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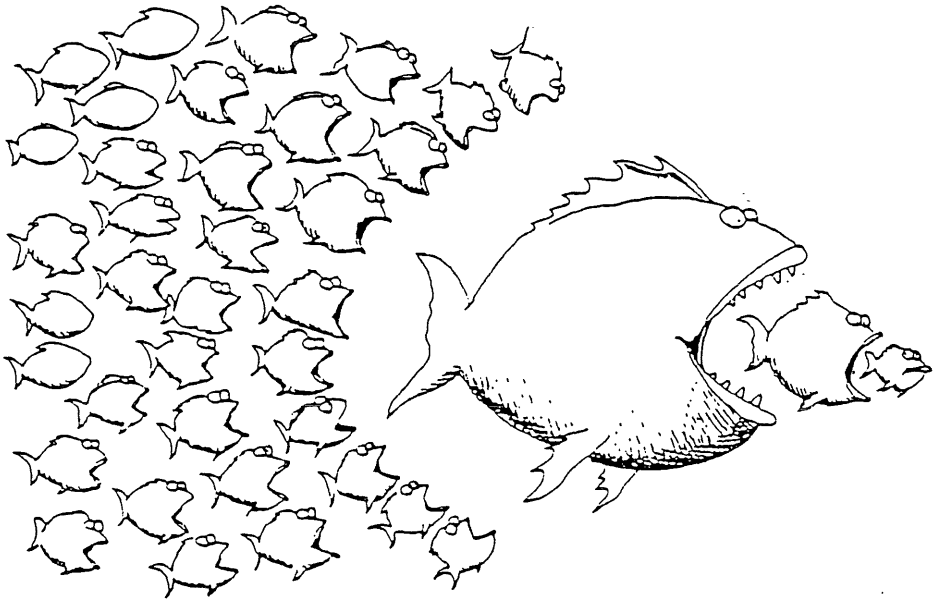
Report of the Working Group on "Environmental Interaction of Mariculture"

IFREMER, Nantes, France
March 25-29th 1996



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

Summary

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The ICES Working Group on the Environmental Interactions of Mariculture met for four days (26-29. March, 1996) in Nantes, France. A 1 day excursion in a coastal wetland area followed the meeting, where drastic changes in the socio-economic conditions occurred with mariculture developments showing clear interactions with other resource users. National reports tabled at the meeting clearly showed that growth of the industry is continuing in some contries while costal aquaculture production is stable in several member states or slightly declining on others.

Production efficiency has increased in almost all areas with regard to finfish as wholesale prices dropped particularly for salmonids. The working group considered the use of chemicals in mariculture, in particular the development of drug resistance in in fish pathogens, the possible spread of drug resistant plasmids to human pathogens, and the presence of antimicrobials in wild fish. Extensive discussion focussed on ??

Technologies today are diverse in response to the need for improved competetiveness. Production cycles have been shortened. Sea bass and sea bream cultivtion has rapidly expanded in the Mediterranean with Greece the fastest growing industry. The working group then the use of chemicals in mariculture, in particular contaminents in sediments under fish farms and their biotoxicity. A major task of the WG focussed on planning and management issues with mariculture as a legitimate competitive partner among the resource users of the coastal zone. Environmental issues were considered also in light of the EU ??on the development of environmental pressure indicators. Concerns were expressed on the lack of clear definitions and guidelines for an appropriate use of biodiversity indicators as tools in environmental management and futur discussions on the subject are suggested. New projects on environmental interactions have been listed.

1. INTRODUCTION

The 1996 meeting of the ICES Working Group on the Environmental Interactions of Mariculture was held in Nantes, France (26-29. March, 1996) at the offices of IFREMER. The Working Group was welcommed by the Director of the Institute.

1.1 There were 25 participants present, representing 8 member countries. Severall invited guests from France provided advice on specific agenda items and introduced the case studies within the coastal wetlands of Nantes which were visited during the field trip. Table in appendix I provides a listing of participants, their affiliation, as far as available, their phone, fax and e-mail contacts. Appendix 2 provides the full list of working group members as nominated by the respective country delegates.

