systems can be roughly inferred from the relationships that exist between species groups and farming systems (tabl. 1). Three farming sets dominate the world aquaculture production:

- advanced extensive systems of sedentary species (mainly marine shellfish and seaweeds; set I), with an overall output approaching half of the total aquaculture production;
- semi-intensive systems: culture of carps, cyprinids, tilapias, ..., mainly in freshwater ponds (set II), with an overall production close to 40% of the total;
- intensive systems: culture of marine and diadrom finfishes and shrimps in cages, raceways and ponds (set III), whose production does not reach 10% of the total world aquaculture production.

Table 1: World fishery and aquaculture production in 1996 (in millions tonnes and percentages) [19]: aquaculture production is split in three large species and environment groups corresponding approximately to the three major farming sets: advanced extensive marine systems of sedentary species (set I), semi-intensive freshwater systems (set II), intensive marine and brackish systems (set III).

Fisheries (+ aquatic ranching)	Farming systems		
	I - Seaweeds and shellfish	II - Freshwater finfishes (carps, cyprinids, tilapias, ...)	III - Marine and diadrom finfishes and crustaceans
90,0 (73%)	16,0 (13%)	14,4 (12%)	3,4 (3%)

Even though technological intensification reduces the contribution of natural resources to production, it does not eliminate the dependence of farming systems upon environment. This would be possible only with fully-controlled systems, but those are still in an infant stage and their contribution to world production is insignificant. In fisheries, it is the tertiary productivity - i.e. that of fish populations - that is binding. In aquaculture systems, cultivated stocks are no more limiting. Thanks to artificial reproduction and appropriation, they represent a capital, similar to other production means, and not to the natural resource. The natural, limiting, factor is the environment. In advanced extensive systems, it is the planktonic and benthic production used as forage by stocks which, above a certain level, limits yields. In these systems, the release of offalls in the environment is low; but the seeding with strains selected for farming purposes or with non-indigenous species may alter the gene pool of wild populations and reduce biodiversity. In intensive systems, it is the offalls (non-consumed feed, feces, antibiotics, medicines, chemicals, ...), as well as the

[1] - For the purpose of collecting statistics, FAO uses the following definition of aquaculture: '*Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or a corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries*' [19]. This definition illustrates the incidence of property regimes on the characterization of aquaculture.

losses of cultivated animals , that have to be adjusted to the assimilation capacity of ecosystems. If technological intensification increases productivity (by unit area), it is at the cost of higher stresses on the environment.

2.3 - Farming systems and property of stocks

Habitat modifications for fish aggregation and growth enhancement

In the simplest extensive systems (artificial reefs, *acadjas*, valliculture), in which man modifies the distribution of fish concentrations and enhances production to a limited extent by simple interventions on habitats, stocks are free in medium and large water bodies (sea and lagoons). In traditional systems, exclusion of outsiders is achieved by customary systems of space occupation and harvesting privileges, hold by riparian fisher communities. In a number of Mediterranean countries (Egypt, Italy, Tunisia, ...), the development of valliculture has been facilitated by the formalization of tenure schemes (collective, individual, or state property) of coastal lagoons.

Transplantation of juveniles

Transplantations of young plaices from coastal nurseries in southern North Sea where growth is limited by the high density of fish concentrations, to fjords and offshore areas where fish density is low, have proved the system effectiveness [20]. Though certain production scenarios are economically efficient, programs, however, never led to significant commercial productions. Constraints are mainly institutional. In Denmark, the property of transplanted stocks is claimed by both the coastal fishermen in the North Sea where juvenile fishes are caught, and by the fishermen in the Limfjord where fishes are released. None of them contribute to the transplantation costs. Only sport fishermen pay a small fee. Under these circumstances, no private contribution has ever taken over public funding to increase the stock substantially. The later remains largely accessible to commercial and sport fishermen.

Shellfish culture

The taking off of shellfish culture has been facilitated by three features of shellfish ecology: (i) filter feeding on the highly productive lower levels of the food chain in rich coastal areas, which permits high stock concentration and production; (ii) tolerance to climatic variations; and (iii) sedentariness which facilitates stock retention and appropriation. However, these ecological assets have been reaped by two institutional innovations:

- stock ownership, which was formalized through the allotment of private leases on the public domain; the legal control of stocks and harvests gave farmers the guarantees that they need for investing in farming;
- the direct involvement of the public sector in the conservation of cultivated ecosystems, as well as in the control of the sanitary state of stocks and the quality of products for human health protection.

Sea ranching

Recent theories of reproductive strategies of fish populations [21, 22]. the range of natural fluctuations of wild populations, and the biomasses reached in advanced extensive systems suggest that marine ecosystems are likely to sustain stocks considerably larger than wild populations. Since only a small portion of marine ecosystems are exploited by ranching, and since natural productivity can be channeled selectively into species that are particularly useful, on purely ecological terms, the prospects of ranching look even larger. The system relies also on the homing behavior which seems to be a common feature of the ecology of aquatic populations faced to the double constrain of survival in a dispersive habitat, and of sexual reproduction which makes the population survival dependent on the periodic return of a sufficient portion of spawners to hatcheries that are stable in space and time.

Still, the control of stocks and harvests is complicated seriously by stock mobility. Owing to their tiny size, fingerlings are hard to brand systematically as can be done for cattle (though morphological features associated to artificial reproduction could be used). More important, the remoteness of fishing grounds, the low density of offshore fishing operations, and the fugitive nature of catches, render the enforcement of property rights on cultivated stocks extremely difficult in the open sea. For that reason, property of mobile stocks is practically never recognized in maritime law. Unlike cattle or sheep, fish escaping from farms become a public resource.

This constraint can be overcome, however, by adopting the methods used in fisheries for limiting and allocating yields (individual catch quotas and fishing licenses). Since, most species that can be ranched are also exploited in fisheries, the incapability of distinguishing cultivated and wild animals in harvests makes the development of ranching dependent on the development of access regulation in fisheries. The risk of stock interception by outsiders, especially in areas outside national jurisdictions, limits seriously the prospects of exploiting the latent primary and secondary offshore productions (see § 3.5).

Obstacles encountered in the development of scallop culture in the Bay of Brest (France) illustrate the complexity of domestication in the ocean. Technological aspects of the system are mastered, and full-size experiments conducted on public funds have indicated that the system is likely to be profitable. Still, the transfer of the seeding costs to primary beneficiaries progresses slowly. The fishermen association accepted that fishermen contribute on a voluntary and fixed basis to a collective program, but is opposed to the seeding on natural beds which are *a priori* the most suitable. It is also opposed to a modulation of individual contributions which would give fishermen recapture rights proportional to their subscriptions, since this would result in a *de facto* recognition of a merchant scheme for allocating individual catch quotas on wild stocks. The rearing of scallops on individual leases is impinged by the scale of fees applied by the fisheries administration for oyster and mussel farming. Potential farmers consider the fees excessive for a new system where the risk is high [23].

For the reasons indicated in the introduction, the production of sea ranching is not known. But, from the examination of scattered data, world and European productions seems to be considerably lower, possibly by one order of magnitude at least, than that of shellfish and seaweed cultures. The gap is even larger when one considers that the volume of ecosystems available for sea ranching is considerably greater than the volume available for the farming of sedentary species. Japan is one exception. It is one of the few countries where sea ranching is making significant progress (salmons, scallop, king prawn, king sea bream, flounder, …), demonstrating the ecological and technical feasibility of the system. During the last thirty years, for example, production of 'chum' salmon has increased tenfold, to exceed 200 000 tonnes at present. In 1998, runs returning to the Hokkaido rivers were ten times higher than the maximum observed throughout the recorded history of the fishery of wild stocks [24, 25]. Japan is also one of very few countries where the exploitation of fishery resources and the uses of coastal environment are ruled under a communal property system. Privileges that fishermen could claim by virtue of anteriority of occupancy and exploitation have been formally recognized in the central legislation. Fishermen cooperatives and private groups hold collective rights of quasi-property on fishery resources and environment. If fishermen cannot sale their rights, the government cannot withdraw them either.

Semi-intensive and intensive systems

In these systems, ownership of cultivated stocks is achieved through the property of ponds or raceways, or the enclosure of stocks in cages and the lease of farming sites on the public domain. In semi-intensive systems, however, fertilization of ponds and establishment of property systems become increasingly difficult as the size of water bodies increases. Depending on the nature of tenure systems (land and water) in force, ceilings vary from regions to regions. In sub-Saharan Africa, for example, regimes of collective exploitation of water bodies in which access is traditionally governed by clans, lineages or chiefdoms, discrepancies between customary systems and central legislations, and difficulties in resolving use conflicts (fishing, aquaculture, pollution) under diverse and changing property schemes [15] are major impediments to the development of freshwater and lagoon aquaculture[10].

2.4 - Technological intensification and economic and social organization of exploitation

Even though the production of fingerlings is sometimes sub-contracted to private firms, non-profit seeding programs aiming at the conservation of wild populations for the benefit of the society as a whole are usually funded and executed by public structures. Organization is similar for transplantation and seeding aiming at sustaining commercial fisheries in which access is not, or loosely, controlled.

Prospects of creating a significant stock raise the twin question of the reservation of access rights to particular fisher groups (foreign/national/local, commercial/sport fishermen, farmers), and the contribution of the primary beneficiaries to seeding or stocking costs. The State of Alaska, for example, allocates licenses to private hatcheries for non-profit salmon ranching operations that are managed by local fisher co-operatives and indigenous communities.

In small-scale seeding programs benefiting traditional fisher communities, harvesting is often reserved to costal communities by collective territorial rights, but seeding costs are mostly covered by public funds. In Japan, for example, commercial fishermen contribute to ranching programs through the payment of fees representing a small percentage of their landings revenue, and access to coastal fisheries is partitioned by membership to co-operatives.

Contribution to ranching programs is a more common practice in sport fisheries. In Great Britain, for example, landowners which rent salmon fishing rights on the stream stretches in their properties finance the stocking programs that increase the price of fishing rights. Some states (Iceland, Chile, ... and, in the US, Alaska, Oregon, Washington, and California on an experimental basis) allow private hatcheries operating for profit. However, in many cases, private ranching projects encounter strong oppositions from commercial and sport fishermen, as well as from the public opinion, who object that they would lead to a privatization of public resources, or would reduce the price of fish to the detriment of commercial fishermen.

Private stock ownership and exploitation are the rule in advanced extensive farming of sedentary species, as well as in semi-intensive, and intensive systems, which make up the bulk of aquaculture production.

The history of shellfish culture in the Yerseke (Netherlands) illustrates this parallel development of technological intensification, economic and social organization of farming units, and stock ownership [26].

- before 1860: fishing natural beds by local small-scale fisher communities; regulation of access by local administration (command mode);
- 1860 - 1933: with differences between mussel and oyster cultures, development of extensive farming with appropriation of cultivated stocks and allocation, through public auction, of individual leases on the public domain;
- 1933 - 1967: expansion of production and outbreaks of epidemics;
- after 1967: vertical integration of farms which become capitalistic; reduction of public interventions.

In the French shellfish culture, mechanisms of individual lease transmission changed also gradually. Initially, leases were allocated by administrative decisions based on the professional status of farmers and social considerations (services rendered to the State, numbers of sons and daughters in the farmer family). The 1983 Law transferred the mandate of allocating leases to bodies of shellfish farmers, established by production basins, and operating under the supervision of the fisheries administration. While keeping a supervision by the fishery administration, the 1986 Law formalized the trade of leases which has been in existence for a long time in an hidden form.

Over the long period, domestication (fishing, extensive -, semi-intensive -, intensive farming), stock appropriation and privatization (*res nullius*, space occupation, stock possession, private - collective and individual - stock ownership), production structures (traditional communities and households, sport fishermen associations, commercial fishing companies, and private farms), penetration of the monetary sphere and central administrations - including for the allocation of leases on the public domain (subsistence, conservation of wild populations, sport fishing, commercial fishing and farming), all these processes are progressing abreast. Capital and labor intensity in the exploitation goes with technological intensification in the production methods.

Three conclusions can be drawn from this rough analysis of farming systems (tab. 1):

- compared to agriculture, the domestication process is markedly less advanced in aquatic environments, and particularly in the ocean; this is illustrated by the predominance of fishing and extensive and semi-intensive farming systems in world fish production;
- the command mode that is currently used for granting access to space may check the taking off of new farming productions in coastal areas that are in great demand;
- irrespectively of their degree of intensification, all farming systems that make up the world aquaculture production are conducted under one form of stock ownership or another; in other words, stock ownership appears as a more critical condition than technological intensification for the expansion of systems that have taken off; this observation shows the limits of strictly technologist and economist models of aquaculture development;
- the role of social, cultural and institutional factors in aquaculture development, beside technological and economic aspects, is illustrated by the uneven geographic development of farming systems; small-scale farming (extensive and semi-intensive systems) predominates in Asia, but not, and for different reasons, in other regions of the world (Africa, Asia, North and South America).

3. The rationalization of farming systems and the property of ecosystems

3.1 - Carrying capacity of cultivated ecosystems, density-dependent yield, and diminishing returns

Shellfish farming gives a good example of the problem of adjusting private uses to the naturally limited capacity of ecosystems. In semi-closed basins where water circulation is weak, the primary production used as forage by shellfish stocks becomes more and more binding as the overall stock biomass increases. Since water is continuously mixing within the basin, farmers cannot adjust separately their stocks to the basin productivity. To increase their share of the overall forage production, it is in their interest to increase their stocks despite the overstocking to which this behavior leads (fig. 1). Individual yields and economic performances of farms decline as the rearing cycle grows longer and mortality rates higher.

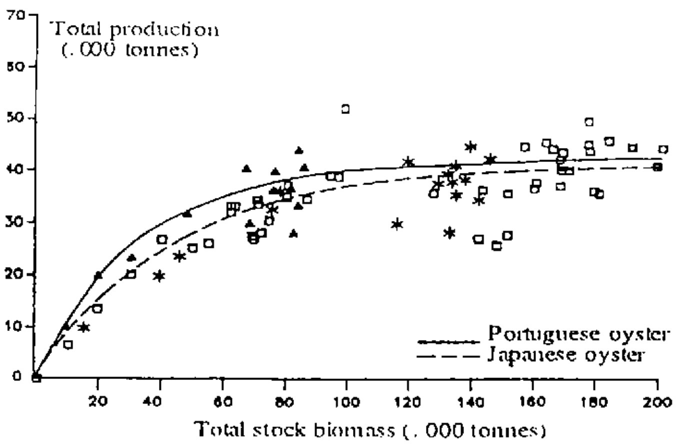

Figure 1 - Annual production and stock biomass in the basin of Marennes-Oléron (France): Portuguese oyster (□), Japanese oyster (Δ), and Japanese oyster in Portuguese oyster assimilation equivalent (*) [27].

Overstocking is also suspected to enhance stock susceptibility to diseases. Epidemics which decimated French stocks on several occasions in the past occurred after maximums of production in major basins (fig. 2). Transfers of stocks between basins specialized in different steps of the rearing cycle (spat collection, rearing, final products refining) contributed to the spreading of diseases.

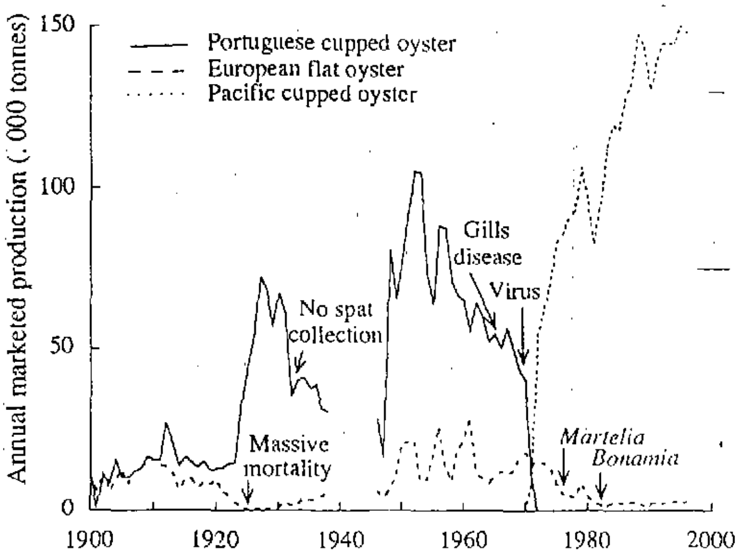

Figure 2 - Annual marketed production of oysters and occurrence of epidemics in France (IFREMER data).

Farming has other negative impacts on the ecosystems:

- release of offalls (organic matter, antibiotics, medicines and chemicals) in semi-intensive and intensive systems;
- introduction of non-indigenous species and exotic strains likely to affect wild stocks and biodiversity;
- contamination risk (pathogens) between cultivated stocks and wild populations.

When their amount approaches the assimilation capacity of ecosystems, these impacts have to be adjusted.

3.2 - Adjustment of competing uses to ecosystem capacity

Irrespectively of farming systems, cultivated stocks are subject to agricultural, domestic, and industrial pollution. These externalities are particularly important in coastal areas where aquaculture takes place. Owing to their fluidity and density, aquatic environments are better vectors of pollutants than terrestrial and atmospheric ones. As a consequence, river flows carry anthropogenic refuses in littoral areas. Shellfish farming is particularly vulnerable to exogenous pollution. Filter feeding concentrates pathogens and toxic substances in products, while the consumption of products in raw increases the risk of contamination. Therefore, the adjustment of cultivated stocks to the ecosystem capacity has to be completed by a regulation of pollution likely to alter this capacity.

Assessment of ecosystem assimilation capacity is complex. When quantitative assessments are lacking, the setting of norms for the release of offalls at the level of polluting units is necessarily arbitrary. Balance of competitive uses of ecosystems cannot be optimized. However, before optimizing, an adjustment capacity has to be acquired. For that purpose, an analysis of the resource structure, uses, and economic and social user organizations is sufficient.

3.3 - Overexploitation: an institutional solution to an economic problem

Owing to the environment fluidity and species mobility, the rationalization of farming systems cannot be achieved by stock ownership alone. Space allotment has to be completed by a regulation, of the overall stock biomass for stocks that are sedentary or reared in enclosures, or of total catches or harvesting capacities for mobile species. In commercial productions, this regulation depends on the introduction of two institutional innovations:

- mechanisms for allocating quantitative use rights to individual farms (and polluting units),
- an exclusivity scheme that matches the ecosystem structure.

The adjustment of stock biomass to the carrying capacity of ecosystems is an economic problem. When access is not, or loosely, regulated, the resource rent - i.e. the value that the ecosystem capacity acquires in becoming scarcer as their exploitation for commercial purposes intensifies - is not distinguished from the normal profit that farmers derive from the management of aquaculture production. When access is open and free, the scarcity rent appears as an overprofit which adds up to the farmers' normal profit. Farmers can increase this overprofit by acquiring additional capacities. In the absence of controls at the scale of ecosystems, farming capacities exceed ultimately what is necessary and sufficient to utilize rationally the natural productivity of ecosystems. These overcapacities lead, first to the dissipation of the resource rent, then to the ecosystem overexploitation, and finally to conflicts (equilibrium E on fig. 3a). For adjusting individual capacities to the ecosystem capacity, an authority is needed at the scale of the ecosystem. This authority can exert the necessary control through different mechanisms. It can, for example, sale or tax farmers' use rights to extract the resource rent. The resource rent is, thus, distinguished from the farmers' normal profit. Farmers receive, then, signals that reflect the relative values of the natural resource and the human inputs (capital and labor). The full extraction of the resource rent is more conservative than the mere application of biological criteria (equilibrium E' on fig. 3b). If overexploitation is an economic issue, its solution rests in the adoption of institutions that are adapted to the commercial and competitive exploitation of natural resources.

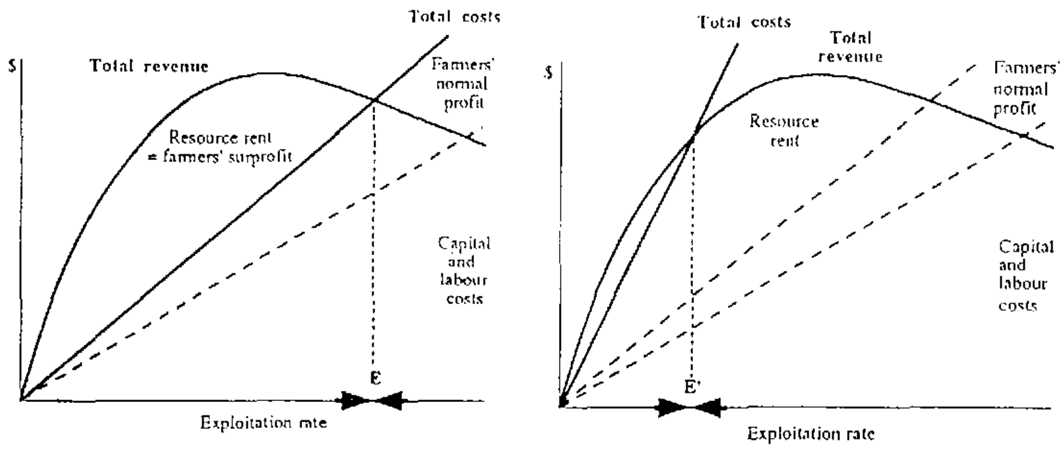

Fig. 3a - Dynamics of overexploitation (open and free access).

3b - Effect on the exploitation rate of a regulation of access to the farming ecosystem.

N.B. : Under equilibrium conditions, changes in the overall rate of exploitation of the ecosystem does not modify the rate of normal profit of farms.

3.4 - Ecosystem ownership and allocation of use rights

The problem of use rights allocation

Three tasks can be distinguished in the adjustment of uses to the ecosystem capacity:

- conserving the ecosystem capacity: this capacity can be optimized by technical measures, such as the choice of cultivated species, the normalization of rearing practices, the optimization of the distribution of sedentary stocks or releases of pollutants, ...
- defining maximum exploitation rates: for a single farming system, this rate will correspond to the balance between economic (maximizing the resource rent), ecological (conservation), and social objectives that is adopted in the management policy; for ecosystems that are subject to several uses, a use rate will be fixed for each use;
- allocating individual rights within the individual use ceilings.

In aquatic ecosystems, the allocation of use rights raises a double problem, one technical, one institutional:

- the disparity of scales between the unit resource - the ecosystem -, on the one hand, and the farming units, on the other hand; it can be overcome by entrusting a single authority - public or collective - with the allocation function; allocation will be effective if the property structure reflects adequately the resource structure, and if resource management is distinguished from farm management;
- the disparity of mechanisms used for the allocation of use rights and of human inputs (capital and labor); schematically, the allocation of rights is done by the management authority which, in conventional systems, relies on the command mode (norms and decisions), completed by consultations with producers' associations; human inputs are mobilized by farmers who, in commercial activities, rely predominantly on market mechanisms for that purpose.

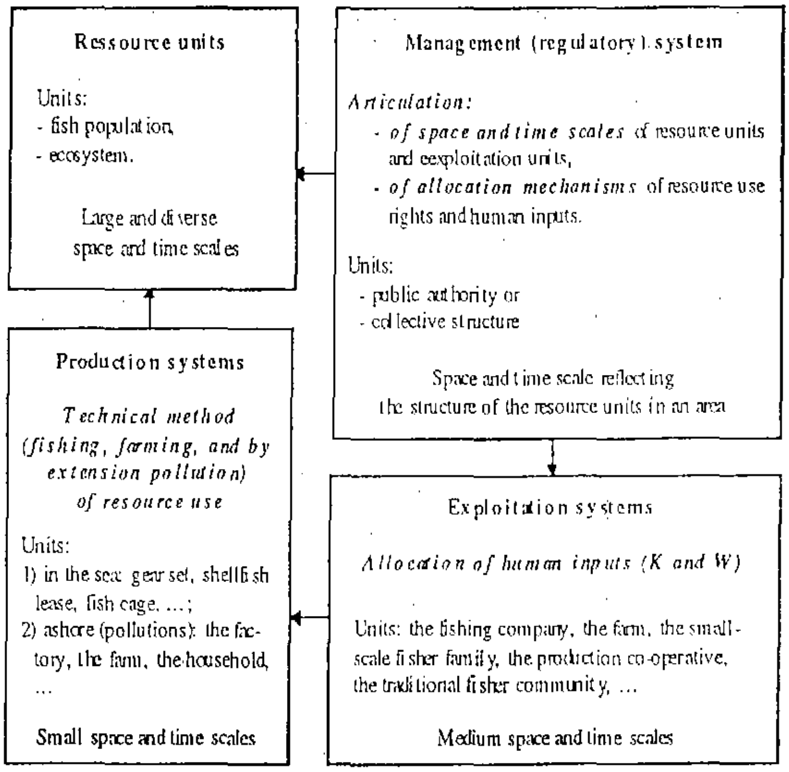

Figure 4 - Articulation of unit resources, and production, exploitation and management systems in uses of aquatic living resources.

Allocation mechanisms

Economic mechanisms (market and taxation) present the advantage of addressing explicitly to the dynamics of overexploitation. Compared to taxation, the market can determine directly the price of use rights. Transactions and enforcement of decisions are facilitated by the direct negotiation of contracts between the resource owner and farmers. Still, when they are faced to a restriction of access that was, so far, open and free, users are not necessarily convinced of the advantages of the new system. Objections of inequity are often voiced for users do not have an equal capacity to benefit from the new system.

The command mode (decisions and norms) and customary systems based on social controls exerted within user communities do not present these advantages. Still, the formal recognition of communal property schemes can be an effective option to offset the disorders resulting from the non-recognition of historical privileges of small-scale communities, and to facilitate their integration into national economies.

Customary systems, however, can provide only partial and temporary solutions. Developed at times when resources were not exploited for commercial purposes, nor globally binding, their primary purposes were to exclude outsiders from communal territories, to harmonize the productive activities of members (technical measures and allocation of sites), to share production outputs, and to ensure the necessary solidarity among members. They did not aim at preventing overexploitation. They are not designed to facilitate technological intensification. In most cases, the scale of communal control schemes does not match the resource structure. They are not designed to tackle conflicts with new uses (urbanization, tourism, intensive aquaculture, pollution). Since the social patterns on which they are based are slowly breaking off under the diffusion of market economy and central legislation, and the associated changes in communities cultural values, they tend to fall into disuse.

The advantage of clarifying property regimes is independent of the identity of right holders, as of allocation mechanisms. If the regulation is effected by a public authority, its effectiveness will be reduced if the responsibilities of the public sector and producers associations, of the different administrations concerned (fisheries, aquaculture, environment), as well as of the various levels of the politico-administrative structure (from municipalities to international bodies) are loosely defined. Sector administrations may encounter difficulties in balancing their dual mandate of producers' protection and resource conservation. In sector policies, the minimization of short-term costs for producers of recurrent conservation measures may receives more attention than the institutional reforms that condition the long-term rationalization of the sector and the resource conservation.

Thus, in the rapports between man and nature, institutions that regulate access are the direct complement of production systems. They provide the framework which conditions the rationalization of uses (fig. 4). Their effectiveness depends on their adjustment to the resource/use/users set. Since the nature and structure of these components differ between uses and change in time, there is no standard institutional solution. The concept of property appears, thus, not as an absolute right on things, but as a coherent bundle of rights, distributed on the basis of the respective capacity of individuals, producer associations, and public organizations to exert the relevant controls at the proper scales (ecosystems, fish populations and cultivated stocks). Effectiveness of property systems depends on the formalization of contractual rights and duties between resource owners and users [28], as well as on the clarification of rights variables, quantities and holders, and infringements and penalties. In commercial activities, the efficiency of use rights will depend on their exclusivity - i.e. that all benefits and losses in the exercise of a control fall upon the right holder -, and combinability - and, thus, of their transferability. They should be physically enforceable, and actually enforced - since a right that is not guaranteed is not a right.

Management structures

The establishment of public authorities, distinct from central administrations, in charge of the formulation of management policies and of the allocation of use rights, could provide an effective solution. Such agencies would be accountable to bodies in which entitled political authorities, administrations and users organizations (including ecologist associations) would be represented. Such a scheme is common in the management of land resources such as forestry and water resources, which share features with marine resources, and has been adopted in some countries (e.g. Australia) for the management of marine fishery resources and environment. If their competence would cover all living and environment resources within an area reflecting the resource structure, irrespectively of their uses, integrated management could make significant progress. Such agencies could use the resource rent to cover the management expenses (resource assessment and monitoring, allocation of use rights, control and surveillance), and to finance resource enhancement programs (sea ranching, eradication of exotic species).

3.5 - State sovereignty

On land, entitlements of property rights are warranted by the sovereign rights of states - army, justice and police [18]. In the historical development of property systems, the enforcement of a common regime appeared finally less costly than collective initiatives of private associations for controlling theft and 'free riding'. For warranting property of natural resources, public solutions prevailed ultimately [8].

In adopting a new ocean regime, the international community extended a similar scheme to the 200 miles stripe. Within their areas of jurisdiction, coastal states are now empowered to adjust the resource property regime, the allocation mechanisms, and the management structures to the new conditions of commercial utilization of living resources and environment. However, the new regime does not provide a full solution to the problem. If it gives coastal states rights of quasi-property on the resources that are fully circumscribed within the Exclusive Economic Zones (EEZ), their authority remains shared for the resources that are distributed within two or more EEZ, and diluted for resources that extend into the high sea (fig. 5).

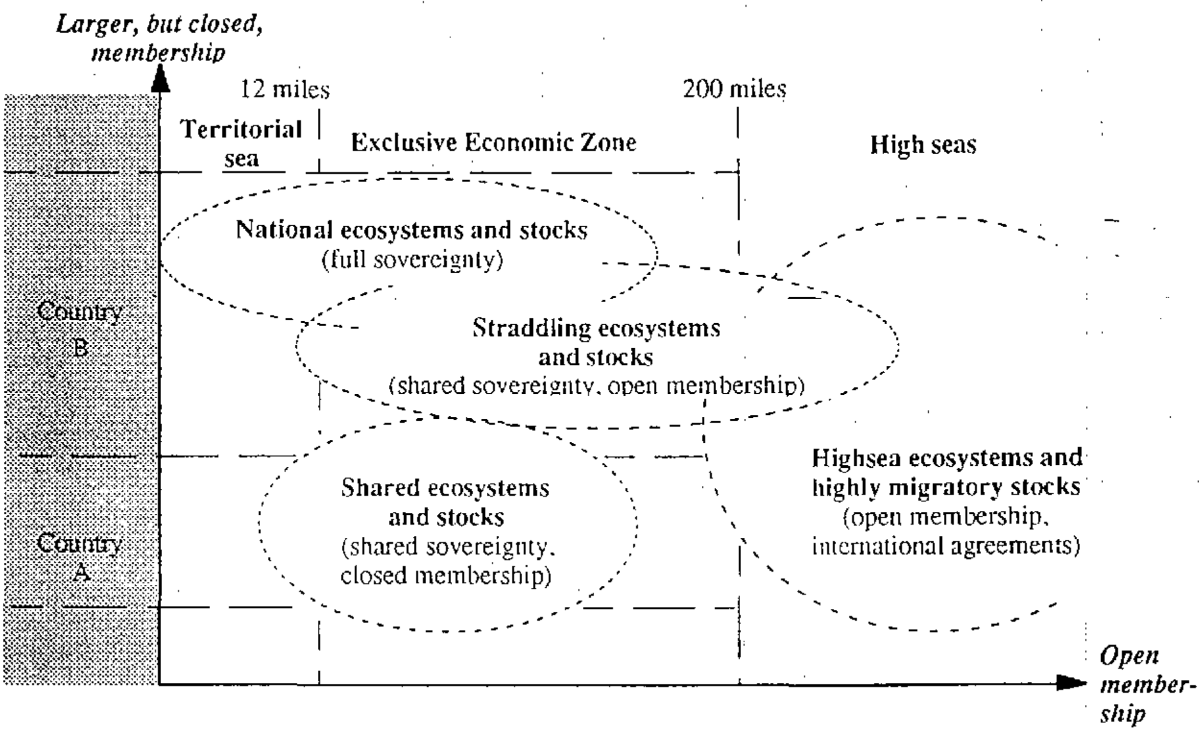

Figure 5 - Areas of national jurisdiction and dilution of national authority.

Except for the ranching of transboundary species (e.g. salmons), the dilution of authority is not immediately critical for the intensification and rationalization of farming systems which are concentrated in coastal areas. Since the devolution of an adequate authority to supranational bodies seems unlikely in the foreseeable future, or will not take place before the inadequacy of simpler international arrangements (governance without government) becomes patent, the management of transboundary resources remains conditioned to the negotiation of adequate arrangements between resource co-owners [17, 18]. The adoption of lasting agreements can be expected for shared resources but, for straddling stocks, agreements will remain precarious since they could be challenged at any moment by the arrival of newcomers.

Salmon ranching illustrates the problem raised by the management of transboundary stocks. The seeding programs carried out by Baltic countries since the turn of this century have been technically so successful that they triggered the development of a multinational fishery in the Baltic [29]. Offshore catches are presently high enough to threaten the wild populations that are caught with cultivated stocks. By ensuring the profitability of sea fishing operations, seeding programs aiming at preserving wild populations decimated by hydro-electric developments and pollution of rivers, are actually endangering them. A banning of sea fishing could provide a solution. This measure has been adopted in the North Pacific where coastal states agreed to ban salmon fishing in offshore waters, or by Iceland which banned salmon fishing in its coastal waters 60 years ago.

4. Conclusions

In the 60s, the prospect of a leveling off of world fish production stimulated a new interest for marine aquaculture. Reference to the Neolithic Revolution was made to justify an increased effort in R&D. Though farming system analysis confirms the similarity of the intensification process in the sea and on land, it shows also differences that limits the analogy.

First, in the ocean, the process of artificialization started much later than on land[1]. As long as the world demand could be fulfilled by the offshore extension of fishing operations, societies could spare the cost of both domestication and institutional reforms. But the situation has changed. To-day, the development of new farming systems as well as the rationalization of mature systems depend on the adjustment of institutions to the new conditions. Technological intensification cannot be an alternative to rationalization.

Two, the scales of resources are considerably greater in the ocean than on land. This complicates both the process of domestication and the adjustment of institutions. The technical device that was adopted several centuries ago in agriculture - i.e. the allotment of space - cannot be transposed mechanically to aquaculture, no more than to fisheries. Even for the cultivation of sedentary species and enclosed stocks, space allotment provides only partial solutions. But complementary solutions exist.

Third, recent works on the origins of agriculture and the expansion of early farming societies underline the limits of the technicist (based on technological innovations) and economist (response to ecological, biological, or population stresses) interpretations of the Neolithic Revolution [30, 2]. Their findings emphasize the cultural change that made domestication possible: in changing their systems of divinities, early farming societies considered their rapports with nature with a different eye. To-day, the commercial utilization of marine natural resources presents similarities with the one prevailing ten millenniums ago. The long lasting existence of resource property on land (in relation to the earlier development of agriculture, relayed by the world expansion of trade and the Industrial Revolution) explains probably why the institutional vacuum prevailing in the sea was somewhat overlooked in early aquaculture diversification policies. Under conventional access regulation regimes, private and social benefits and costs cannot be matched properly. Without adequate controls on stocks and harvests, potential farmers do not receive the signals for taking the risk of investing in new farming systems. In mature systems, their short-term interest is to increase their stocks beyond the minimum required to exploit ecosystem capacities rationally. The difficulties encountered by public administrations in stewarding the environment, or the priority given to long-established uses over new farming systems, are the direct consequences of the current property systems shortcomings, and of the low efficiency of the mechanisms in force for allocating resource use rights in commercial exploitations.

At international level, the extension of national jurisdictions represents an historical step for the development of ocean resources. Coastal states have now the opportunity to introduce in their EEZs the property regimes that would promote the intensification and rationalization of farming systems. Though institutional requirements differ between farming systems, stock property is critical for the expansion of all systems, as are the clarifica-

[1] - Except the extensive culture of sedentary species whose development is simple.

tion of resource property schemes and the adoption of modern allocation mechanisms for the optimization of mature systems. However, if the problem of access regulation is well understood, the conditions of institution formation in particular contexts require further investigations. Because resources, use systems, and social and economic organizations of users differ and change with time, there are no ready-made solutions. The design of institutions that would facilitate the integration of small-scale communities engaged in commercial productions into national economies raises particularly complex problems.

Despite the emphasis put on integrated management, the regulation of access is still largely done by sectors. This approach contributes to maintain the mismatch between resource and control structures. The abrogation in 2 002 of the derogation which allows coastal states of the European Union to manage separately their fisheries in their territorial seas would result, for example, in the extension of the EU fishery management scheme to territorial seas. This would maintain a centralized management scheme that does not reflect the resource structure, nor the diversity of uses, and prevents to draw benefit from the particular relationships that prevail between inshore resources, coastal user groups, and local administrations.

Still, the EU framework could be used for designing and implementing an integrated scheme of management units that better reflects the resource structure. Considering the current mismatch between ecosystem and stock boundaries, and the pattern of political borders, such a goal may look unrealistic. Technically, however, the problem is less complicate than its seems. The two units - the animal or plant population, and the ecosystem - that structure living and environmental resources, are independent of their uses, and their scale would allow a significant devolution of management duties, at local level for inshore resources, and at provincial level for neritic demersal stocks. But, owing to the geographic extension of semi-enclosed seas around Europe, this development would depend on the negotiation of new forms of cooperation, in which coastal countries would share at subnational level their sovereign rights on resources.

Even when opportunities are considerable, institutions do not emerge spontaneously. Institutional and technological innovations differ substantially in this respect. Though the later can be expensive, their development is often within the reach of private initiatives, and potential benefits accrue to entrepreneurs who are ready to take the risk. Institutional reforms, on the other hand, come up against entrenched interests, dreads of political effects of institutional changes, and bureaucratic inertia. The short-term costs of institutional reforms are not only high, but their long-term benefits accrue to the society as a whole, and not to the administrators and political leaders who would be ready to take initiatives. Five centuries ago, Machiavel noted already: '*... there is no task more difficult, more risky to handle, more uncertain of its success, than attempting to introduce new institutions: for the innovator will have enemies in all those who were favored by the ancient order, and will receive only lukewarm support from those who would gain from the new one*' (The Prince).

If societal organizations are rational, the wide geographic and sector gaps that persist in economic development show that societies do not necessarily grasp the opportunities that occur. Societal changes are non-deterministic. Because institutional innovations are part of political processes and depend on public initiatives whose expression is uncertain, it is in the adjustment of institutions that the public sector should invest its energy in priority.

So far, public research agendas have given priority to technological and economic aspects of aquaculture development. Larger scale issues - e.g. the reproductive strategies and the recruitement determinism of fish populations that are critical for designing comprehensive ranching programs, the process of technological intensification in aquaculture, the regulation of access to natural resources, or environment economics - have received less attention. These topics concern all uses of living resources and environment. Considering the similarity and complementarity of issues, analyses would gain in coherence and perspective if the regulation of all uses of marine natural resources were part of the same research programs. Basic theories and field observations are available. Comparative studies covering the full range of uses could produce analytical grids for comparing, on the basis of preset criteria, the merits of different regulatory schemes, and for understanding the conditions of institutions formation in different use systems.

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Appendix 7

ARTIFICIAL REEFS IN LANGUEDOC - ROUSSELLION

BEATRICE PARY

ARTIFICIALS REEFS IN LANGUEDOC-ROUSSILLON:
AN INVESTMENT FOR SMALL SCALES FISHERIES

1) FISHERIES IN LANGUEDOC-ROUSSILLON.: AN IMPORTANT ECONOMIC PLACE – SPECIALLY FOR THE SMALL SCALE FISHERIES

- **2 main types of coastal fisheries**

Number of boats in1998	**1224 boats**
trawlers	128
tuna senners	44
small scale fisheries	1062
Number of fishermen **Direct employment**	**'2500 fishermen**
Number of jobs related to fisheries : reparation, furniture, commercialisation, transport, transformation,	**4500 employs**
Landings per year (out shellfish) NB : production shellfish cultures mussels : 8 000 tonnes, oysters : 10 000 tonnes	**37 000 tonnes**
Turn over production :	**430 M.F. de CA**
of trawlers :	200 M.F.
of tuna senners :	130 M.F.
of small scales fisheries :	100 M.F.

- **trawlers :**

2 types of trawlers that target either bottom fish either pelagic fish, and work on the Lion' Gulf, which is a large continental tableland, with sandy bottom:

* Pelagic trawlers have known a great development and fish anchovies and sardines, in the continental tableland – less than 40 mills from the coastline -

* Trawlers specialised on demersal fish

- **small scales fisheries**

We could just evaluate the importance of this fishery by taking into consideration only numbers: more than thousand boats who carry on their activity in the ponds (38 00 hectares) or on sea on the side of 3 mills.

But we can also consider these fisheries like an especially important activity for the territory management. Because this activity is permanent, the whole year (on the contrary of tourism) and respectful with environment. These fishermen are first to detect and first to suffer from distortions of environment.

- **locals partnerships : CEPRALMAR**

National rules have given to the regional council some responsibilities for aquaculture and fisheries. For fisheries, regions can give economic assistance to small boats under 18 meters long.
The Languedoc-Roussillon has chosen to reserve a financial envelope per year (25 MF) and to create an association to give technical advises. This association has an administration council divided in 2 groups: professionals (fishermen and aquacultors) in one side and elects from coastal zones. Members of CEPRALMAR examine all documents and projects that have links with fisheries, and give advice for the financial aids.
Moreover this association has wage earners, specialised in one sector: aquaculture, fisheries, environment transformation of marine products...

The objective is to consider the needs of producers and find solutions to improve things:

- organisation of the profession,
- development of quality on board and on earth,
- management of the coastal activities and amenagement

For small-scale fisheries, the main problem is the quality of environment: what kind of arrangement can be found to improve the fishing conditions in the ponds and in the sea.