1.2. Working Group Recommendations

1.2.1 The 1996 TORs (WG Recommendations)

The TORs for the 1996 Working Group meeting as approved by the Council at the 1995 Annual Meeting are published under No. 2:33. They are as follows:

The Working Group on Environmental Interactions of Mariculture (Chairman: Prof. H. Rosenthal, Germany) will meet in Nantes, France from 25-28 March 1996 to:

(a) update the catalogue of completed, ongoing, and new research progrmmes on environmental interactions and related issues related to mariculture in ICES member countries and identifies major research priorities;

(b) review progress in analyzing contaminant residues in sediments under and near fish farms (e.g. antimicrobials) and identifying their bioactivity in order to provide advice on adequate monitoring strategies and interpretation of monitoring data on residues with respect to their wider ecological implications in consultation with the Working Group on Statistical Aspects of Environmental Monitoring;

(c) analyze, document, and disseminate information of the status of mariculture, existing trends and future innovations in the culture of different species and concomitant resource requirements and implications for planning and management, with attention to trends in other coastal resources development and utilization;

(d) continue to study the interactions of mariculture with other users of the coastal resources and analyze the outcome of the proposed Workshops and Study Groups in order to prepare guidelines for the management of mariculture within the larger context of an Integrated Coastal Zone Management Programme (ICZMP);

e) examine the papers submitted to the Mariculture Committee on coastal zone management through the Committee Special Topic, Workshops, and the ICES Theme Session "R" in 1995 and coordinate the preparation of a projected ICES Cooperative Research Report on the subject of "Mariculture Interactions in the Coastal Zone";

(f) consider potential contributions to the 1997 ICES/NASCO Symposium on the "Interactions between Salmon Culture and Wild Stocks of Atlantic Salmon: The Scientific and Management Issues";

(g) consider the recommendations from the Workshops in 1995 on Coastal Area Planning and Modelling Environmental Interactions within the Working Group programme.

1.2.2 Status of work on the 1994 Working Group Recommendations

Since the last Working Group Meeting, two years have passed. At the time the Working Group recommended :

(1) - that a study group should be formed to evaluate recent development in land-based and sea-based salmon farming technology. The group should identify various opportunities for the development of rearing strategies, including technical, economical and safety aspects. The composition of the group should include manufacturing specialists, insurance experts, and biologists.
Status of work: Several scenarios were discussed during the meeting and intersessionally, including options for offshore farming. However, off-shore trials

are mainly based on a trial and error approaches with little hope for a rapid breakthrough. Criteria for the development of technology standards for various systems which address in particular the minimization of technical failures (e.g. cage losses, net destruction from predators,etc.) would greatly assist in minimizing ecological risks associated with escaped fish and diseases. Such criteria are not yet available.

(2) - that ICES Member Countries support the preparation of a list of models currently used in mariculture along with detailed descriptions, scope of applicability, and availability. The list will be prepared intersessionally by individuals selected by the parent Committee at the next Statutory Meeting.
Status of work: The various models presently under development were briefly considered while the results of the 1995 workshop were presented both at the Statutory Meeting in 1995 and during the 1996 Working Group meeting. A editorial committee has been formed to review and summarize existing models, including shellfish farming.

(3) - that ICES Member States organize a workshop on "Modelling environmental interactions of mariculture" to be chaired by individuals selected by the parent Committee at the next Statutory Meeting and to be held during 1995.
Status of work: The workshop was held in Dartmouth , Nova Scotia, Canada in 1995. The results will be incorporated into the proposed Cooperative Research Report on the subject.

(4) - that consideration be given to alternative oral matrices by which medication might be presented to fish to improve bioavailability and thus improve efficiency and reduce the amount of medication passing into the environment
Status of work: The problems and implications of the poor bioactivity and bio-availability has been discussed on the basis of recent literature and expertise of WG members. The outcome is summarized under item 3.2.

(5) - that the 1994 TOR (d) (to assemble and compile, intersessionally, information on ongoing monitoring programmes in each country related to assessment of the impacts and interactions of mariculture with the view to its publication in the ICES Cooperative Research Reports series be changed and the report and comments prepared at the 1994 meeting be attached as appendices to the existing Draft Technical Report on "Management of the Envrionemtal Impacts of Mariculture".
Status of work: Not much progress has been made on the subject. Firstly, membership of the Working Group has changed, leaving a gap in monitoring expertise; secondly, the GESAMP Working Party 31 has prepared a document on monitoring issues for coastal aquaculture, describing a number of scenarios. This document will be soon available; thirdly, rapid changes in monitoring strategies still occur in member countries in conjunction with the development of new culture strategies. The issue will therefore be revisted at the next meeting.