So that CEPRALMAR have early worked on artificial reef to test the opportunity of managing coastal border with this kind of material: it managed a big program in 1984-1985, with immersion of 15000 m3 concrete models, directed coming from the Japanese technology (cf. document) in 5 experimental zones.

Another operation conducted by CEPRALMAR was the introduction of shellfish culture on longlines :

ORIGINALS REEFS : SHELLFISH LONGLINES

	GRUISSAN	VENDRES	SETE - MARSEILLAN	ARESQUIERS
Surface brute	261 has	648 has	2754 has	540 has
Number concessions Total	87	144	348	90
Nb concessions exploited	33	51	240	
Nb longlines	36	25	260	
Enterprises	4	3	120	
Production mussels	800 tonnes	600 tonnes	6000 tonnes	
Nb boats	4	3	80	

10 years after the immersion of the first long-line, this sector represents, in 1997 : 7 à 8 000 tonnes mussels / year - 300 direct employment - 50 M.F. de turn-over ... and privileged places for fishermen

2) ACTUAL POLITICAL for ARTIFICIALS REEFS IN L.R.

2 1) MAIN OBJECTIVE FOR HAVING ARTIFICIAL REEFS ON SEA IS TO HOLD SMALL-SCALE FISHERIES … from witch the regional council has responsibility.

This economic sector has known an important reduction during the last ten years: this sector, in the Mediterranean french shore has been reduced from 50 % between 1983 and 1998. The responsible coming from the prud'homie have asked the public utility to do something to limit conflicts and to preserve the coastal zone.

1) Indeed many **conflicts** take place in the coastal border into the zone of 3 mills, between trawlers and small boats.

- the trawlers work very near from the coastline, so that they can fish noble fish … but very often, under the commercial size, above nurseries.
- They often take over the nets of small boats

So, artificial reefs can be used a **protection reefs**, to share space between 2 types of nets and to prevent the heavy utilisation of some well known hard-bottom areas along the coast.

2) We notice a reduction of catches near the coasts, so fishermen must go far away to try to capture enough fish. But theses reefs can also be **production** reefs :

- they concentrate noble fish and different types of commercial species, specially species associated to rocky places
- they constitute a home for genitor and a protection for small fishes
- they can favour the use of selected tackles like longlines

2-2) HOW TO BUILT A PROJECT

For the recent projects, we have had always the same scheme:

An initiator: the prud'homie.
Prudhomies are old organisations that gather all fishermen of a port or a jurisdiction. Fishermen are used to consider that the environment is fragile and the resources are limited. And they have been responsible for the protection of the resources since the 15eme century, date of constitution of the prud'homies, who are special corporation for fishermen. Corporation who exists only around Mediterranean sea, and whose chief is a fisherman elected by his colleagues. The objectives of these prud'homies is to provide rules, to organise fisheries …

So they determine:
- schedules for going out of the port,
- special features for fishing tackles (net meshes)
- if some places are to tie fallow

To sum up, these prud'homies are ideal collocutors for institutions and people who are in charge of the fisheries sector.

A technical co-ordinator : CEPRALMAR who :
- organise meeting for giving information about the different possibilities, and collect needs of each partner,
- meet all the partner – elects, fishermen, scientists to settle the type of reef, their best localisation ...
- presents the project in front of technical commission, who give an advice for having public subsidies

A political leader : often the town or a group of collectivises

2 –3) A NECESSITY to determine the consequences: a SCIENTIFIC FOLLOWING

After the immersions in Agde and Marseillan, the Region has worked on a scientific following to estimate the effects of these investments. So we chose an association of 2 scientific agencies who suggest following the colonisation by skin-diving. Their conclusions are very interesting and encouraging:

Recording to the type of reef:
- the concrete tube is useful to protect the areas against trawlers, (so as a protection reef), it's solid, but they can silt up and are too much simple : they favour certain species like congers.
- diversified populations have colonised these tubes, from useful commercial species (Dicentrarchus labrax, sar, congers ...)
- the protection role appears by protection of eggs and juveniles (sole, rouget ...),
- some species who had disappear from the landings have been found again (escargots, Dorado, rays ...)

Recording the activity of fishermen :
around the arranged zones, we have had many installations of young fishermen, on the contrary of what happens in other ports in L.R. the captures have increased and a commercial organisation have been created in order to organise commercialisation.

Recommendations :
The conclusions of the etude show that we'll have to :
- install reefs more diversifies to have a better variability of habitats,
- concentrate reefs in the space and if possible as nearest as possible from rocky zones

So, in the next project – in the Aigues Mortes Gulf, we have taken account this recommendations Immersions will take place in june 1999, and it'll be a very big program with a study during 3 years, with an great place given to the effects on fisheries, and tests of differents types of reef in relation with the type of fish we'd like to fix.

2 - 4) RECENT IMMERSIONS OF ARTIFICIAL REEFS IN LANGUEDOC-ROUSSILLON

	MARSEILLAN	AGDE	AIGUES MORTES GULF
Year of realisation	1992 and 1996	1995	Foregone june 1999
Leader Maître d'ouvrage	Town Marseillan	Town Agde	Syndic for fishing development and protection of coastal zones in Aigues Mortes gulf
Cost (H.T.)	1° step : 450 000 F 2° step : 500 000 F	1 855 000 F	3 000 000 F
Finance	Town : 50 % Region. : 25 % Department 34 : 25 %	Town : 50 % Region. : 25 % CG 34 : 25 %	Région L.R. : 33 % (1 MF) CG 34 : 17,5 % CG 30 : 17,5 % 5 towns : 33 %
Types de modules	double concrete tubes	Double concrete tubes	tubes cubes 1,2 m3
Number of modules	60 modules en 1992 et 50 en 1996	200 modules en 1995	109 tubes concrete de 8 T 25 piles of 20 cubes each
Surface concerned	7 km²	20 km²	14 km²
Depth of immersion	between 10 and 22 m (1° phase) till 35 m (2eme phase)	between 9 and 22 m	Between 7 and 15 m Between 1 and 2 milles from coastline around rocky zones
Number of fishermen concerned	30 small boats	10 trawlers, more than 80 small boats (prud'homie d'Agde)	30 trawlers, almost 100 small boats (prud'homies de Palavas et le Grau du Roi) associated at the program specially for the localisation of reefs

CONCLUSIONS

If the fishermen are at the initiative of this immersions on Languedoc-Roussillon, the elects and technicians are convinced that artificial reefs are a main element of coastal management.

Useful for the fisheries :

- share space,
- diversify the habitats so the species for commercial use,
- give security for small scale fishermen who don't have to worry about having their nets taken away during the night,
- conduct to use selected tackles : we have done experiences with fishermen who have worked specially around reefs to take congers, which are great predators, in order to observe if other species could come if the congers were out
- can reduce the use pressures that natural hard-bottom areas endure.

For the economy :

- artificial reefs are an element among others for the gestion : it 's possible to imagine zones selected for tourism, anglers, divers (many things have already be done in the USA) but also on link with aquaculture.

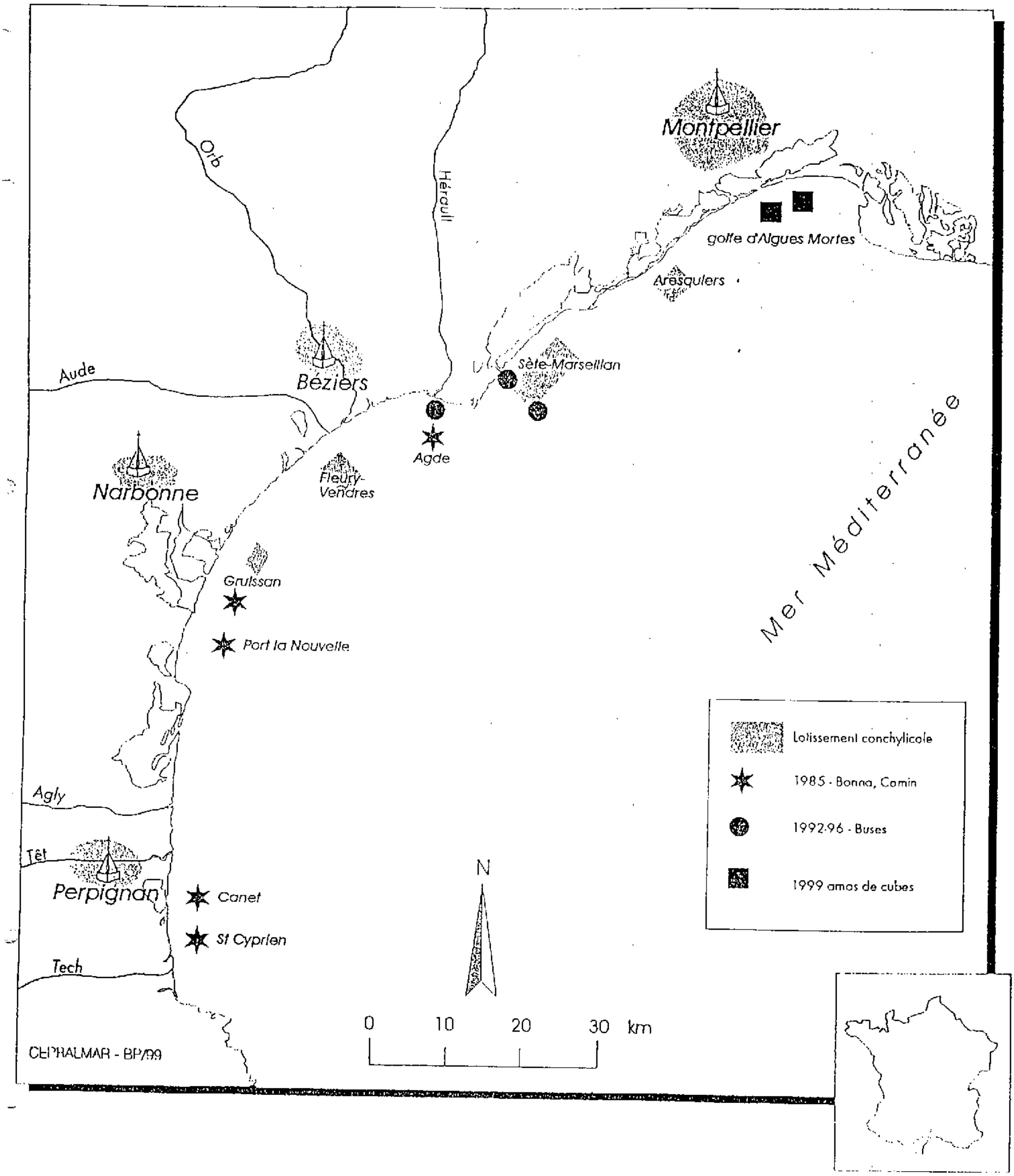
Artificial reefs and aquaculture :

- we have seen that one of the best reef was the shellfish longlines, and some studies show the movements of fish between coastal front, reefs and allotments
- we could imagine many possibilities for extensive aquaculture for example : to catch savage juveniles and put them in reefs zones, or use juveniles from aquaculture

Actually, 3 other ports have a project of immersion, and an important program of study will take place on Aigues-Mortes Gulf. But we are in the beginning of the work on artificial reefs. Many collectivises from the other french regions are interested. It 's time to engage partners in some new direction and to narrow fisheries and extensive aquaculture.

Les récifs artificiels dans la bande cotière du Languedoc-Roussillon

- localisation et époque des immersions -



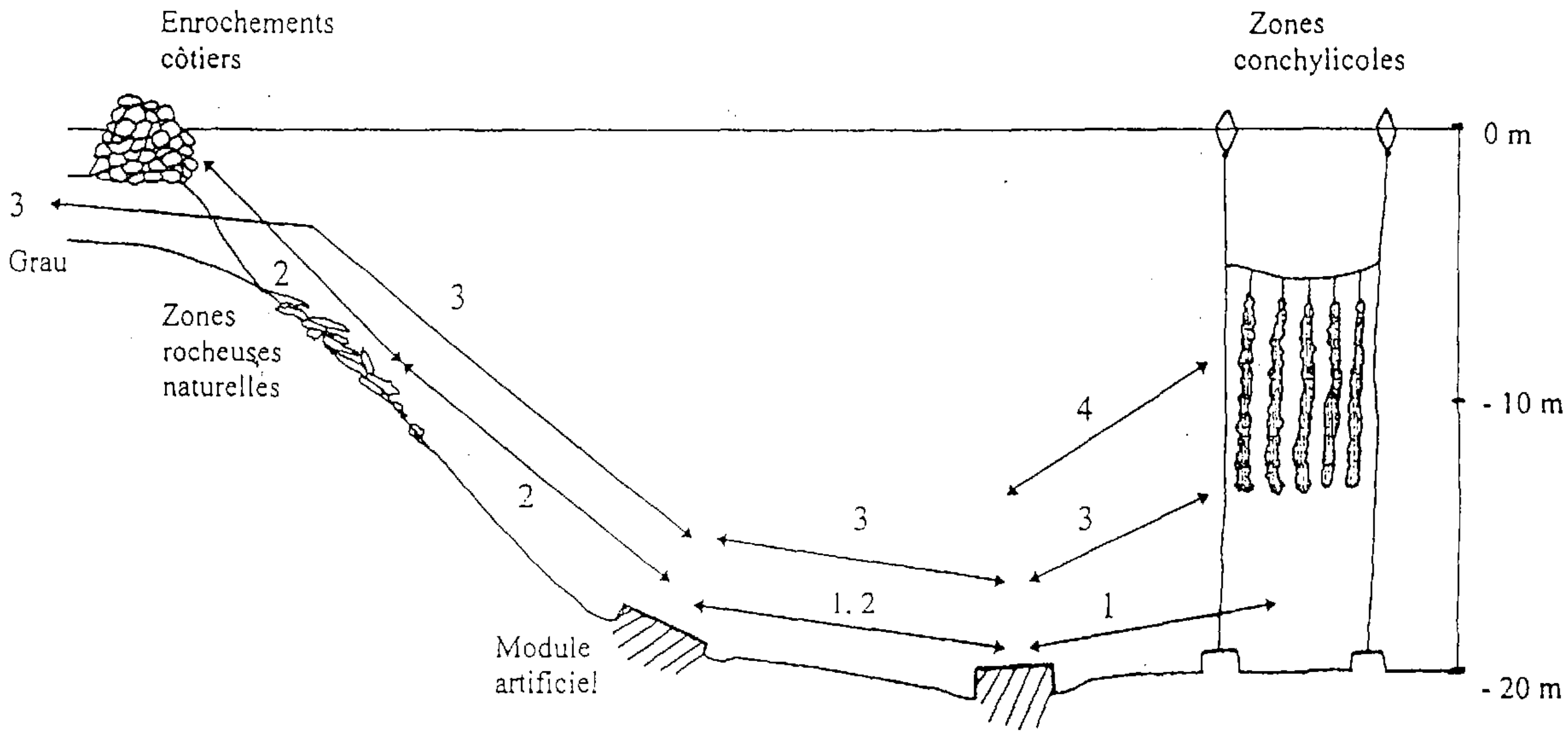
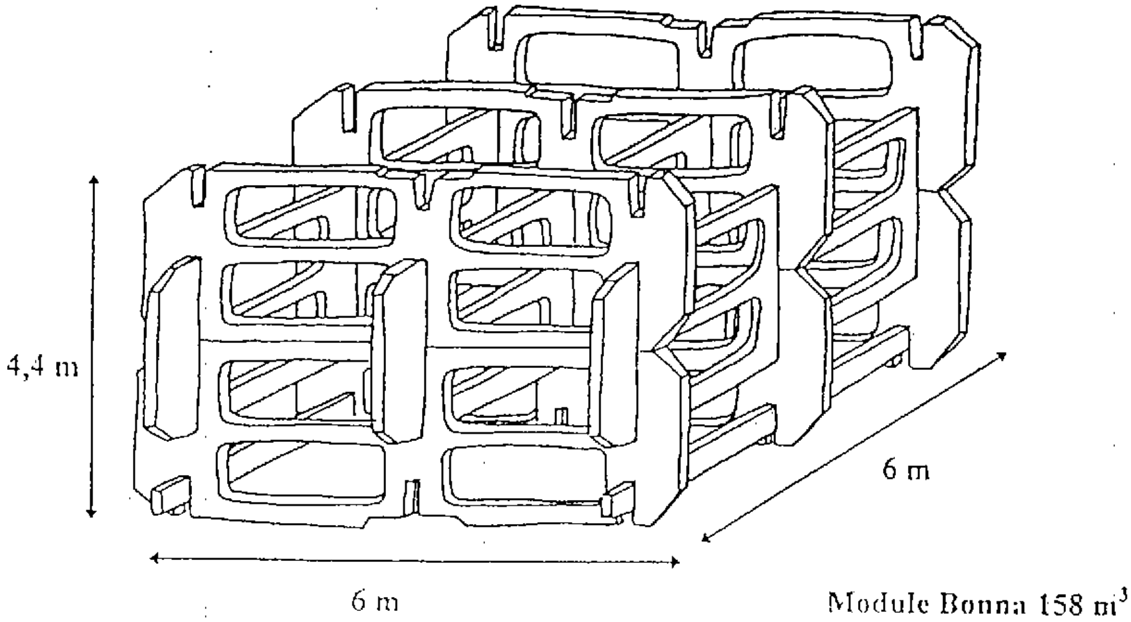
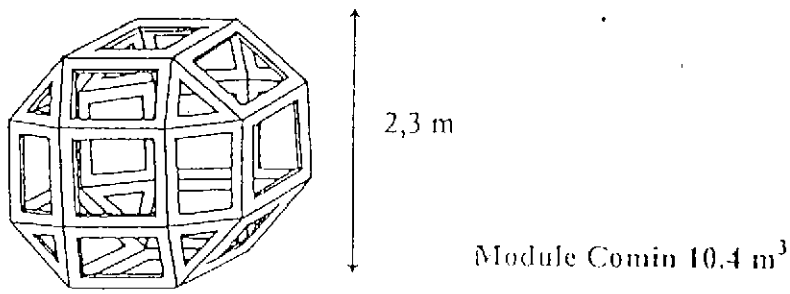
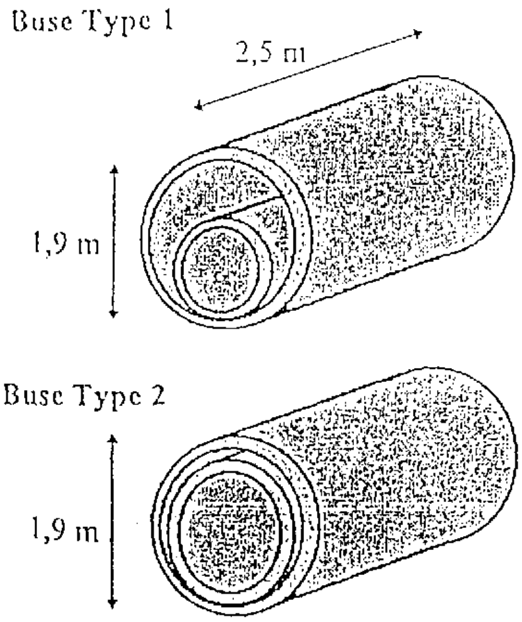
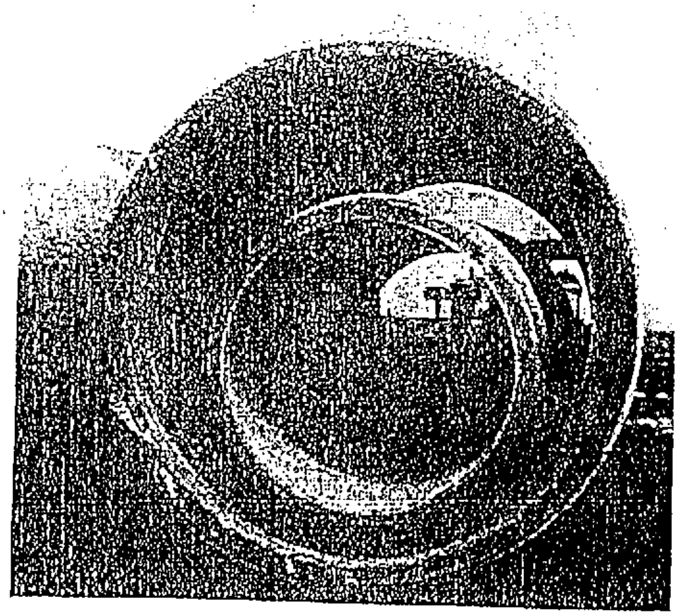


Figure 44 : Représentation schématique des déplacements probables de quelques espèces entre différentes zones littorales naturelles ou aménagées. Espèces : Loup *Dicentrarchus labrax* (1), Sar commun *Diplodus sargus* (2), Dorade *Sparus aurata* (3), Bogue *Boops boops* et Chinchard *Trachurus mediterraneus* (4).



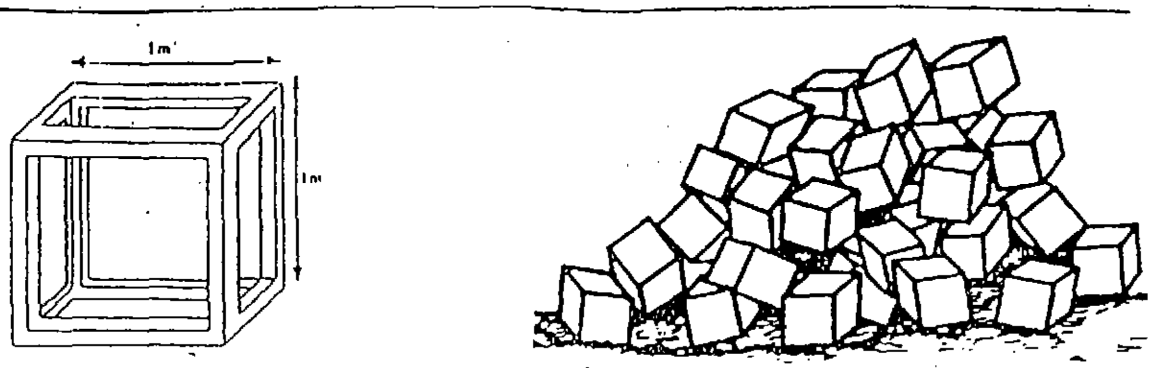




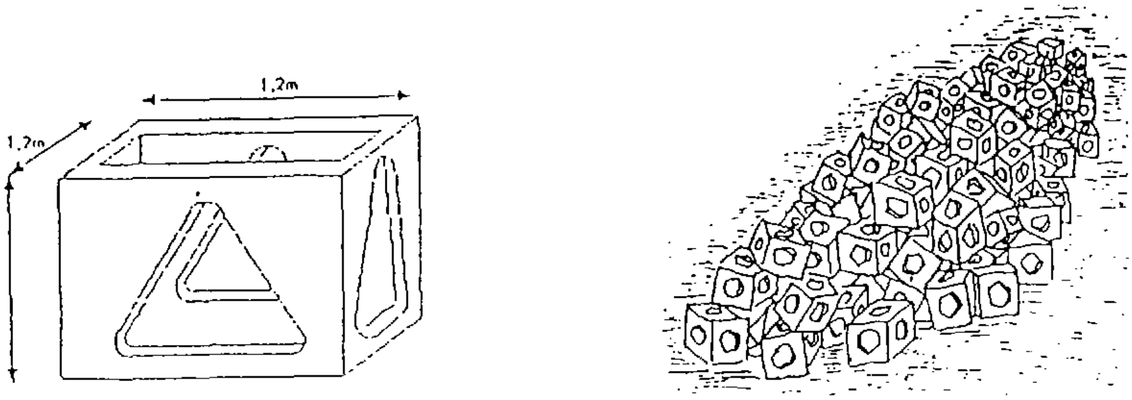


Buse Type 1

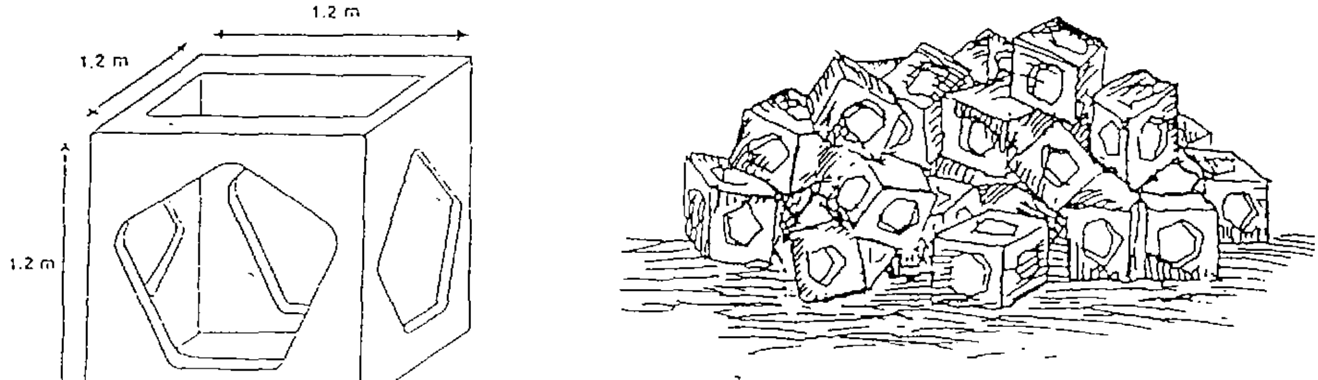
Figure 1 : Représentation des différents types de récifs artificiels immergés dans le département de l'Hérault, sur les secteurs d'Agde et de Marseillan : modules Bonna 158 m3 et modules Comin de 10.4 m3 (premier programme d'immersion en Agde en 1985) ; buses en béton utilisées à Marseillan (1992, 1996) et Agde (1995). Pour les buses, le type 1 est représenté en haut et par la photographie, le type 2 en bas.



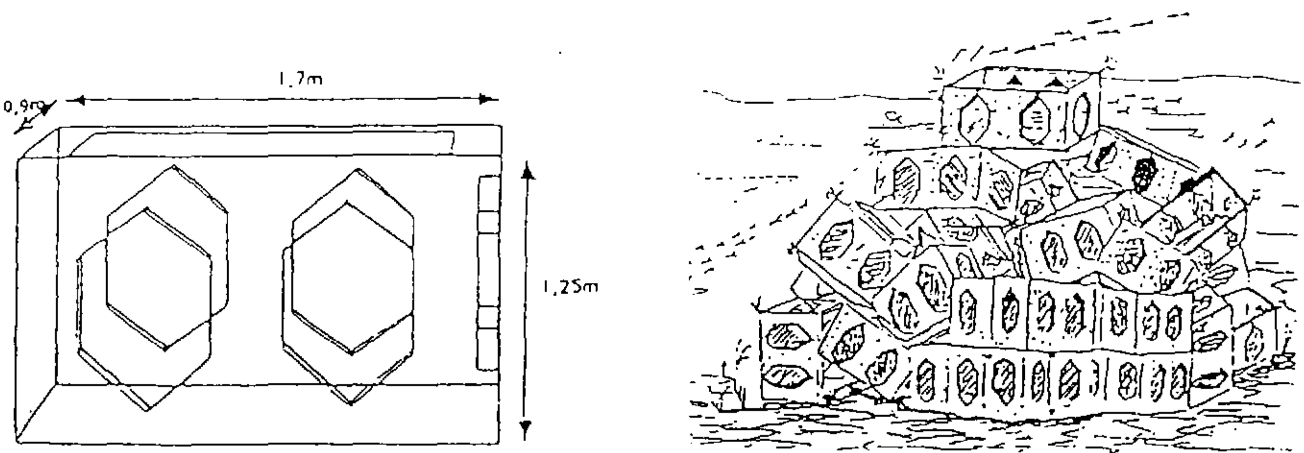
Module 1 m^3



Module 1.4 m^3



Module 1.7 m^3



Module 2 m^3

Figure 42 : Présentation schématique des 4 types de modules petits volumes (1 à 2 m^3) utilisés en région Provence-Alpes-Côte d'Azur et disposition en tas chaotiques sur le fond (d'après Charbonnel & Francour, 1994*a*).

Tableau 31 : Comparaison des données biologiques disponibles sur les récifs artificiels en Méditerranée française pour les peuplements ichtyologiques (modifié d'après Charbonnel & Francour, 1994*a* et *b*). - = donnée manquante. Volontairement, certaines espèces n'ont pas été prises en compte (microphages, espèces cryptiques, Girelles). Les données ne sont donc pas exactement identiques et seuls les ordres de grandeurs doivent être considérés. Concernant le présent suivi, nous avons délibérement exclu les densités de Gobies et de juvéniles de Pageots qui masquaient l'importance des autres espèces. Pour les biomasses, deux chiffres sont considérés : biomasse totale et biomasse sans les Congres (entre parenthèses).

Région	Récifs	Richesse spécifique	Nb espèces/ relevé	Densité (ind./m3)	Biomasse (gr./m3)
Languedoc (présent suivi)	Buses 7.1 m^3 Mars. (1992)	12 à 17	7.7	3.9	9 167 (475)
	Buses 7.1 m^3 Agde (1995)	10 à 14	6.6	3.6	7 080 (524)
	Géants 158 m^3 Agde(1985)	10	-	0.4	199 (12)
	Comin 10.4 m^3 Agde(1985)	7	-	1.4	733 (24)
Côte Bleue (Ody, 1987)	Alvéolaires (1983) Cubes 2 m^3 (1985) Géants 158 m^3 (1985)	35 à 37 22 à 28 15 à 24	18.1 à 18.9 10.8 à 11.4 7 à 7.3	2.8 à 3.0 0.7 à 1.0 0.1 à 0.2	144 à 179 82 à 116 5 à 17
Côte Bleue (Charbonnel & Francour, 1994a)	Cubes 1.7 m^3 (1989) Géants 158 m^3 (1985) Cubes+Géants 158 m^3 (1985/89)	26 à 28 18 22 à 25	13.7 à 16.2 7.9 à 11 13.4 à 16.2	2.0 à 4.4 0.14 1.1 à 3.2	277 à 421 24 à 94 106 à 464
Alpes-Maritimes (Charbonnel, 1989, 1990)	Alvéolaires (1983) Pneumatiques (1982) Cubes 1 m^3 (1985) Cubes 2 m^3 (1985) Cubes+Alvéo (1983/85) Géants 158 m^3 (1986)	19 34 28 à 35 20 à 27 24 à 32 9 à 18	10.1 17.1 14 à 19.7 8 à 11.4 10.7 à 15.8 4.2 à 8.2	2.7 1.5 1.2 à 2.0 0.4 à 1.3 0.5 à 1.2 0.08 à 0.2	556 191 345 à 384 55 à 279 189 à 279 7 à 27
Monaco (Barnabé & Chauvet, 1990)	Alvéolaires (1977 à 83) Blocs (1977 à 83)	4 à 13 9 à 12	- -	- 2.9 à 7.9	2 à 62 94 à 212
Port-Cros (Ody & Harmelin, 1994)	Cubes 1 m^3 + Alvéo (1985/89)	32 à 38	11.5 à 13.5	2.6 à 3.7	-

Appendix 8

OFFSHORE MUSSEL CULTIVATION

CLAUDINE L'HOSTE

30 YEARS OF DEVELOPMENT OF SHELLFISH CULTURE IN THE OPEN SEA

experimental phase → development and stabilisation phase

1968	• 1st series of work in the coastal band with artificial reefs (Palavas)
1970 – 1981	• research (ISTPM) on spat collecting and breeding of the flat oyster • 1er big trials of mussel breeding on metal frame by producers → failure (storm)
1982 – 83	• **1er trials on long lines → success** • regional support
1984 - 85	• establishment of techniques and breeding cycles • study trip to Japan • establishment of barges for mussel working
1986 - 87	• **+ 100 long lines installed** • define of a development plan • 1000 tons of production per year
1988 – 90	• **installation of allotments in the sea** (4200 ha) • construction specialised barges • implantation of long lines • 1ère detection of Dinophysis
1991 – 93	• construction of 3 specialised harbours • 250 licence holders, 300 long lines • **10 000 T/year, 50 MF /year**
1993 – 98	• abandons, storms, financial difficulties • concentration of enterprises • 150 licence holders, 250 long lines • **8 000 T/year, 40 MF /year**

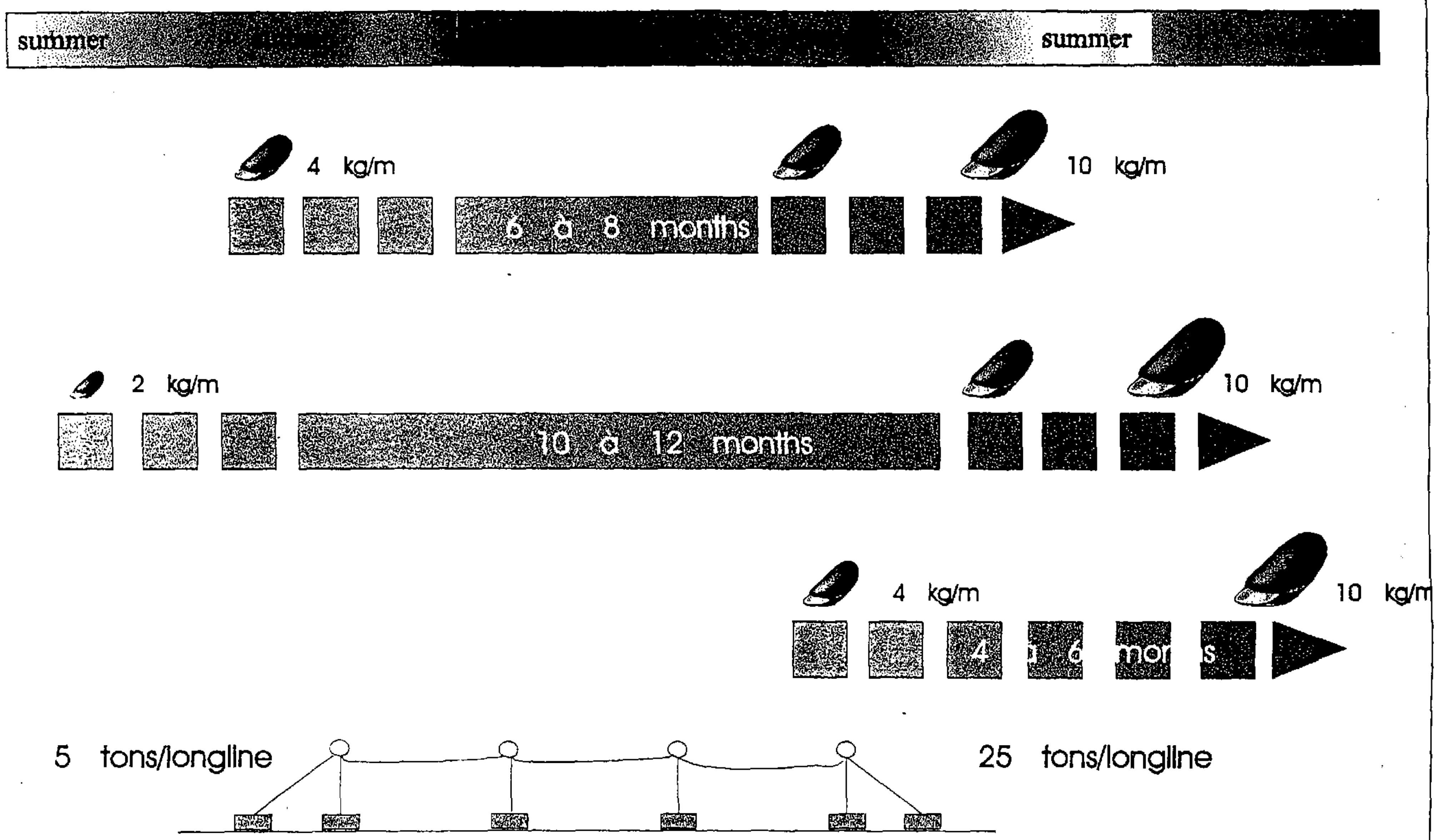
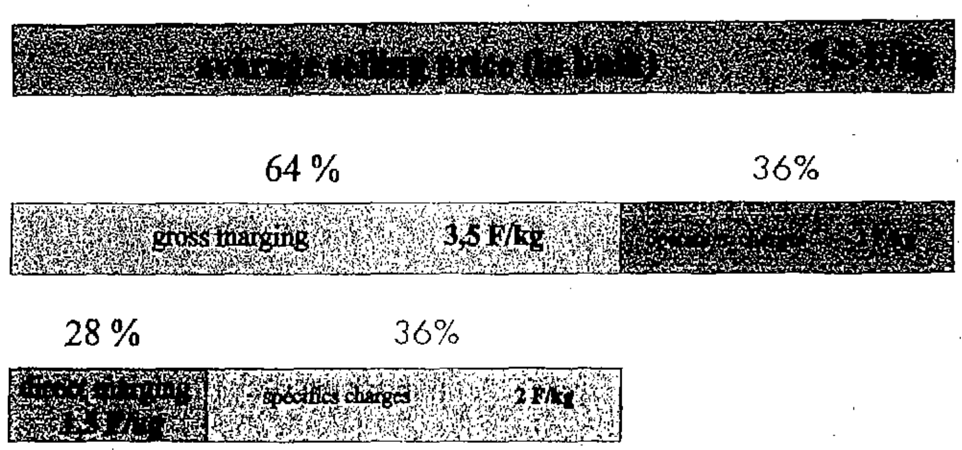


Figure 1 : shellfish culture in the open sea in the region of Languedoc-Roussillon
exemples of breeding cycles

Figure 4 : Musselculture in the open sea in Languedoc-Roussillon
selling price, gross marging and direct marging



Interactions between shellfish culture activity and others activities in the open sea

	conflicts - contraints	synergies
ENVIRONMENT		
- physico-chimical	- storms	- support of flora - sheltering, diversification of fauna
- biology	- predators	- nursery
FISHERIES		
- trawlers	- suppression of fishing areas (illegal) - dammages to nets and long lines	- nursery effect (recruitment)
- small scale fisheries	- suppression of fishing areas (legal)	- nursery effect - attract of fauna
- leisure		- increase of ressources - fishing areas around long lines - fighting against predators
NAVIGATION	- danger and annoyance for the navigation	
- trade	- displacement of allotments	
- leisure	- beaconing (cost)	
- army	- long lines at 5 metres under the surface	

Appendix 9

RE-STRUCTURED TEXT OF WGEIM 1998, SECTION 6
I M DAVIES AND P BURBRIDGE, IN CONSULTATION WITH OTHER MEMBERS OF WGEIM

6. Integrated Coastal Management and Mariculture

6.1 The Concept of Integrated Coastal Management

The United Nations Conference on Environment and Development (UNCED) established Agenda 21 which forms an international plan of action to promote wise and sustainable use of the earth's natural resources. Section 17 of Agenda 21 deals specifically with the resources of the seas and give priority to the development of integrated approaches to coastal zone management as the primary means of achieving sustainable use of marine and coastal areas and resources. The resources generated by coastal ecosystems sustain many different forms of human activities. Mariculture is one of these activities.

The term Integrated Coastal Management is used to describe a continuous and dynamic process that unites government and the community, science and management, sectoral and public interests in preparing and implementing an integrated plan for the protection and development of coastal systems and resources (GESAMP, 1996).

The ICM process is explained by Chua Thia-Eng as follows:

"ICM provides the opportunity to allow policy orientation and development of management strategies to address the issue of resource use conflicts and to control the impacts of human intervention on the environment. It provides institutional and legal framework, focuses on environmental planning and management, coordinates various concerned agencies to work together towards a common objective. Sectoral planning and management is still essential but should operate within the general framework of ICM. Maintaining species habitats, natural resource base and management of development processes are part of ICM programme". (Chua quoted in Clark 1992).

The concept of integrated management of human activities within a sovereign nation has two major dimensions, namely:

1. The vertical integration of the process of governance in the form of policies, management arrangements and development plans from national through to local levels of government, including community based approaches to coastal management.

2. The horizontal integration of policies, management arrangements and development plans across national, provincial, district and more local levels of government, as well as among different interest groups with common interests in coastal areas and resources.

At the international level, the value of ICM in addressing economic, social and environmental development issues is reflected in the UNCED Agenda 21, Section 17 which gives priority to the development of ICM strategies and management plans as a means of promoting the wise and sustainable use of marine resources. Section 17 emphasises the integrated nature of terrestrial and marine systems and the need to improve the management of human activities which adversely influence the linkages between these two realms and reduce their ability to sustain human development pressures.

ICM is a management tool which can contribute towards the following benefits:

1. Facilitate sustainable economic growth based on natural resources.
2. Conserve natural habitats and species.

3. Control of pollution and the alteration of shorelands and beach fronts.
4. Control of watershed activities that adversely effect coastal zones.
5. Control over geomorphological changes in coastal systems resulting from excavation, mining and other alteration of coral reefs, water basins and sea floors.
6. Rehabilitate degraded resources.
7. Provide a mechanism and tools for rational resource allocation.
8. Control of the release of ballast water to prevent the introduction of pest species and diseases.

All these require coordinated action. Coordination can be fostered through the development of awareness on the parts of different parties of their common dependence on coastal resources and benefits that can be gained by cooperating in the resolution of common problems and the avoidance of conflicts. Awareness, cooperation, and coordination are stepping stones to the development of effective integrated planning and management.

The recent conference on Lessons Learned from International Experience in ICM held in Xiamen, China concluded that it was appropriate to consider ICM as a dynamic process in which it is desirable to:

1. Start at the local level and focus on priority issues in developing ICM.
2. To build expertise in ICM at the local community and governmental agency level.
3. Develop local "ownership" of the ICM plans and management strategies.
4. Provide national support for local, district and provincial/state ICM initiatives.
5. Develop national ICM policies, strategy, and management guidelines.