(6) - that in response to TOR 94/(h) the proposed special session on "Coastal Zone Management" be built around papers already submitted and invited speakers (see listing under 13). The session should be co-chaired by the Chairman of the Mariculture Committee (Dr. Cook, Canada), Dr Peter Burbridge (Scotland, as

expert on CZM) and Dr. H. Rosenthal, (Germany). Additional expertise should be invited as proposed by the Chairman of the Mariculture Committee.
Status of work: The session was held at the 1995 Annual Science Conference with a report given on the outcome at the 1995 Annual Science Conference of ICES in Aarhus, Denmark.

(7) - a Study Group on **Coastal Zone Management** be established to meet in early 1995 for 3 days under the Chairmanship of Dr. Peter Burbridge (Scotland). Such a group should be charged with exploring ways of promoting the integration of mariculture into Coastal Zone Management initiatives and should include the required expertise from neighbouring disciplines not yet available within the fisheries and oceanography- oriented scientific community of ICES.
Status: This recommendation was not approved by the Council. During the intersessional period members tried to participate in meetings of other national and international organisations dealing with coastal zone issues in order to gain knowledge and keep abreast with ongoing developments in this area.

(8) - The GESAMP Working Party on Coastal Aquaculture Impact be invited to participate in the activities of the WGEIM, including the Special Session of the Mariculture Committee at the 1994 Statutory Meeting of ICES, the proposed Modelling Workshop and the Meeting of the proposed Study Group on Coastal Zone Management.
Justification: GESAMP is about to prepare within its Working Party on Coastal Aquaculture Impact a document on coastal zone planning issues with main emphases on oceanographic and biological aspects and the Working Group recommends a coordination of effort, placing the emphasis on other areas of central focus such as resource use conflicts.
Status: Due to financial constraints the Chairman of the GESAMP Working Group was unable to attend. However, contacts have been maintained by correspondense.

The Technical Report on Chemical usage in Mariculture has been finalized during the intersessional period and was published as Cooperative Research Report No. 202 in 1995.

The Working Group continued its work in 1995 by correspondance and the Chairman collected material which was presented at the 1996 Working Group meeting. It is incorporated into this report..

2. Summary of Country Reports and Research Priorities

2.1 Trends in Production and development of Production Systems

In most ICES member states in which mariculture has developed, extensive investigations have been conducted to safeguard both, the environment and the industry. Because of the fact that over the past decade environmental concerns have been expressed at an early date, the extent of the environmental problems of mariculture have been identified in many studies, and the appropriate management and mitigation

strategies for a sustainable developement of the industry were suggested. These efforts continue with an impressive number of new projects being implemented in several member states. Despite these efforts, public concern has risen, and in response an increasing number of inquiries are notable in most member countries, demanding even tighter administrative control measures to restrict mariculture in coastal areas. Considering the extent to which environmental assessment statements are prepared, in some countries several agencies not previously involved in the assessment begin to discover the issue and start re-inventing the wheel. This has necessitated a number of repetitive studies in some areas while in most countries the scientific effort focus on the following subject areas (see also Appendix 3 and 4; new- and ongoing projects):

The trend towards interaction studies rather than "impact" studies with larger emphasis on coastal zone management issues is obvious. Additionally, much progress has been made on the evaluation of use of chemicals while also the output of mariculture has seen varied trends in different member countries. While Norway experienced a substantial gain in salmon production (despite several constraints faced by the industry), the salmon industry also gained notably in Scotland and Canada while in other countries the production rise was modest or non-existent.

2.2 Evaluation of progress in research on environmental issues

Environmental assessment methodologies for any mariculture activity have made substantial advances in several areas, in particular in finfish culture where modelling various farming activities has been greatly improved. New simulation models on benthic deposition under cage farms have been presented. Models on dispersion and excretion based on metabolic rates of fish and flux models for fjords and largely enclosed basins have become available. For shellfish a number of modelling tools have also been developed that try to verify carrying capacity and predict production potential while providing methods for input assessment (including factors such as deposition pattern, resuspension of solids, metabolic rate, phytoplankton availability etc.) (see also chapter xxx3.3).

Most of the issues found in the country reports have been considered by subgroup 2 and incorporated in section 3 of this report.