The European Union is currently supporting 35 demonstration projects on integrated coastal management, many of which have come about as a result of major concerns over conflicts among different activities, including mariculture, and the need for stronger management strategies and plans to avoid future conflicts. The case study on Bantry Bay, Eire is one of these demonstration projects and presents a good illustration of complex coastal management issues surrounding the sustainable development of mariculture and other fisheries (see Section 6.3).

A thematic evaluation of the 35 demonstration projects on ICM has recently been initiated in order to provide the European Union with information of good practices which support the ICM process. Examples of the integration of mariculture into coastal management are provided in the Case Studies in Section 6.3.

To be fully effective, ICM requires access to sound scientific information and advice which will be effective in addressing coastal development issues. It will also require well trained professionals with interdisciplinary skills and a wide body of public support. Establishing and maintaining such support requires active participation of a wide cross section of interested and affected parties, including coastal communities. These are commonly referred to as stakeholders.

Agenda 21, the work of GESAMP and other recent developments have established a useful framework for the WGEIM to help to establish principles and practical procedures for use in developing sustainable mariculture. These can include local, or "bottom-up" mariculture strategies that enable coastal communities to improve their economies as well as the development of national, or "top-down", coastal management strategies that provide the framework and support to enable local initiatives to succeed while protecting the integrity of coastal systems

6.1.1 Goals and objectives of ICM

The overall goal of ICM is to ensure optimum and sustainable use of coastal natural resources. Related goals include the maintenance of high levels of biodiversity and effective conservation of critical habitats. These goals help to conserve the natural resources that sustain food supplies and maintain the economic and social welfare of coastal communities. Management objectives which will support these goals include, for example, supporting the development of mariculture and capture fisheries, protecting the community from the ravages of storm surges, attracting tourists, promoting public health, maintaining yields from mangrove forests, and protecting coral reefs.

Resource management and environmental conservation which provide the motivation for ICM are not incompatible with economic growth. In fact, enhanced long-term economic development may be the overall driving force of ICM. Advocates of ICM must ensure that it is not perceived as having negative impacts on jobs, revenue, or foreign exchange. If such negative perceptions occur, the development of ICM initiatives would not be able to survive even the initial planning stage.

6.1.2 Consistency of the goals of ICM with mariculture and capture fisheries

The goals of ICM are entirely consistent with the objectives of developing sustainable mariculture and capture fisheries. However, there are specific obstacles to the integration of mariculture and, to a lesser extent, new forms of marine capture fisheries into the ICM process on an equal basis with other forms of coastal development. These include:

1. Perceptions among certain interest groups/stakeholders that mariculture will cause degradation of coastal environments and will cause disruption to other activities, including capture fisheries, tourism, navigation, etc.

2. Imposition of controls over mariculture which impose constraints which are not applied to the same degree to other more established activities such as agriculture.

3. Resistance to private controls over public resources.

4. Changing the widely held concept that mariculture sites are owned, instead of leased based on adequate performance required by the regulatory authorities (eg MOM system in Norway).

These issues have been identified in the July 1995, April, 1996, March 1997 reports of the ICES Working Group on Environmental Interactions of Mariculture. These obstacles can be overcome through concerted efforts to:

- Improve our scientific understanding of the functions performed by different coastal ecosystems, the resources they generate and how these functions and resources sustain mariculture and other fisheries;

- develop methods and techniques for the monitoring and evaluation of the coastal zone;

- develop more balanced perceptions of the potential beneficial economic, social and environmental effects of well planned and managed mariculture development;

- developing a more level playing field on which mariculture can compete equitably with other forms of natural resources development activities in coastal areas;

- developing the awareness of decision makers, planners and managers from different sectoral agencies that they have a common interest working with fisheries interests in promoting the conservation of coastal ecosystems;

- achieving a shift in emphasis away from coastal development based primarily upon controlling the end use of resources derived from coastal ecosystems and a shift toward a more balanced approach where emphasis is given to maintaining the health and productivity of coastal ecosystems so that they can continue to supply flows of resources that sustain different forms of activity, including mariculture;

- developing multiple use management approaches to the use of coastal ecosystems and resources which allows different sectoral agencies to meet their economic objectives without adversely affecting their respective economic objectives or the ecosystems that help sustain their economic activities;

- developing policies, plans and management strategies that seek to optimise the sustainable use of coastal areas and renewable resources to meet social and economic development objectives.

These are by no means simple tasks. There have been major advances in promoting the concept of wise and sustainable use of coastal systems through the adoption of international treaties and conventions. The legal and administrative opportunities for achieving sustainable coastal system development are greater today following the United Nations Conference on Environment and Development (UNCED) which stimulated broad political agreements concerning international and national sustainable development goals. Section 17 dealing with the marine environment from Agenda 21 from UNCED sets out the strategic role of integrated coastal management as a means of implementing sustainable coastal and marine resources development.

The FAO Code of Conduct for Responsible Fisheries sets out guidelines for sustainable fisheries. Article 10 deals with the integration of Fisheries into Coastal Area Management. However there is no article dealing with the integration of mariculture into Coastal Management. While there are general policies and some practical guidelines, the implementation of wise and sustainable forms of coastal system use continues to be constrained by low levels of awareness of the social and economic value of coastal systems and a shortage of people trained to plan for and manage the sustainable human use of coastal ecosystems.

This report builds upon the recommendations set out in previous Working Group reports and makes a case for stronger integration of principles and practical measures for the promotion of sustainable mariculture and fisheries management into the process of integrated coastal management (ICM).

The advantages of the inclusion of mariculture in the coastal zone planning are far beyond its economical and financial values. Provided that some elementary precautions are taken, mariculture can act as:

- a renewable resource-based activity which can be easily sustainable;
- a additional and diversified source of seafood and primary products to complement capture fisheries;

- a guarantee of good water quality, the main integrating element in coastal resource systems, because mariculture is quickly affected by any deterioration in environmental quality, and thus;
- a protection against the threats from less environmentally friendly industries.

Mariculture is of great value in developing, planning and managing the coastal zone in terms of:

- land use and occupation;
- population welfare and stabilisation;
- best uses of renewable resources;
- preserving environmental quality.

ICES is therefore encouraged to promote the pro-active integration of mariculture into the ICM process through supporting initiatives to:

- strengthen the contribution of mariculture/fisheries science in better informing the process of planning for, and managing, mariculture as an equal partner in ICM;

- support initiatives to enhance public perceptions of the positive economic, social and environmental benefits which can be derived from sound planning and management of mariculture;

- supporting linkages between mariculture and tourism;

- providing materials to educate the public about mariculture, and its requirement for high environmental quality;

- provide management tools for assessing the interdependence and external effects between stakeholders in the coastal zone;

- provide advice on management tools appropriate to reallocate resource-rent and safeguard against overcapitalisation and over exploitation of the resource.

6.1.3 The integration of mariculture into the coastal development process

Mariculture represents a relatively new activity in many countries which has to establish rights of access to coastal areas and resources in competition with other more established activities. In France for example, mariculture activities prevailing within the coastal zone represent approximately 1% of the total economic from all activities in coastal communities. Fish farming represents only 0.1%, while a much greater share come from tourism activities (around 85%). As a result of the present modest contribution from mariculture, more established activities often receive more political recognition and technical support from governmental agencies. A major challenge is therefore to create conditions where mariculture is given recognition for the contribution it can make the expansion and diversification of local as well as national economies and to ensure that opportunities to develop mariculture will remain open to future generations.

<u>6.1.3.1 Mariculture and its place in coastal development</u>

Modern mariculture is diversified and the supporting technology has evolved quickly. It is likely that it will remain more diversified than agriculture. Rapid technological development means that aquacultural systems that exists nowadays will evolve rapidly. Nobody knows about the systems that would prevail in 2020-2030, but there is broad agreement that, given the axiom that every man will eat the same amount of marine products in the future, mariculture output will have to increase substantially to meet such demands. This will accelerate pressures on coastal resources and will increase the importance of taking pro-active steps to integrate mariculture into coastal planning in order to avoid detrimental effects it could bring, to avoid adverse impacts on mariculture that result from poorly planned and managed activities in other economic sectors, and to avoid major conflicts which could lead hinder its acceptance by the public.

When we speak about conflict resolution, it means that we have already failed to adequately develop the integration of competing activities into coastal zone management strategies, plans and management arrangements. Pro-active approaches to the integration of mariculture into the integrated coastal management process are the only logical way to avoid conflicts arising and to maintain future options for the sustainable expansion and diversification of mariculture. In planning for and implementing sustainable mariculture we face a problem similar to the "tragedy of commons" in that many of the coastal resources which mariculture depends upon are common property and unregulated competition will lead to their over-exploitation. Unfortunately, most planning and legislative systems have been established to protect existing activities and it is difficult to establish a level playing field in which mariculture is given equal rights of access to and use of coastal and nearshore marine areas and resources. As a new form of development, mariculture is often subject to levels of control and standards which are not applied to existing development and are not be particularly beneficial to the integration of mariculture into coastal management plans.

One of the key issues in addressing these issues is how to improve the transfer of scientific knowledge concerning the benefits of mariculture to social systems and how to accelerate the evolution of the institutions which support the integration of mariculture with other activities which compete for coastal and nearshore marine locations and resources. **Figure 1** illustrates the accelerating gap that has been developing between advances in scientific knowledge and technology and their integration with social systems and the development of institutional arrangements to make full and effective use of new knowledge and skills. If we do not appropriately address this question society incur major losses of opportunities to meet

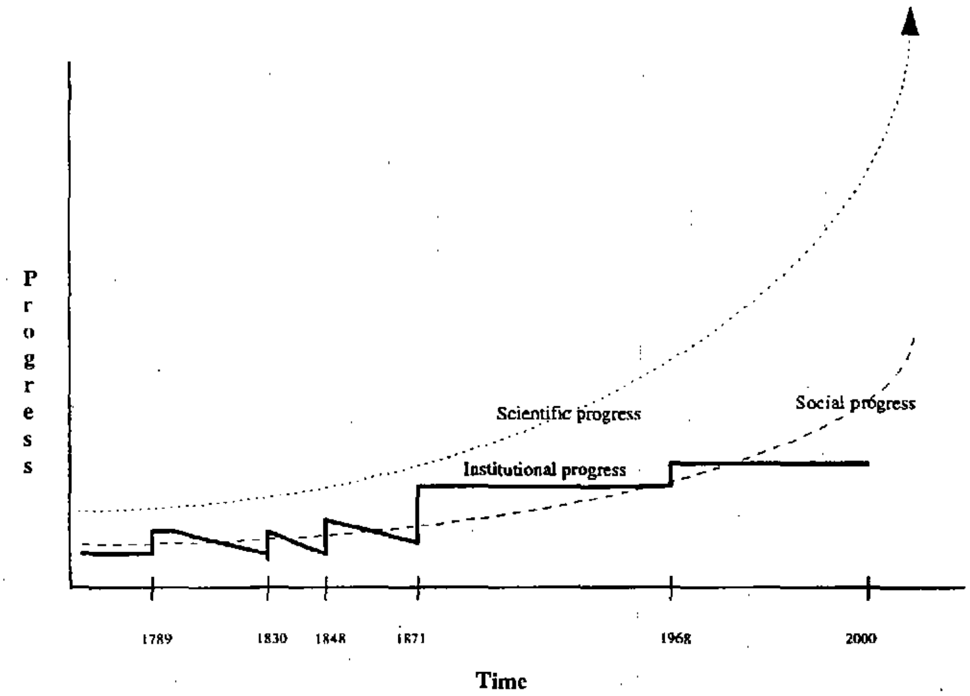


Figure 1. Comparative evolutions of the various forms of progress.

increasing needs for marine protein , as well as the diversification of rural economies - losses never to be recovered. Therefore, when addressing the question "how to ensure equal access to and uses of resources for mariculture" we must adopt an ecosystems perspective that will maintain the functions and resources that sustain mariculture and innovative planning and management systems that will help meet the multiple objectives for sustainable use coastal zones.

One important point in the context of integrating mariculture in the coastal zone is the need to enhance the interaction between natural and social scientists, and policy makers, planners, and managers. Each of these latter groups require information in a format understandable to them. Thus the information and management recommendations from scientists must be as simple as possible and relevant to the needs of the user community.

6.2 The Integration of Scientific and Management Information on Mariculture into the ICM Process

6.2.1 Background

The effective integration of mariculture into the ICM process must begin with a clear recognition of the role of mariculture in coastal development. This must be complemented by the early integration of scientific information from the natural and social sciences into the process to provide a sound information base from which to identify options for mariculture development within an integrated coastal management policy, incorporating resource allocation strategies, spatial plans, regulations, monitoring and control, as well as more adaptive management systems, which are capable of responding to changes in the natural environment.

A major difficulty in integrated advances in science towards the sustainable development of mariculture is the transfer of new information into the development of social systems. This is compounded by the slow rate of the development of the capacity of sectoral institutions to adapt to the integration of different forms of development which compete for access to, and use of, coastal resources. This is illustrated by Figure 1, the comparative evolution of the various forms of progress.

Figure 1 illustrates the rapid evolution of scientific and technological information. Progress is not necessarily constant, but is continuous. This progress is aided, in part, by the limited and often well-defined topics handled by the scientific community and the use of new technologies. It also appears that social progress evolves along a similar path, but at a lower rate. There is consequently an increasing gap between the development of new scientific information and technology and the incorporation of this new knowledge into social systems and institutions. This may in part be due to the natural resistance to innovation that prevails in many human societies. This gap is often a major source of conflicts, which may be exacerbated by the stepwise development of institutional progress.

The rapid advance of mariculture technology has not been matched by the development of institutions to effectively integrate its development into society. The dynamic nature of the technological development of mariculture has progressed more rapidly than the development of the institutional framework necessary to ensure its sustainability. In parallel with this failure to convert scientific know-how into sound regulations, there has been an increase in public concern arising from limited understanding of the role of mariculture in coastal development and in meeting social needs. New institutional mechanisms are required to ensure that mariculture is provided with equal rights of access to coastal resources, and to avoid conflicts between other forms of human activity and mariculture development.

6.2.2 Constraints on the sustainable development of mariculture

Recent analyses have suggested that there is little likelihood of significantly increased yields from capture fisheries. Mariculture can play a significant role in helping to meet current and predicted demands for marine protein. Figure 2 illustrates the potential for increasing mariculture production by the year 2020. This development path is supported by rapid increases in productivity and technological development leading to more cost-efficient production of fish and shellfish in culture systems. This can help diversify and expand the economic base of coastal zone communities, increase the economic benefits of mariculture to the coastal zone, but also increase the demand for suitable production sites. Competition with other forms of development in the coastal zone can be expected to increase. Integrated coastal management can be used to avoid potential conflicts and support the sustainable development of mariculture.

A basic objective is to ensure that natural systems which sustain mariculture, capture fisheries and other activities are protected and that society can capture the economic benefits from the utilisation of the coastal resource base. The development of activities in the coastal zone is most often demand driven. For mariculture, the driving forces are political in the sense that food security, housing and employment in rural areas and the basic growth philosophy are legitimate policy objectives in most countries.

A socio-economic assessment of the role of mariculture is needed to establish the relative importance of this sector in maintaining the viability of coastal communities. National and regional input-output models are made for national income accounting and prediction in most countries and may be used for estimating the consequences of a rise in production in mariculture on income, employment, indirect taxes and exports. These models are presently being developed to include the external effects of pollution and changes in the quality/stock of natural resources (green input-output models). This work is not yet at a stage where it is directly applicable, but this work should be undertaken.

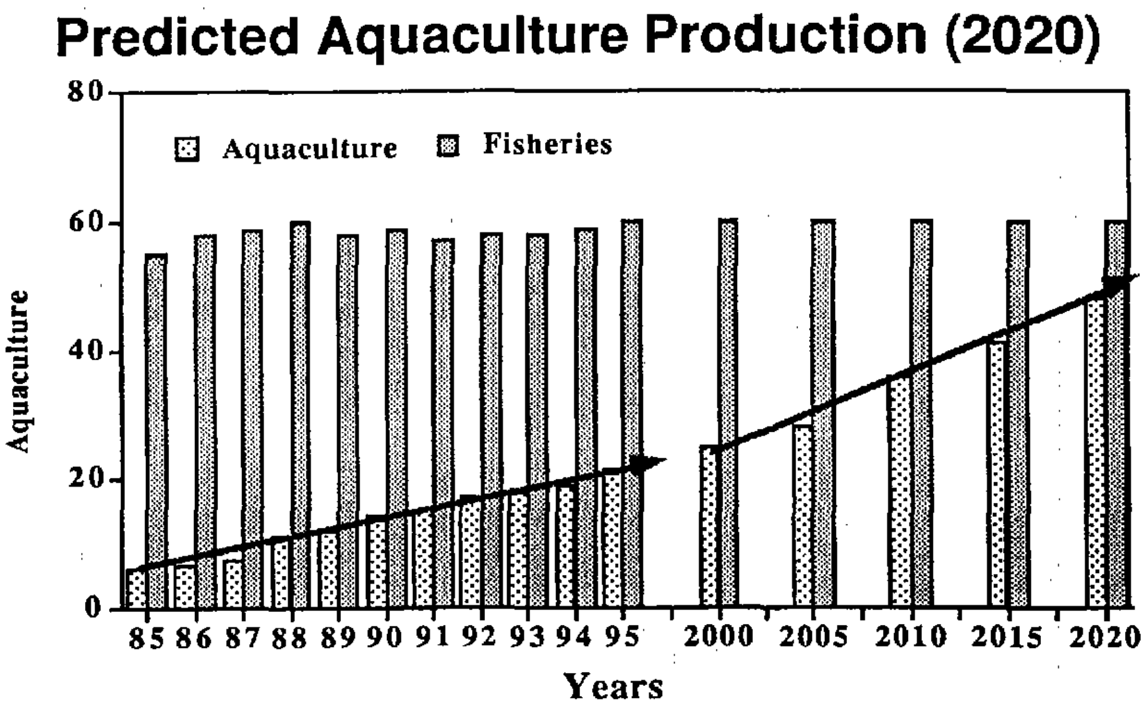


Figure 2

We have briefly discussed the development of "ownership" and the resistance to private control over public resources. Both statements touch on the paramount question of "property rights" crucial to CZM. The property and rights regime of the coastal zone can grant exclusive rights to individuals, groups or what is known as non-property (ie an open-access regime).

Bromley (1991) suggests that "Property is not an object such as land but rather a right or group of rights to a property stream that is only as secure as the duty of all others to respect that stream". This approach applies to all kinds of natural resources and is therefore also applicable to mariculture sites and the right of aquaculturists to intake of water from natural water sources. W P Davidse *et al.* (1997) states that rights are considered as "property rights" when they are exclusive. Davidse *et al.* (1997) identifies three types of property rights 1) state property; 2) private property; and 3) common property. Open access can be seen as a situation of non-property. They also identify that management of natural resources aimed at restricting the exploitation of a resource has created property rights to individuals and groups of individuals. This have implication for the structural development of the mariculture industry as well as decisions taken by the enterprise. The study by Davidse *et al.* (1997) analyses property rights of fisheries and their effects on the industry and on the effectiveness of fisheries management policy. Similar problems have arisen in the mariculture sector, as the property rights regime may not have been explicitly decided upon before the management schemes are implemented. This creates unintended effects in the structural and economic development of mariculture. Three of the conclusions may be cited here:

- Management systems tend to evolve unavoidably in the direction of individual property rights regimes from the moment that limitations has change into rights and vested interests have arisen.

- Property rights do not have advantages in themselves, but they have to be considered against a background of preferences and attitudes of policy makers and fishermen.

- Under a regime of individual property rights, effective protection of the rights leads to proper protection of the fish stocks (W P Davidse (Coordinator), H Harmsma, M O van Wijk, V McEvan, N Vestergaard, H Frost, Property Rights in the Fishing Effects on the industry and effectiveness for fishery management policy, Onderzoekverslag 159, LEI-DLO, November 1997).

6.2.3 The use and misuse of scientific information in resolving conflicts between mariculture and other activities

In the 1997 Working Group Report we drew attention to the "Tension" created among competing interests in the Coastal Zone. We wish to re-iterate this process as it has shown subsequently to be of increasing significance in several jurisdictions (as exemplified by case histories discussed at this meeting). It was outlined that, in the past, the environmental regulations related to mariculture were built on a reactive process rather than a more constructive, pro-active approach. This is one reason why over-regulation in response to public pressure built-up often follows a pioneering period. It is recognised that public reaction to any new form of development is often conditioned by a limited understanding of the potential positive and/or negative effects of that development. This misunderstanding can be increased because interest groups who may oppose the development often employ non-scientific information in forming their opinions and may misuse information to strengthen support for their views (see Box B in Fig. 3). This can mis-inform the general public creating entrenched positions where sound scientific information is not used to good effect in promoting sustainable economic and environmentally responsible development. This will cause adverse and unnecessary pressures on the coastal resource uses, including mariculture, and on the decision process. It also contradicts the principle of ICM in building consensus based on best available knowledge (pathway C in Fig. 3). It therefore seems necessary in the future to strengthen the role of factual reasoning in the entire process by early promotion of direct inputs from Box A to Box B and simultaneously from the Planning and Management Process into Box B. At the same time, the tension pressure in D should be put through a quality assurance path (objectivity gateway) before finalising the response to either the pro-active science-based improvement process or the developer (proposer).

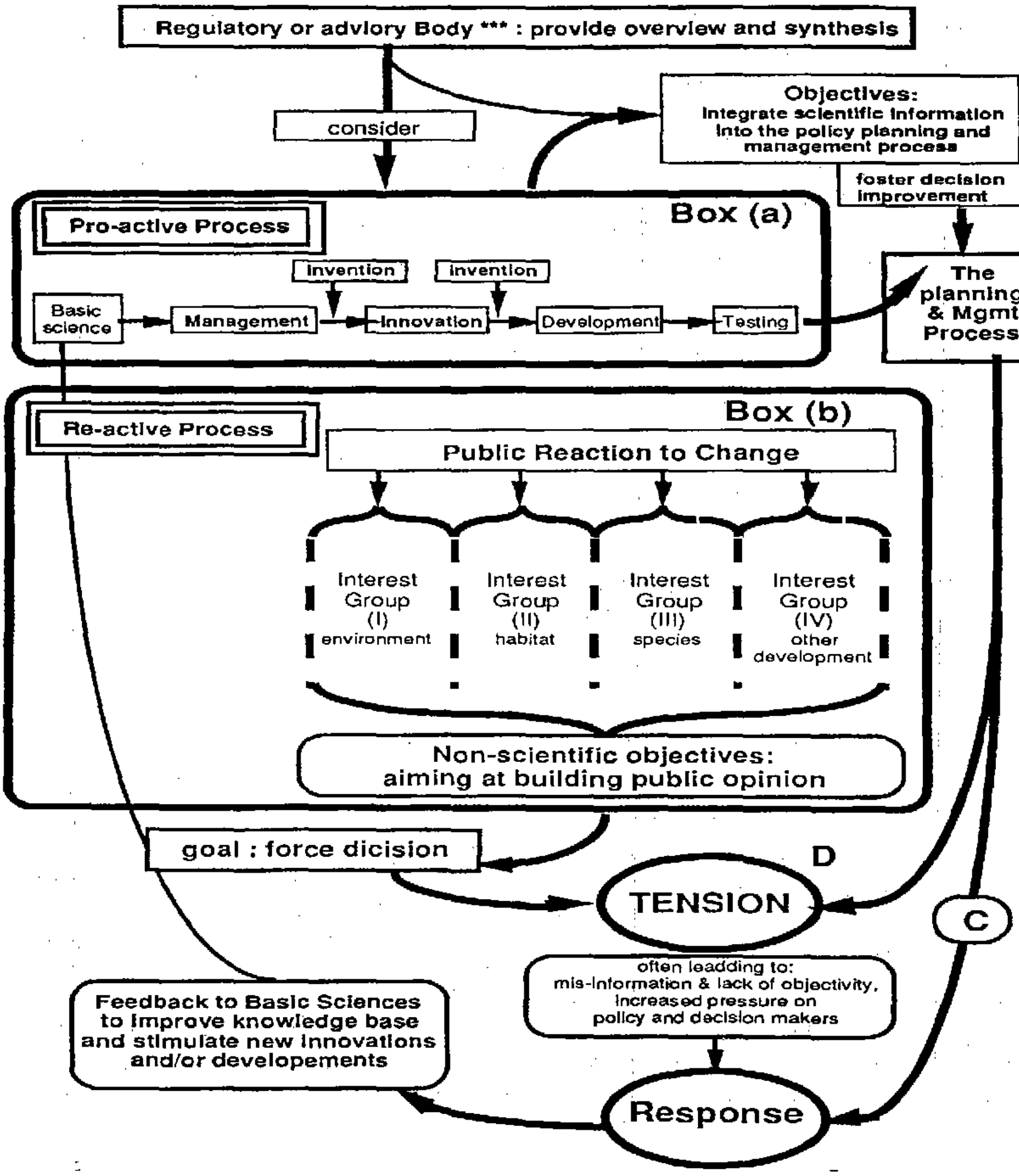


Figure 3. Interactions between regulatory and planning authorities in the management decision process with other stakeholders and the role of scientific advice in improving the decision process

There is very strong evidence that mariculture will develop regardless of current constraints, such as competition for access to resources and adverse environmental conditions caused by poor standards of environmental management of other coastal activities. If positive steps are not taken to make more effective use of available scientific and management knowledge on how to integrate mariculture into the ICM process there is a grave danger of mounting conflicts and loss of potential economic, social and environmental benefits to current and future generations.

The report of the ICES Working Group on Mariculture Environmental interactions recommended in its report on Coastal Management of March 1997 that:

"ICES should adopt a pro-active approach to the application of good science to better inform the formulation of mariculture policy and the process of planning for and developing mariculture within coastal regions. This will pay greater dividends than being enmeshed in sorting out conflicts which in the main are avoidable".

Since this report was written the Council of Europe has produced a draft Model Law on Integrated Coastal Management and draft Guidelines on Integrated Coastal Management. The draft Model Law is framed in the style of a policy which may form the basis for a new Directive on Integrated Coastal Management. The draft Guidelines provide little information which could assist coastal managers in working with mariculture interests in developing sustainable production. Both documents would be enriched through the incorporation of sound scientific information and management guidelines which would facilitate the integration of mariculture into the coastal development process.

6.2.4 Examples of local and regional ICM initiatives

There are planning initiatives and procedures in place in a number of countries to aid the process of integrated coastal zone management. These procedures are designed to empower local participation in the planning process, enhance dialogue between stakeholders, and lead to agreed frameworks within which development can proceed.

These procedures have been discussed previous reports from WGEIM. They include the Sea Loch Framework Plans (Scotland) in which mariculture as integrated with spatial plans at a detailed level, and broader schemes such as SUCOZOMA (see the country report for Sweden in the 1998 WGEIM report), and LENKA (Norway).

LENKA works at a regional level, and the capacity for mariculture production was originally estimated by indices indicating the assimilative capacity for different types of water bodies. This production capacity can now be simulated by a model which is part of the MOM-system. MOM has the main emphasis on site level, but work is being done to merge the LENKA and MOM into one system, which also include a GIS programme.

6.2.4.1 The St Abbs and Eyemouth voluntary marine reserve

The only Scottish Voluntary Marine Nature Reserve is at St Abbs in Borders Region. This was established in 1984. It extends along the coast from Thrummie Carr north of St Abbs Head down to Luff Hard north of Eyemouth. The offshore boundary lies along the 50 m depth contour. Since 1980, the headland has been under the ownership of the National Trust for Scotland which manages it with the Scottish Wildlife Trust. The Harbour areas of both St Abbs and Eyemouth are under the jurisdiction of the Harbour Authorities and the seabed is owned by the Crown Estate Commissioners. The sublittoral environment around St Abbs has been extensively studied because of the clarity of the water and because access is often easy. The main interests are the grazer-dominated communities and the deep rock communities that occur relatively close inshore. The northern nature of the marine life reinforces its interest. In addition the geology of this area has resulted in steep cliffs which have made this area of major importance for sea birds.

A Joint Management Committee has been set up which is responsible for producing a Code of Conduct dealing with publicity, educational material and the operation of the Reserve. The committee is made up of representatives from Sub-Aqua clubs, Fisherman's Associations, Harbour Trusts, the Marine Conservation Society, Community Councils, Scottish Wildlife Trust and the National Trust for Scotland (Gubbay, 1988).

6.3 Examples of the Integration of Mariculture into Coastal Development Plans

The expansion of mariculture in coastal areas will continue, mainly because of its socio-economical benefits to remote coastal communities, the increasing demand for fish and the downward trend in fisheries activities. The absence of mariculture, as an equal partner, in the Integrated Coastal Management (ICM) could result in a defensive approach to its development, with potential unnecessary negative socio-economical and environmental impact. For example, the allocation of sub-optimal sites or use of sub-optimal techniques to avoid conflicts, factual or perceived, with traditional stakeholders of the coastal zone.

The custodian role of mariculture for the conservation of environmental health in coastal zones has already been discussed in previous reports (ICES, 1994). The need for pristine environmental conditions for sustainable mariculture development should be sufficient to establish their important role in Integrated Coastal Management. Site selection and management for mariculture activities in a coastal zone, in itself, provides a survey tool to evaluate the environmental conditions of the system. Monitoring of mariculture site productivity is also crucially beneficial to the management of a healthy and productive coastal environment. Existing, low-cost, monitoring programs for mariculture operations can be compared to the "canary in the mine" for the coastal environment. Examples of such programs are the REMORA, REPHY and REMI in France, Oyster Monitoring Network and Shellfish Aquaculture Monitoring Program in Canada and MOMS in Norway. These mariculture environmental monitoring programmes are important tools that can contribute to the management of the coastal zone and the integration of mariculture into the ICM process.

6.3.1 Richibuctou, New Brunswick, Canada

Public participation in the development of coastal mariculture within the context of integrated coastal management, is clearly demonstrated in the case of the Richibuctou Project, NB Canada. This project is lead by Dr Andrew Boghen of the Université de Moncton, with collaboration from federal, provincial, municipal, international and local stakeholders. Like most integrated coastal management projects, this project involves the various stakeholders from the Richibuctou coastal zone, as well as an integration of all coastal activities, from tourism to peat harvesting and fisheries. Unlike other project of this nature, the Richibuctou areas is enriched by the existence of three different ethnic populations, Arcadians, Anglo-Saxons and Aboriginal people. Historically, these three populations have had little to no interaction in community management. The Richibuctou project, therefore, has a unique opportunity to eliminate ethnic barriers and promote dialogue among stakeholders, through the concept of integrated coastal management. This is essential in ensuring full public participation in coastal management. Discussions on molluscan resource management have already provided some opportunities for the different ethnic communities to gain information on their respective socio-economical and cultural perspectives and concerns. This exercise has also proven beneficial in promoting discussions on the interaction on various coastal activities, including mariculture, agriculture, peat harvesting, fisheries and recreational or tourism industries. In the beginning, negative perceptions of mariculture activities resulting from the lack of open and respectful dialogue, was the dominant parameter in the management discussions. The mutual concern for healthy coastal environment, however, quickly became the common thread among various stakeholders, and progressively evolved into a positive discussion of themes ranging from environmental to economical development of the Richibuctou coastal zone. The development of mariculture in this area has played an important role in the integrated coastal management approach. Healthy environment requirements, and community acceptance and collaboration for the development of the mariculture industry, provided the reason for establishing the equal footing of all stakeholders. Being relative newcomers in the coastal zone, the mariculture industry was overly victimised by the perceptions of uninformed co-stakeholders, complicated by the ethnic bias. Integrated Coastal Management in the Richibuctou area is providing the base for establishing an equal partnership for all stakeholders with the added value of opening a respectful dialogue among ethnic groups.

6.3.2 Corsica: integration of aquaculture with other activities

There are examples where the coexistence of mariculture and other activities, especially tourism, have been successful. On East coast of Corsica, lagoons are traditionally exploited by fishing and mollusc culture on floating rafts. For many years, these two activities operated together, with mutual respect. Sea bass farming appeared during the late 1980s and began to develop in these lagoons. Experimental studies and early monitoring, with special attention to disease transmission, proved that fish farming was not detrimental to bivalve culture, and bivalve culture was not detrimental to fish farming. Fish farming then continued to develop, through cage culture technology. The increasing interest on the utilisation of these lagoons, surrounded by biological reserves, led to an increase in the number of visitors, who could easily see a number of different activities in the same location. In order to exploit this new "resource", a fish farmer decided to build a restaurant on shore. A tour was also organised, including the exploration of the natural environment, a description of fishing techniques, and a visit to the mollusc and fish farms. Within a few years, the income from tourism reached the same level than oyster and mussel culture. In that sense, mariculture and tourism have supported each other and demonstrated their compatibility.

6.3.3 The Cherbourg Bay (France) experience

This example shows that once the local authorities are convinced about the contribution of mariculture (in this case salmonid cage rearing) to employment and income, the whole process can run itself. The institution in that particular case filled the gap between social and science progress. The authorities (state representatives and local electives) decided to undertake a comprehensive study in order to estimate the carrying capacity of the Bay. When that had been done properly by scientists, using mathematical models for example, appropriate concessions could be defined and realised. During that period, concertation meetings had been held under the responsibility of local authorities themselves, eventually supported by scientists. This enhanced the chances for success. It must be emphasised that the local people had been "educated" for several years through a local association, funded by the Region and the Department, with the contribution of scientists. The same process proved successful for the implantation of artificial reefs in the coastal zone of the Languedoc-Roussillon region in the Mediterranean.

6.3.4 Japan

The world leaders in maximising yield from ICM are probably the Japanese. The large coastal fishery/mariculture developments are part of a national government plan to meet the huge demand for seafood that exists in Japan. Government provides support of up to 50% for approved schemes. Local government prefectures have development responsibility and artificial reef building/coastal modification are controlled by local coastal communities with traditional ownership rights to exploit marine resources. The assessment of success is pragmatic and to a large extent, local. Have modifications to existing coastal features or placing of artificial reefs increased the yield of the local fishermen? Have they received significant benefit in terms of catch security, reduced fishing costs, increased saleable product. It appears that if local criteria are satisfied then the programme is deemed a success.

The Japanese example is of interest but will not translate directly into a western context because of the huge differences in social structure. Western ICM can learn from the examples of engineering and modelling skills developed, the conflict resolution that is achieved, generally starting from the coastal community and working up, rather than top down, and the integration of aspects of ICM such as coastal defence and mariculture, artificial reef placement and mariculture.

6.4 Enhancing Public Participation in the Integration of Mariculture into ICM

It is important to have effective stakeholder participation in the formulation and implementation of ICM strategies concerning mariculture development, bearing in mind the potential weaknesses of the participatory process, for example:

- access or investment may be denied to more intrusive or insensitive outside interests;
- economies of scale may not be achieved. With external effects, the private optimum (economies of scale without including the external effects) is always higher than the social optimum;
- management may be influenced by local political whim or prejudice; problems of powerful vested interests, eg local authorities. It is essential to make sure that regulatory and statutory arrangements include the right to appeal local decisions to higher administrative authorities;
- existing problems of over capacity may be difficult to reduce;
- initiation of conflict resolution strategies may encourage transfer of issues to the conflict arena, which otherwise would not have been. Conflict resolution and mediation must always be viewed within the context of the overall integrated coastal resource management process, which is iterative.

6.4.1 Positive interactions among mariculture and other users of the coastal zone

Public perception of finfish mariculture is often influenced by negative assessments of the environmental impacts, often citing earlier studies in the 1980's after which industry practices improved markedly. For example, the percent of waste feed and the use of antibiotics have decreased by orders of magnitude. Recent monitoring programs in Maine and Washington, USA, and elsewhere, have documented an increase in biomass and abundance of benthic invertebrates and fish around salmon cages. These positive environmental effects need to be included in the environmental interactions of mariculture. Some of these positive environmental effects are illustrated in Figure 4.

Benefits	Type of Mariculture					
	Fresh water hatcheries	Salt water hatcheries	Nearshore fish farms (cages)	Nearshore shellfish suspension culture	Nearshore shellfish bottom culture	Offshore finfish and shellfish culture
Employment*	X	X	X	X	X	X
Tourism revenue			X	X		X
Recreational fishing	X	X	X		X	X
Water quality	X	X	X	X	X	X
Education	X	X	X	X	X	X
Stock enhancement	X	X		X		

*Employment includes rural development, transportation, packaging and appropriate income multipliers.

Figure 4. Positive Interactions Among Mariculture and Other Users of the Coastal Zone

6.4.2 Overcoming negative public perceptions of mariculture

Limited understanding of the nature of the environmental implications of mariculture have lead to public misconceptions which have been responsible for loss of opportunities for economic growth in some jurisdictions. The WG chair felt that the experience of the British Columbia with moratoria would be instructive in considerations of both the effective use of scientific information and in the dynamics associated with decision making in coastal zone management.

One technique for conflict minimisation is to prevent the further development of an activity causing the conflict. Such a decision is often perceived to "hurt no one" and yet give both sides of a conflict something. The detractor stops development of an activity and the proponent continues to exist. The consequence of such a decision is, however, much broader in its implication in that it impacts on the total benefit society can achieve from an activity and at the same time it maintains the risk that conflict resolution may not be achieved. For some of the stakeholders, conflict resolution may be not their ultimate goal and an opportunity to achieve a negotiated and true balance of interests is lost.

In many ways, the development of the salmon farming industry on Canada's west coast is a good example of such a phenomenon. Public uncertainty about the environmental implications of the industry and the rapidity of its development engendered considerable and understandable apprehension in the publics view of the desirability of the industry. In 1987, in response to the public concerns, an inquiry (The Gillespie Inquiry) reviewed the operation of the industry world wide and in BC. This review was accompanied by a moratorium that lasted a few months and the creation of a Ministers' Aquaculture Industry Advisory Committee composed of representatives of the industry and potentially competing coastal zone users. In 1988, questions about administrative fairness were reviewed in a report by the BC Ombudsman's Office. No moratorium occurred during this review and the report emphasised the need for integrated coastal zone planning with a mechanism for consensual dispute resolution. Over the same period, ICES and a number of other intergovernmental agencies such as EIFAC and GESAMP reviewed the potential interactions of mariculture and the environment. None of these reviews intimated that development of salmon farming should cease or that the industry should be prevented from operating. In spite of this, government administration in BC prevented issuance of any additional licences until it was prepared to announce a formal moratorium in 1995. At this time, it permitted the issuance of a few of the applications it received and then issued a notice of a moratorium which was supposed to last approximately nine months while another review of the environmental interactions of the industry was undertaken. In 1997, the report from that review was delivered. While there were recommendations for modifying administrative and monitoring procedures, it was determined that the industry should be allowed to expand, albeit under new rules. In the period 1988 to 1995, numerous other scientific reviews had been conducted in other jurisdictions which had reached these same conclusion. As of March 1998, the moratorium had still not been ended. With the exception of the few licenses let in 1995, there has been a *de facto* moratorium on salmon culture development in BC since the beginning of the decade.

In 1990, BC was the third largest producer of cultured salmon behind Norway and Scotland. In that time, Norway with a coastline similar in length and composition to BC has increased production more that four fold to approximately 315,000 tonnes in 1997. Scotland with a much smaller coastline has also increased production approximately four fold to 83,000 tonnes in 1996. Chile, which had lower production than BC in 1990, today produces approximately three times as much cultured salmon as BC. Conservatively, the environmental and business constraints should have permitted similar growth however administrative concerns have permitted only approximately a 13% growth over that period. BC production in 1996 was valued at $127,000,000 and might, if it had kept pace with world development been valued closer to $450,000,000/yr. That is a loss in turnover of over $300,000,000 in 1997. Smaller losses would have occurred in previous years but in total the loss of economic activity to the province is likely in the order of a billion dollars in the 1990s due to constraints on salmon farming.

In addition to the monetary losses, a fundamental but *de facto* redistribution of power has occurred in the governmental administration of mariculture. The trade off of technical and policy considerations has become very lopsided. In the absence of any technical information suggesting that significant negative environmental effects would result from the development of the industry, and in contradiction to numerous local and international reviews of the industry, significant growth in the industry has been prevented though the use of politically expedient moratoria.

6.4.3 Case histories incorporating public participation

6.4.3.1 Maine, USA - volunteer water quality

In the late 1980's, some oyster farmers from the Damariscotta River, Maine, USA, had their harvesting interrupted by high counts of faecal coliform bacteria in the water. Working with the University of Maine Cooperative Extension Office, a local high school science class, a local land conservation organisation and the Maine Department of Marine Resources, they helped to establish a volunteer water quality monitoring program in the Damariscotta and St George Rivers in mid-coast Maine. The purpose of the group was to identify and eliminate pollution sources, mainly from waterfront house with failing septic systems or overboard discharges. Since its start, the program now includes over 50 towns, hundreds of students and over 1,000 total volunteers, and has become a model for local involvement and stewardship for water quality. A water quality coordinating council composed of representatives from the mariculture industry, volunteers and regulators have helped to focus the goals in the US Food and Drug Administration's requirements for approved shellfish growing areas, emphasising quality control and certification of volunteers, sample collection for regulatory authorities, and more recently shoreline surveys for pollution sources and toxic phytoplankton monitoring. Currently, volunteers have doubled the sampling efforts along the Maine coast and have resulted in the reclassification of thousands of hectares of shellfish growing areas as approved for shellfish harvesting, both for the aquaculturists and the wild shell fisheries.

6.4.3.2 Bantry Bay, Ireland

The contribution of mariculture to the ICM process can be emphasised by highlighting its contribution to the economy of the coastal communities, enhancing rural stability and providing the impetus for ICM, which in itself will secure the rights of other user groups to access coastal resources. In Ireland, mariculture is worth 55 million pounds per year, and Bantry Bay accounts for 50% of Ireland's production. Thus, mariculture has a sound economic basis in ensuring sustainable development of peripheral coastal communities, in accordance with local Agenda 21 initiatives. The presence of mariculture in an area highlights the need to address the social and economic factors affecting the exploitation of a particular resource.