2.3 Management and ICZM issues

The MOM concept, which was presented in the 1994 WG report, integrates environmental quality standards (EQS), a monitoring programme and a simulation model in one management system for marine fish farm sites. The system has been further developed, and consensus has been reached regarding zones of influence, associated monitoring programs and environmental quality standards. The impact area surrounding a fish farm has been divided into three zones. For the Local Impact Zone (LIZ), where the greater part of the large particles settles, A-, B- and C-investigation are recommended (see below) and special EQS's are applied. The Intermediate Impact Zone (IIZ) outside the LIZ is impacted by small particles the fish cages (ground feed pellets and excrements) and the outmost Remote Impact Zone (RIZ) is mainly

influenced by dissolved nutrients. The IIZ and the RIZ are monitored through the C-investigation, and general EQS's set by the State Pollution Control Agency are applied. This monitoring is performed by experts. In addition the RIZ is monitored through a governmental monitoring programme. The model can simulate maximum fish production and critical organic load (maximum sedimentation rate) at a site, together with the effects on secchi depth and oxygen consumption and concentration in deep water in the recipient, the effluents of the farm, fish growth and wave statistics. A module for simulation of water quality in the fish pens is yet to be developed.

The monitoring program consists of three types of investigation performed at different intervals in the various impact zones . The A-investigation is part of an internal control carried out by the fish farmer and the C-investigation is a benthic fauna investigation performed by experts. The B-investigation is restricted to the LIZ and includes three groups of parameters: 1) the presence or absence of fauna, 2) pH and redox measurements and 3) a group of qualitatative parameters like gas bubbles, smell etc. At the end of the investigation an index is calculated for each group of parameters by special procedures. The site condition is finally determined by considering the indexes from the three groups in a fashion where, in case of discrepancies between the results from the groups, group 1 is given priority over group 2 which has priority over group 3.

In 1996 MOM will be tested at 25 fish farms in 4 regions in Norway, and the system is expected to be included in the regulatory framework for Norwegian mariculture in 1997.

3. Consideration of the 1996 Terms of References

During the Meeting several subgroups were formed and met during the Working Group meeting to address specifc TORs. The membership of these subgroups was as follows:

Subgroup 1 (Contaminent residues)
membership: Ian Davies, Harald Rosenthal, Guillaume Blanc; by correspondance Peter Smith and David Aldermann
The group reviewed progress in analysing contaminant residues in sediments under and near cage farms (e.g. antimicrobials) and identifying their bioactivity in order to provide advice on adequate monitoring strategies and interpretation of monitoring data on residues with respect to their wider ecological implications in consultation with the Working Group on Statistical Aspects of Environmental Monitoring

Subgroup 2 (Status and Trends in mariculture, innovations and resource requirements)
membership: Robert Cook (chairman), Jaqueline Doyle, Gunnar Aneer, Arne Ervik, Alain Febvre, Susan Utting
The group analysed, and documented information of the status of mariculture, existing trends and future innovations in the culture of different species and concomitant

resource requirements and implications for planning and management, with due attention to trends in other coastal resources development and utilisation

Subgroup 3 (Interactions of mariculture with the environment and with other resource users)
membership: Edward Black (Chairman), Peter Burbridge, Bernhard Glaeser, Mark Kempf, Håkon Kryvi, Eva Roth,
The group considered " the interactions of mariculture with other users of the coastal resources and analyse the outcome of the proposed Workshop and Study Groups in order to prepare guidelines for the management of mariculture within the larger context of an Integrated Coastal Zone Management Programme (ICZMP)"

Subgroup 4 (Modelling environmental interactions)
membership: Bill Silvert (Chairman), Maurice Heral, Jan Aure, Antoine Dosdat
The subgroup revisited the material assembled during the previous working group meeting and also considered the material presented at the Halifax workshop while preparing an outline of a table of content for a cooperative research report on the subject.

3.1 Updating of catalogue on completed, ongoing and new projects in ICES member states

Numerous projects have been initiated since 1994 and it was decided to list these in a new table while updating the older projects has only partly been achieved. With time it seems to be difficult to trace the individual projects as in several cases working group members do not always have direct contacts to project-leaders and some of these may have changed jobs since completion of the projects without giving final notice on the outcome of the project to WG members. While Appendix 3 will be maintained for reasons of continuity, it seems advisable to start the new listing country by country. It is intended to start for each fiscal year a new listing which will be followed through separately until projects are terminated. The new listing starts this year with Norway.