The Bantry Bay Charter Project was proposed by the Coastal Resources Centre, in collaboration with Cork County Council and the Nautical Enterprise Centre of the Cork Institute of Technology. The proposal was awarded funding under the LIFE programme of the EU, started in September 1997, and will run for three years.

The principal conflicts in the Bantry Bay area concern interactions with mussel farming. Between 1990 and 1997, licensing was not in operation, and there was unregulated expansion of mussel farms. Many of these farms were placed on traditional inshore fishing grounds, in particular scallop grounds. Farms consist of floating long lines, with blue flotation buoys. In addition, there is an accumulation of debris from the mussel farms, which entangle in fishing gear. Starfish settle out on the mussel bags, are removed, and then target the scallop grounds. Other issues include a need to licence spat collection from the shore, to reduce the risk of navigation hazard to other water users, to assess the carrying capacity of the bay, to provide treatment facilities for ballast and waste water from shipping (to the coastal quarry, to the oil terminal and the Klondykers). Also, the pier usage should be such that it respects the needs of other users - fishermen, tourist, water based leisure. In Ireland, shellfish farms are not required to produce an EIS. In general, the development of a code of practice among the mariculture industry would have great influence on the public perception of the industry.

The Bantry Bay Charter project is based on community involvement from the start, with the aim to encourage local management and ownership of any strategies developed. Existing sectoralism has led to conflict. The following are the conflict resolution procedures which we have adopted to date in the Bantry Bay Charter Project:

1. All local stakeholders were identified and notified about the project.

2. Interviews were given to the local and national press, and national radio.

3. Newsletters were circulated, introducing the concept of the project, the partners and their areas of expertise, and GIS as a decision support tool for sustainable management of coastal resources.

4. A web page on the project was set up.

5. Three introductory meetings were organised in different locations in the area. The concept of the project was outlined, a demonstration of a GIS for the area was given, and the mediators in conflict resolutions were introduced.

6. Stakeholders were invited to fill out questionnaires to identify their sectoral interests, their main concerns and their willingness to contribute to a GIS.

7. A second newsletter was circulated.

8. Two further rounds of sectoral meetings were held with the mediators.

9. A GIS questionnaire was circulated and responded to.

Conflicts tend to be over fixed resources. The conflict resolution mediators are identifying and isolating particular issues of conflict and points of agreement. These will be assessed by the project team, ideas for modification will be suggested and presented to the sectoral groups separately, then together. Thus, opportunities for and obstacles to building consensus will be determined, and areas of mutual gains will be emphasised.

Through this method of conflict resolution, emphasis will be placed on consensus building through face to face discussions between contending stakeholders. By addressing the needs of all stakeholders, the charter developed should produce stakeholder commitments that can be implemented, are pragmatic and can be maintained. The community should then believe that a good precedent was set, and at the end of the project they should be left with a method to settle their differences in the future. Increased participation of resource stakeholders in strategies developed is the key to managing the coastal resources in a sustainable manner. In the Bantry Bay Charter Project, the partners aim to convince the people of the need for joint action, and to foster a shared vision.

Future steps include the establishment of a local stakeholder committee, a regulatory authority committee, and school visits.

The stakeholders were informed of the use of GIS as a decision support tool for resource management, and emphasis was placed on the ability to overlay scientific, socio-economic and cultural data. Involving the stakeholders in the data contributions for the GIS emphasises the local ownership of the project and local empowerment. When the project partners have finished, this GIS will be transferred to the local authority offices for up dating, and will be housed in two locations in the study area. Bringing the GIS into the public arena emphasises the role of the stakeholders decision making by resource managers, while the GIS is also a powerful dissemination tool.

National GIS databases of mariculture sites could be established as a first step. GIS allows integration of *in situ* and remote sensing data. The iterative process of resource assessment is well suited to updating in a GIS. GIS facilitates ease of integration of socio-economics data with scientific data.

6.5 Conflict Resolution

There are a number of factors which can give rise to conflicts, or can mitigate against their resolution. These include:

- General complacency towards existing planning and management mechanisms which leads to apathy.
- Lack of coordination between management in different sectors and on different spatial scales leads to a feeling of impotence about what local interest groups/stakeholders can do.
- The need to perceive that a problem has reached an advanced stage of development before action can be justified (lack of precautionary or pro-active thinking).

- Lack of resources to permit small-scale or politically diffuse stakeholders to be represented.

- Transaction costs may be so high, that the costs involved in the process may *a priori* invalidate the resolution of conflicts through stakeholders participation. If the anticipated benefits of future changes are estimated to be lower than the costs another solution (command and control) may be more efficient.

- If the stakeholders cannot be identified or are so numerous that the process is, *a priori* not valid, then another solution should be thought.

6.5.1 Conflict avoidance versus conflict resolution

A basic principle we propose is that greater emphasis should be given to Conflict Avoidance in the planning and management of mariculture. It is better to avoid conflicts than to waste time and money resolving problems where attitudes/positions have become entrenched. This can be facilitated by the measures set out in this document. However, attention must also be given to the fact that many problems have already been created, many of which impact on mariculture, which must be resolved.

6.5.2 Practical techniques for the resolution of conflicts

Examples of techniques for the resolution of conflicts include:

- Survey of attitudes of local people/stakeholders towards the coastal and marine environment/mariculture.

- Identifying opportunities for change.

- Development of a Partnership with others in developing a management strategy which promotes the integration of current and future uses of a designated coastal area for the purpose of achieving a level of social, economic and ecological development for that area that is compatible with the principles of sustainable and equitable use of natural resources (eg Solway Firth Initiative).

- Need to encourage meaningful involvement from a wide range of non-statutory interests through small topic groups or sub-groups.

- Develop mechanism for sharing information.

- Encourage existing management arrangements to be more accountable and integrated.

- Identify specific issues which need to be resolved, and identify key actors/stakeholders.

6.5.3 Collaborative management

Some of these principles have been formalised into a system known as collaborative management. Collaborative management is based on the participation of all individuals and groups that have a stake in the management of a resource, This approach can be referred to as cooperative or co-management and is based on the following elements:

- All stakeholders have a say in the management of a resource on which they depend. This guarantees their commitment and participation, and permits the incorporation of their knowledge, aspirations, and experience.

- The sharing of management responsibility varies according to specific conditions. In some cases, much of the authority is in the hands of local community organisations; in other cases, much of the authority rests in the hands of a government agency. In virtually all cases a level of government continues to assume responsibility for overall policy and coordination functions.

- Social, cultural, and economic objectives are an integral part of the management framework. Particular attention must be paid to the needs of those who depend on the resource and to equity of participation. (White *et al.*, 1994; Renard, 1991; Wells *et al.*, 1994).

Co-management can be effective in fisheries development where government and fisheries interests have shared power and responsibility. This is accomplished mainly by linking the efforts of fishers and aquaculturists as local resources dependent activities as long-term users of local ecosystems and/or as residents of a local area in which they have a particular interest. (Pinkerton, 1989) Pinkerton (1989) observes that co-management within a community with a goal of improving and protecting the fishery resources will generate benefits which are fed back into the community. This, in turn, reinforces the participation of the community in fisheries development and management and creates a self-perpetuating, positive feed back loop where the more that community does to improve the management of the resources, the more it benefits.

6.6 The Challenge (Sense of Direction)

The above discussion of integrated coastal zone management, with particular reference to mariculture and ICES suggests a number of questions and concepts which can form an outline framework for the further development of the subject. ICM is being increasingly adopted by nations throughout the world as a means of promoting sustainable development of coastal and near-shore marine resources. ICES is encouraged to adopt the concepts and principles of ICM. These are fully consistent with recent strategies within ICES which seek to integrate environmental and fisheries issues into coherent policies which reflect the interactions within marine ecosystems and between user groups.

The ICM framework is capable of supporting many different forms of activity that concern ICES, and can provide a powerful vehicle for greater integration of science into the natural resource development and management process. The suggestions listed below (Section 6.6.1) indicate steps that ICES (in the form of WGEIM) can take to strengthen the availability and utility of scientific information that will enhance the sustainable and equitable development of mariculture.

In addition to the forms of environmental interactions of mariculture which fall within the expertise of the current membership of WGEIM, there are a number of other related scientific issues which need to be addressed in order to fully inform the ICM process as it applies to mariculture development. Such issues include:

- Effects of escapees
- Interactions with birds
- Interactions with marine mammals
- Interactions with other wild populations
- Issues concerning ballast water

- Concerns arising from poor management of low-lying coastal land
- Salinisation of groundwater and soils
- Introductions and transfers
- Interruptions of coastal processes (alterations to flow and sediment regimes, navigation, etc)
- Interactions with coastal capture fisheries

By ensuring that mariculture interests and interactions are more fully represented in the coastal planning process, it should be possible to avoid or reduce the adverse effects on mariculture resulting from poorly planned and managed coastal development. WGEIM therefore recommend that Mariculture Committee, Marine Habitat Committee (and others as may be appropriate) request that the appropriate Working Groups build on this framework document and develop strategies that will lead to robust assessments of the significance of the interactions of mariculture within their fields of expertise and develop practical guidelines that will appropriately inform the ICM process.

6.6.1 What WGEIM can do to further support and integrate mariculture into ICM

A. Research

Steps to integrate socio-economic and environmental dimensions. The two most important objectives for further environmental research in the coastal zone are:

1. To provide cost-effective, simple monitoring measures to assess all of the major classes of environmental effects, eg organic inputs as from mariculture and pulp and paper mills, municipal sewage, fisheries and agriculture wastes.

2. To provide efficient and simple methods for predictive purposes in the coastal zone, eg models for predicting the holding capacity of fish farm sites or which can match sites and the best resource use there.

3. To develop management measures able to deal with multiple objectives and property rights issues suitable for sustainable management in the coastal zone.

   Every effort should be made to support environmental methods which meet these above criteria and in addition look promising but require further research and development. Such methods include but are not limited to:

1. Characterising sedimentary environments by acoustic devices such as side-scan sonar, multi-beam swath bathymetry, etc.

2. Develop new methods for determining net organic inputs to sediments by measuring carbon, sulphide and redox.

3. Develop simple methods for characterising marine eutrophication.

4. Develop simple methods for monitoring or modelling water movement a specific sites.

5. Develop further the use of GIS in monitoring and predicting the optimal resource uses in the coastal zone.

6. Develop methods to determine the decay rates of organic deposition as a function of hydrography and bioturbation.

There is also a need for regulators and scientists to define what is acceptable as far as environmental impacts are concerned, eg the absence of fauna in the MOM system.

B. There is a need to compare difference ICM procedures, ie undertake some form of "intercalibration" of methodologies

C. It is necessary to develop new economic tools for optimising multiple use of coastal systems and integration of competing activities

Economics is basically husbandry with scarce resources to satisfy "unlimited" human wants. As the coastal zone is a limited resource and in short supply, the allocation between individuals and other user-groups may therefore be treated as any other economic problem where a choice has to be made. Every time a choice is made an opportunity is forfeited, and an opportunity cost is incurred.

The measuring rod for economic analysis is value in terms of money and the valuation of environmental goods has demanded the development of new economic tools for valuation of in particular non-market goods (eg non-commercial recreational facilities). This valuation is a precondition:

- To identify or approximate optimum economic exploitation.
- To demonstrate the economic importance of regulations.
- To evaluate the benefit of regulations by *ex ante* and *ex post* valuation.
- To include the non-market goods (or just quality of life) in national accounting.
- To estimate the damage costs of over-exploitation and/or pollution (the insurance argument).
- To compare non-market and market exploitation of the same resource (the conflicting use problem).

The valuation of non-market goods is to be included together with the more standardised valuation of commercial enterprises in national accounting (input-output tables and econometric models), cost-benefit analysis and bio-economic modelling.

The economic models have as the primary objectives the calculation of the optimal economic return of natural resources. Contrary to other resources under individual property rights regime (private farmland, private forests) the regulation of the coastal zone is a precondition for reaching a state of "optimal economic return". Free access inevitably leads to overexploitation, externalities and loss of economic return. Knowing these trade-offs between competing and conflicting objectives has therefore led to new approaches to the design of regulation in the presence of multiple objectives (Robert W Hahn, A New Approach to the Design of Regulation in the Presence of Multiple Objectives, *Journal of Environmental Economics and Management*, **17**, 195-211 (1989)) and especially their costs to the regulated firms/public.

Socio-economic analysis does not necessarily lead to the best possible economic solution to a planning and management problem, but it offers an input which makes it possible to design cost-efficient regulations and calculate the opportunity costs of second-best solutions.

6.7 Recommendations

The preceding text has been written very much from the point of view of mariculture development and of the environmental interactions of mariculture. WGEIM have recognised that a number of other important issues concerning the interactions of mariculture with other activities in the coastal zone have been addressed only at a broad and strategic level. This is particularly clear from the technical recommendations in section 6.6.1 above. WGEIM recommend that these other issues (see section 6.6 above) are referred to the appropriate ICES Working Groups with a view to these Working Groups contributing their expertise to this document to improve its balance and usefulness.

The science of integrated coastal zone management is relatively new to both ICES and the wider community. WGEIM have indicated how the concepts inherent in ICM can be applied to one specific activity in the near-shore environment, namely mariculture. The document that has been prepared indicates both the complexities of the problems, and routes to solutions. WGEIM recommend that ICES Committees consider whether a similar approach should be applied to other activities in the coastal zone that fall within ICES area of expertise, for example aggregate extraction, artificial reef construction, local fisheries management, fishing gear regulation, macro-algal harvesting, etc.

Appendix 10

INTEGRATED COASTAL MANAGEMENT AND MARICULTURE

Discussion Paper Concerning the Way Forward

Introduction

The role of ICM has been discussed extensively and accepted in principle from previous WGEIM reports as an important tool to facilitate the integration of mariculture in coastal development. The development of mariculture is often the newest user to compete for access to valuable natural resources in the coastal area. This development has been rapid and is expected to continue thereby leading to debate and potential conflicts with other coastal users. ICM is the tool for addressing these potential conflicts so as to manage the environmental impacts in the coastal zone, while optimising the use of the resources.

Although it is recognised that ICM is a socio economic process, the environmental consideration has a paramount role in the decision making process, and therefore will continue to be an important topic of discussion for the WGEIM. An attempt to maintain an information flow from the social, political, economical and ecological contexts of ICM will continue to be made, in order to provide a balanced position on the expansion of mariculture and its interaction with other coastal users.

The WGEIM recognises that mariculture has played and continues to play a pivotal role in the advancement of ICM, mainly because it requires access to natural resources in which property rights is a major constraint in an area (Coastal Zone) that is almost exclusively managed on an (open) Access System. ICM must, therefore, include evaluation of access modality, given that open access will not sustain the expansion of mariculture activities due to the increase competition for environment and space.

As the principles for the integration of mariculture in ICM structures are established, the role of WGEIM will include the review and recommendation of environmental thresholds, monitoring techniques, predictive mathematical models, environmental quality objectives and standards, and other information required for the integration of mariculture in the ICM, within the context of optimising the use of the coastal resource.

Objectives

1. Identify critical environment requirements for efficient and sustainable mariculture activities.
2. Identify the critical output of mariculture activities for the evaluation of its impact on the ecosystem.
3. Identify critical environmental outputs from other CZ users that can interact with mariculture.
4. Evaluate and recommend monitoring methods and techniques.
5. Establish a system for data gathering and analysis for all CZ users.
6. Prepare predictive ecosystem models capable of analysing available data to assist in the management of the CZ.

Identify Critical Environment Requirements for Sustainable Mariculture Activities

- Water characteristics (physical and chemical).
- Access requirements (space, security).
- Benthic characteristics.
- Geomorphological characteristics.
- Interspecific competition (predation, competitor).

Identify the Critical Output of Mariculture Activities for the Evaluation of its Impact on the Ecosystem

- Description of the farmed stock: density, biomass, average size.
- Site characteristics: size, location, physical and chemical characteristics.
- Husbandry practices: feed characteristic, chemical use.

Identify Critical Environmental Outputs from Other CZ Users that can Impact Mariculture

- Organic and chemical pollution from industrial, municipal and commercial transport sources.
- Physical disturbances from commercial transport, fishing activities, space limitation and geomorphological changes (sedimentary habitat).
- Ecosystem disturbances from species introduction (including ballast water), species extinction, disease and abundance changes.

Evaluate and Recommend Monitoring Methods and Techniques

- Physical evaluation methods including the use of sonar for sediment evaluation (hydro-acoustic), water flow and turbulence.
- Chemical evaluation methods.
- Establish a systems for data gathering and analysis for all CZ users.
- Standardisation of data from all users.
- Establish a GIS resource mapping capacity.

Prepare Predictive Ecosystem Models Capable of Analysing Available Data to Assist in the Management of the CZ

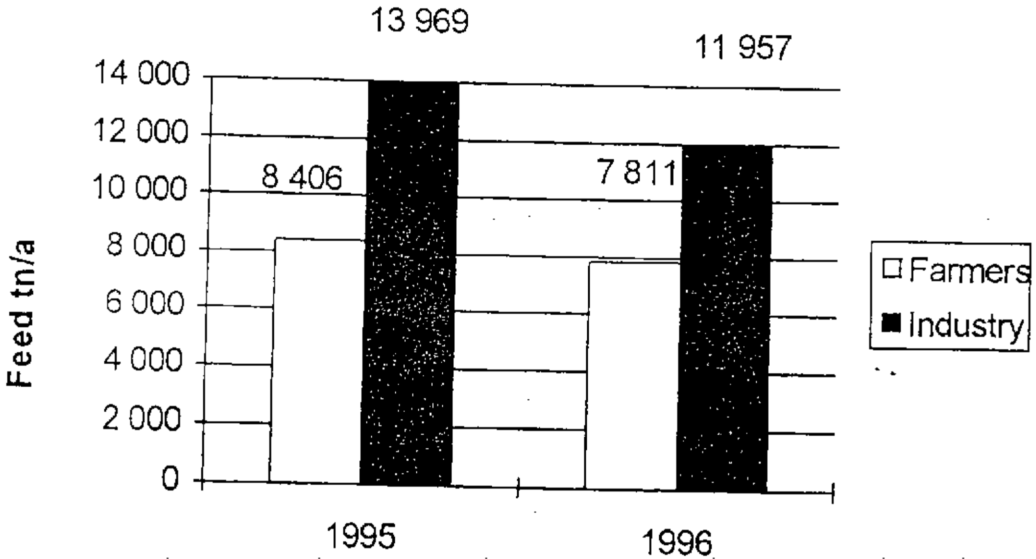
- Development of predictive 2D and 3D mathematical models of fish farming which integrate environmental physics, husbandry practice and environmental interactions.
- Assessment of holding and carrying capacity.

Appendix 11

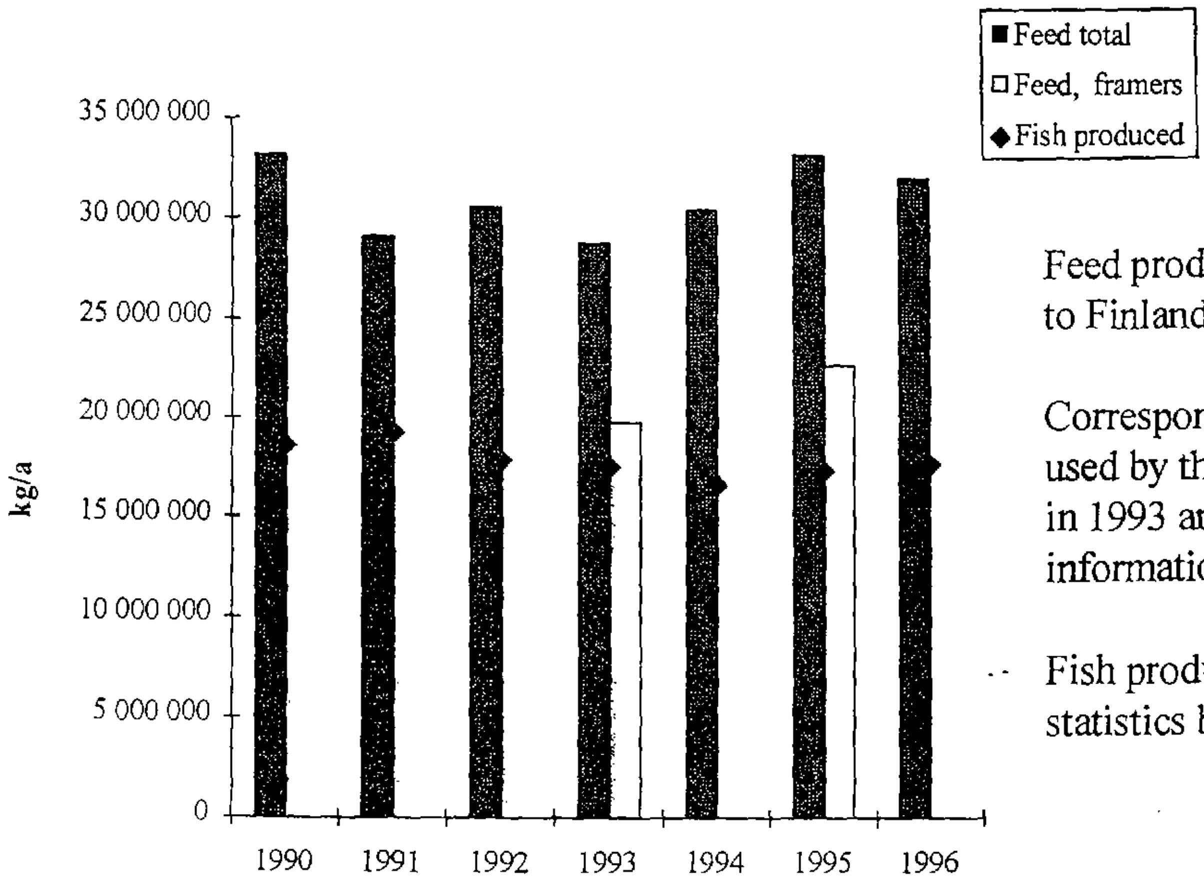
INFORMATION FROM FINLAND ON AQUACULTURE IN THE BALTIC ARCHIPELAGO SEA

Archipelago Sea

- Use of feed according to the information given by the farmer and the corresponding amount of feed sold by the feed manufacturing industry and the importin companys tn/a in 1995 and 1996.



Feed and Production, Finland

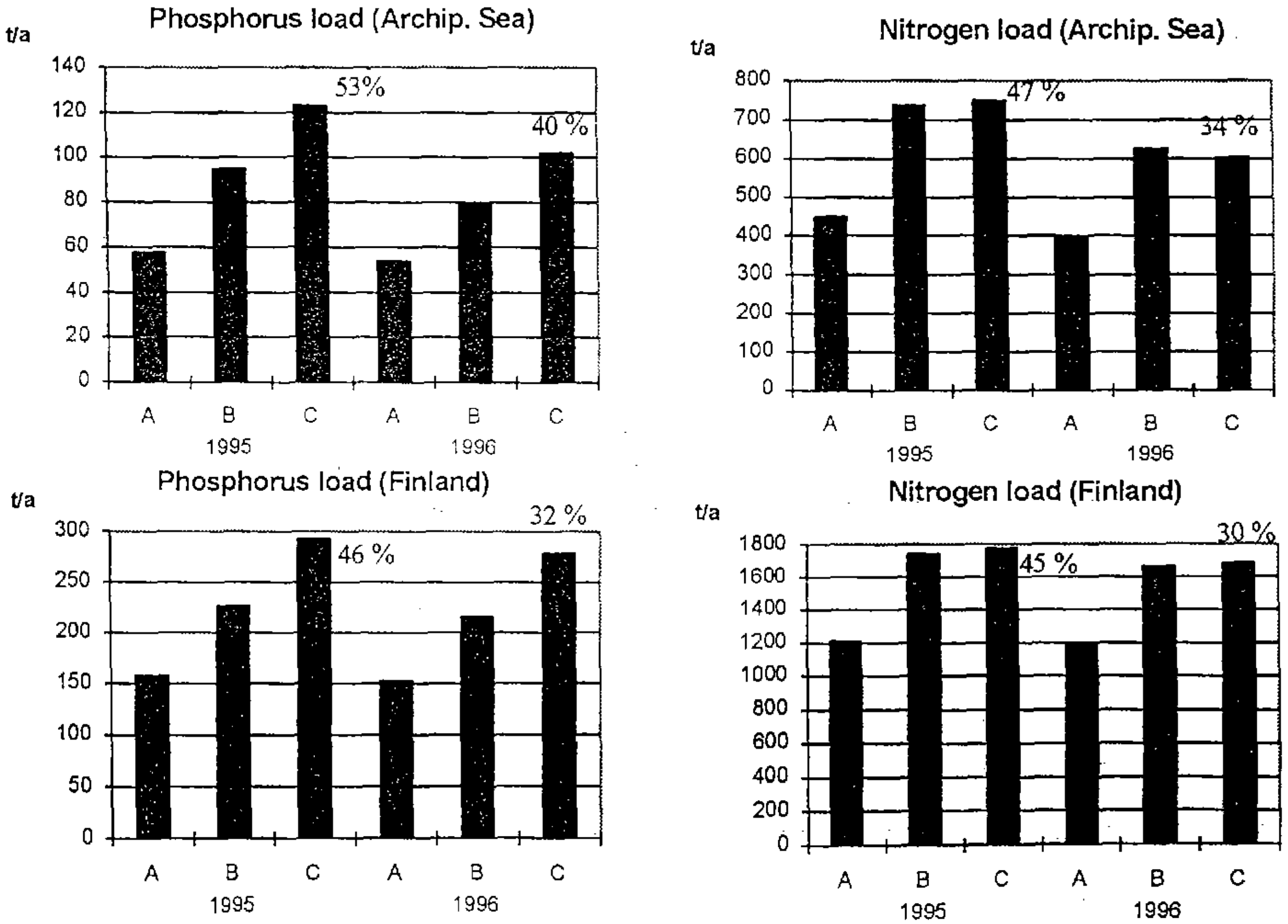


Feed produced in and imported to Finland

Corresponding statistic of feed used by the Finnish fish farmers in 1993 and 1995 according to the information given by the farmers

Fish produced according to the statistics by FGFRI

Nutrient load in 1995 and 1996



A= information given by farmers, B = Calculation with the amount of feed sold by industry, C = as B + Feed P and N analyses

Appendix 12

RESTING CYSTS OF *ALEXANDRIUM* SP., A PSP-PRODUCING DINOFLAGELLATE IN COASTAL SEDIMENT OFF NORTH-EAST SCOTLAND

E MACDONALD AND S HEANEY

Resting Cysts of *Alexandrium* sp., a PSP-producing Dinoflagellate in Coastal Sediments off North East Scotland

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Paralytic Shellfish Poisoning (PSP) in the UK is often attributed to the toxic dinoflagellate *Alexandrium tamarense* (Lebour) Balech. This species produces non-motile resting cysts as part of it's life cycle, which sink from the water column to the sediment where they may remain viable for many years. Initiation of toxic blooms may be closely associated with germination of cysts from "seed beds" into motile cells when environmental conditions are suitable, and these motile cells may provide the inoculum for subsequent blooms. In order to help understand how bloom initiation may develop in different areas, it is important to map the distribution of cysts of potentially toxic dinoflagellates in coastal sediments.

Dinoflagellate resting cysts were examined from sediment sample collected in the Moray Firth and Orkney Islands, both areas where PSP toxins have been detected, during November 1992. Sampling sites were chosen on the basis of previous PSP outbreaks and sediment type. Samples were collected by Day grab or Craib corer depending on sediment type, and were examined in the Laboratory. All dinoflagellate cysts observed were enumerated and recorded.

Total numbers of full cysts ranged from 80 to 2,320 cysts cm^{-3} sediment in the Moray Firth and from 0 to 3,816 cysts cm^{-3} sediment in Orkney. Cysts belonging to the genera *Scrippsiella* Balech ex Loeblich, *Protoperidinium* Bergh and *Spiniferites* Ehrenberg were most commonly represented, whilst *Alexandrium* cysts were found only at four of the 25 stations sampled in the Moray Firth and 10 of 28 sites sampled in Orkney. Highest numbers of *Alexandrium* cysts found were 39 cysts cm^{-3} sediment and 80 cysts cm^{-3} sediment in the Moray Firth and Orkney respectively. In Orkney, when *Alexandrium* cysts were present, they accounted for between 0.2% and 14.3% of the total population of full cysts, and in the Moray Firth, for between 1.3% and 4.2% of the total. Of the 10 Orkney sites where *Alexandrium* cysts were found, only at one site did they account for >7% of the total cyst population. A Concurrent cyst study from the Humber to Aberdeen found highest *Alexandrium* cyst concentrations in the Firth of Forth, another area where PSP toxicity has regularly been detected, with maximum concentration of 400 cysts cm^{-3} sediment. In this area, the proportion of *Alexandrium* in the full cyst population was mainly between two and five except in eight samples when they accounted for >10% of the total (Lewis *et al.*, 1995). Further work is required to establish:

- how cyst germination and subsequent growth of motile cells vary in different areas;
- if blooms result from *in situ* germination or an advected inoculum of motile cells.

Sediment samples from the north and west parts of the Scottish coast have subsequently been collected and examined for dinoflagellate cysts. These data will be added to the east coast data to produce distributions of species composition and abundance in Scottish coastal waters. The Orkney area has been re-surveyed recently, and these data will be used to examine any changes in cyst distributions.

Reference

Lewis, J., Higman, W. and Keunstner, S. 1995. Occurrence of *Alexandrium* sp. cysts in sediments from the north east coast of Britain. In: *Harmful Algal Blooms*, P. Lassus, G. Arzul, E. Erard, P. Gentien and C. Marcaillou (eds). Lavoisier, Paris, pp. 175-180.

Appendix 13

RECOMMENDATIONS

WGEIM 1999 Recommendations

The recommendations are numbered according to the section of the report from which they are derived. In many cases, additional explanatory information can be found within the relevant Sections.

5. WGEIM invite the Mariculture Committee to accept the following general expression of the proposed areas of activity of WGEIM, within the general Objectives of Mariculture Committee to increase mariculture production and to encourage sustainable development of mariculture. Individual Terms of Reference would be viewed within this general framework.

A. Collation of Information on Production Patterns

This information is not currently available to ICES through any other route and describes the basic structure of resource utilisation on which the rest of the work of WGEIM (and MC) must be based.

B. Meeting Specific Requests for Information From ICES or Other International Bodies

The WG recognise this as a fundamental aspect of the work of ICES as a whole.

C. Review of Information on Technological Change in Mariculture, Including the Utilisation of New Species, with Particular Emphasis on the Consequences for Production and the Environment

This item meets the need to have adequate awareness in these areas of implications of current and likely new developments in the mariculture industries.

D. Review of New Research and Monitoring Programmes

The emphasis in this task would be making accessible to member countries the products of completed programmes which might not be readily available (eg in the Grey literature), and the review of the trends and directions in research and monitoring priorities to inform MC and member countries of developments in scientific opportunities and activities, and public attitudes and concerns.

E. Review of Monitoring Activities

The purpose of this item is to ensure awareness of new environmental concerns, new monitoring targets and new monitoring methods as an aid to ensuring that mariculture is undertaken in sustainable ways.

F. Review Issues of Sustainability in Mariculture, Including Interactions Between Mariculture and Other Users of Resources in the Coastal Zone

The aim in this item is again to support the development of mariculture in ecologically (in a broad sense to include other human activities) sustainable manner. One of the approaches that would be to incorporate mariculture in ICM structures.

6. WGEIM invite Mariculture Committee to accept the following proposal for a plan to collate information on the effects of mariculture activities in the Baltic Sea.

WGEIM note that they cannot address all the issues that arise from this request, and invite Mariculture Committee to direct questions relating to the effects of re-stocking (see following table) to appropriate Working Groups.

WGEIM recommend that it is also necessary to take a range of socio-economic issues into account in coming to a balanced view of the consequences of mariculture in the Baltic Sea, and recommended that Mariculture Committee put mechanisms in place whereby the scope of the information to be included could be expanded beyond environmental matters.

Effects of Mariculture in the Baltic Sea - A Plan

Issue	Approach	Responsible person
Location, scale and nature of fish farming.	Approach national members of Mariculture Committee.	Ian Davies
Nutrient releases direct o sea water.	Estimate from current production levels and reasonable values for FCR, and place in context with other inputs of nutrients (data from HELCOM PLC3 programme).	Anders Alanärä, using data from Ian Davies on production levels. Ed Black to assist. Ian Davies to approach HELCOM re: PLC3.
Nutrient releases in fresh water.	Estimate from current production levels (FAO database) and reasonable values for FCR. Make allowances for the trapping of solid waste in lakes, and for losses of nutrients in estuaries, and place in context with other inputs of nutrients (data from HELCOM PLC3 programme).	Use method from Ackefors and Enell paper. Anders Alanärä and Timo Makinen, probably with assistance from Hans Ackefors.
Effects of re-stocking on: Stock size Population genetics Disease Other fish stocks	Seek advice from other ICES WG, or from the Fisheries Board of Sweden.	Ian Davies to approach ICES for advice.
Use and discharge of chemicals.	Data on medicines use is available centrally in Sweden. Antifoulants - Contact fish farms direct for information.	Anders Alanärä to deal with data for Sweden. Ian Davies to approach Timu Makinen about Finland. Anders Alanärä and Timu Makinen to complete the task.
Scale of impact on the sea bed.	Literature review and estimation by analogy with other marine sites.	Ian Davies to approach Timu Makinen as most of the work has been carried out at Finnish sites.
Transfer of diseases from farmed to wild fish.	Results will be available from Anders Alanärä's project.	Anders Alanärä

Issue	Approach	Responsible person
Escapees: From Baltic farms From farms outside the Baltic	Results will be available from Anders Alanärä's project. Other information from NASCO.	Anders Alanärä Ed Black
Use of Baltic herring to make fish meal (protein) for the manufacture of fish feed. Effects on nutrient balance, eutrophication, other fisheries, etc.	Results will be available from Anders Alanärä's project.	Anders Alanärä
Effects on marine mammals.	Approach Chairman of ICES WGMMH.	Ian Davies
Effects on birds.	Approach Chairman of relevant ICES WG.	Ian Davies

9. WGEIM recommends that Mariculture Committee include in its forward plan an ASC Theme Session on the linking of modelling of processes leading to effects on the benthic environment, and the temporal patterns of change (degradation and recovery) of the benthic fauna.

13. WGEIM recommends that Mariculture Committee supports the drafting of a report "Towards sustainability in mariculture in the ICES area", and allocates to the appropriate Working Groups responsibility for completion of sections outside the area of responsibility of WGEIM.

Report Outline: Working Title: "Towards Sustainability in Mariculture in the ICES Area"

Topic area	Responsible persons	ICES group
Environmental - Fish.	Antoine Dosdat Ian Davies	WGEIM
Environmental - Shellfish.	Maurice Heral	WGEIM
Inter-specific interactions. The trophic argument (cf Naylor *et al.*). Fish meal and oil utilisation.	Thomàs Landry (+ Harald Rosenthal)	WGEIM
Interactions with other activities, emphasising ecological matters, and encompassing procedures such as LENKA and MOMS.	Peter Burbridge Dave Wildish	WGEIM
Economic aspects Socio-economic aspects.	Eva Roth Bernard Glaesser? Several members of the WG to seek out national reports.	WGEIM

Topic area	Responsible persons	ICES group
Coastal management issues, including: ICM Resource management structures Access Property rights Opportunity costs Time averaged benefits, etc	Eva Roth Peter Burbridge Bernard Glaesser? Ed Black and others	WGEIM
Genetic matters including escapees.		MC to refer to appropriate WG
Disease aspects, including transfer to and from wild populations.		MC to refer to appropriate WG
Other interactions with wild stocks, including the sea lice/sea trout issue.		MC to refer to appropriate WG
Other issues as may be identified by MC.		MC to refer to appropriate WG

14. It is recommended that WGEIM meets for five days in the first fortnight of March 2000 in Aberdeen, Scotland to undertake the following tasks. The tasks are structured according to the general areas of work developed in Section 5 of this report.

1. **Collation of information on production patterns**

Justification: This information is not currently available to ICES through any other route and describes the basic structure of resource utilisation on which the rest of the work of WGEIM (and MC) must be based.

1a. **Specific task: to receive and review country production reports from WG members**

Justification: See above.

2. **Meet specific requests for information from ICES or other international bodies**

This is a fundamental aspect of the work of ICES as a whole.

2a. **Specific task: to complete the preparation of a contribution to the HELCOM Fourth Periodic Assessment of the State of the Marine Environment of the Baltic Sea on the effects of mariculture activities in the Baltic Sea**

Justification: This is required to meet a request from HELCOM [HELCOM 1999/3].

3. **Review of information on technological change in mariculture, including the utilisation of new species, with particular emphasis on the consequences for production and the environment**

This item meets the need to have adequate awareness in these areas of implications of current and likely new developments in the mariculture industries.

3a. **Specific task: to discuss and assess progress made in the performance, environmental compatibility and economic viability of modern recirculation technology, with an emphasis on salt water systems**

Justification: Most of the attempts to utilise recirculation systems have been in fresh water and expansion to salt water has until recently been a research activity (other than in shellfish hatcheries). Re-circulation systems offer potential benefits in independence of the water resource, the ability to treat effluents to a high standard, reduced risk of escapes of animals or disease, and a greater internalisation of the environmental cost. It is timely to review the development of these technologies and identify opportunities for their utilisation and research requirements to improve their applicability.

3b. **Specific task: to compile information on the actual and potential environmental impact of halibut cultivation, including comparison with the recognised impacts of salmon mariculture**

Justification: Production of halibut has now reached several hundred tonnes and is concentrated in Norway and Scotland. Juvenile production in these countries now approaches 500,000 per annum. It is timely to review the technological and environmental aspects of halibut farming to aid regulators in the incorporation of halibut farming into the generality of mariculture and into coastal zone management structures.

3c. **Specific task: to review the ecological aspects of the report of the ICES/EU Symposium on artificial reefs to be held in summer 1999**

The presence of reefs may have a range of effects on the ecosystem beyond the target effects of increasing the availability of desirable species. The effects may have similarities to those induced by mariculture structures such as cage groups, shellfish landlines, rafts, etc. The comparison of the two areas of study may open new perspectives.

3d. **Specific task: to review the current state of the art in the environmental consequences of the control of sea lice in salmon cultivation**

Justification: Sea lice are probably now the most significant health problem in farmed salmon. Control of sea lice often requires the use of therapeutic chemicals which are subsequently released to the environment and have given rise to considerable scientific and public concern. Approaches to sea lice control, and attitudes over the acceptability of treatment chemicals differ between countries and are changing rapidly. This has considerable potential consequences for both salmon farming and for the environment.

3d: **Specific task: to review the success and usefulness of closed systems in mariculture**

Justification: Closed systems are normally rather expensive to install and operate, but may have application in particularly sensitive areas, and they could offer the potential for the confinement and treating of effluents and greater control of the cultivation environment. Increasing concern over environmental consequences of mariculture may lead towards greater utilisation of closed systems in the medium to long term.

4. **Review of new research and monitoring programmes**

The emphasis in this task would be making accessible to member countries the products of completed programmes which might not be readily available (eg in the Grey literature), and the review of the trends and directions in research and monitoring priorities to inform MC and member countries of developments in scientific opportunities and activities, and public attitudes and concerns.

4a. **Specific task: to review the proceedings of the 1999 ICES Symposium on environmental effects of mariculture**

Justification: This major Symposium has been organised by members of WGEIM and should provide indications of important new developments and provide a basis for the specification of new tasks for the WG.

5. **Review of monitoring activities**

The purpose of this item is to ensure awareness of new environmental concerns, new monitoring targets and new monitoring methods as an aid to ensuring that mariculture is undertaken in sustainable ways.

5a **Specific task: to review developments in the capability to model, predict and monitor the effects of mariculture on the sea bed**

Justification: Alteration of the benthic ecosystem is a clear result of mariculture in many locations and forms the basis of some regulatory procedures. Reliable predictive methods, and efficient monitoring techniques linked to expressions of acceptable degrees of change are therefore essential elements in the assessment of the sustainability of mariculture.

5b. **Specific task: to review the availability to the scientific and regulatory community of mathematical models related to environmental interactions of mariculture**

Justification: Site assessment, regulation, monitoring and research are increasingly dependent upon mathematical models for their design or data analysis. The availability of reliable and robust models to the relevant user communities is important for the progress of these subjects.

6. **Review issues of sustainability in mariculture, including interactions between mariculture and other users of resources in the coastal zone**

The aim in this item is again to support the development of mariculture in ecologically (in a broad sense to include other human activities) sustainable manner. One of the approaches that would be to incorporate mariculture in ICM structures.

6a **Specific task: to collate contributions and prepare a report with the working title of "Towards sustainability in mariculture in the ICES area"**

Justification: There is increasing expression of concern over the long term consequences and wider sustainability of intensive fish and (to a lesser extent) shellfish cultivation in marine waters. A critical scientific review would be a valuable contribution to the debate. The report will emphasise ecological aspects of the question. Completion of the task would require that the question of sustainability of mariculture is addressed by other ICES WGs, covering such aspects as genetics (escapes and Genetically Modified Organisms), disease, and other interactions with wild stocks (eg the sea trout/salmon/sea lice issue).

6b. **Specific task: to review the current state of the art of the application of Environmental Impact Assessment and Environmental Impact Statements to mariculture**

Justification: Recent changes in EU legislation have increased the requirements for formal EIA and EIS activities in relation to mariculture. Parallel changes have occurred in national legislation, and in some countries the mariculture industries have responded in a pro-active way to define methodologies and the content of Statements and Assessment documents. Such procedures can contribute directly to the ICM process and to sustainability and are likely to become a more important aspect of the regulation of mariculture.