3.2. Review on contaminants in sediments of fish farms and biotoxicity

3.2.1 Comments on Cooperative Research Report (CRR) 202

Since the 1994 meeting of WGEIM, a technical report concerning „Chemicals used in Mariculture" has been published in the ICES Cooperative Research Report series (no 202). The report was prepared by members of the WG during the 1992 and 1994 meetings, and through intersessional work. It provides information on the chemical and biological properties of a range of substances used in mariculture in the ICES at the time, and extensive bibliographic lists. However, it was notable that in many cases there was relatively little information on the environmental implications of the use of the substances, and their subsequent release to the environment, either directly with waste feed or treatment baths, or after excretion/depuration from treated fish.

Of the various types of contaminant chemicals used in mariculture, two primary groups which have the potential to give rise to measurable concentrations in sea bed

sediments in or around fish farms are antimicrobial compounds and chemicals used for the control of external or internal parasites.

3.2.2 Antimicrobial compounds and regulatory aspects

As indicated in ICES CRR 202, there are a number of antimicrobial chemicals authorised for use in the ICES area. The specific list available for use varies from country to country and also according to diseases being controlled and the particular situation concerning marketing authorisation in each country. The main application of antimicrobials in Scottish salmon farming is as a component of the measures available to control furunculosis, whereas in France the main application is against Vibriosis in farmed sea trout. However, in general, currently available substances include:

Oxytetracyline
Oxolinic acid
Potentiated sulphonamides (trimeoprim/sulphdiazine)
Amoxycillin
Flumequine

Not all compounds are authorised in all countries, for example only the first 4 are authorised in the UK, and the 5 in Ireland. The list is undergoing continuous change as compounds become unavailable (see below) and "new" compounds are considered or brought forward for licensing. Chloramphenicol, which was permitted in a few situations in aquaculture until recently, has been placed on Annex IV of EC Regulation 2377/90. Compounds in that Annex are prohibited from use with food animal species.

It is likely that other compounds, eg oxolinic acid, will cease to become available for food animals in the not too distant future. This is because they are unlikely to have an MRL set and therefore will have to be withdrawn. Currently the termination date for such compounds is 31 December 1996, but the EU Commission has under consideration an extension of this, since many valuable compounds in other areas of veterinary medicine would also cease to be available for use in food species because of the amount of data needed to gain an MRL and the shortness of the available time left.

There is continuing pressure from the mariculture industries for additional substances to be added to the range of antimicrobial compounds that can be prescribed for use on farmed fish. Previous experience of the serious consequences of multiple resistant disease strains has made the industries very conscious of the need to continuously seek for new substances to take the place of those that become unavailable, for example for regulatory reasons, or through lack of efficacy. In the UK for example, antibiotics (and other measures such as vaccination and husbandry techniques) are providing adequate control of furunculosis and vibriosis in salmon, but there is no effective authorised treatment for BKD in salmon or trout, and amoxycillin is really the only effective treatment for rainbow trout fry syndrome (cold water disease), and reports of resistance are now appearing. Research and field trials are in hand leading towards the authorisation of new compounds for application in mariculture. For example, in France, two new antimicrobial compounds are undergoing field trials, and one new

compound in the UK, although it is not clear when/if marketing authorisations will be granted.

3.2.3 Toxicological and Ecotoxicological aspects of antimicrobials

The process of assessment of the potential environmental impact of fish medicines is included in the authorisation procedure. The outline of the UK approach to this was described in the 1994 report of WGEIM. Ecotoxicological information of various types is required to allow estimation of the hazards involved in the use of the medicine, and subsequently to allow derivation of appropriate controls to ensure that any risk to the environment is minimised. In addition to fundamental physico-chemical properties of the medicine, information is required on toxicity to an appropriate range of marine organisms, and information on the pathways of the substance through the environment, its persistence and potential for bioaccumulation, etc. In the case of medicines whose main toxic action is directed at macro-organisms, the prescribed procedures provide an overall indication of likely risks. However, in the case of compounds which primarily affect microrganisms, and may be relatively innocuous towards larger organisms, the description of hazards and assessment of risk enters fields of greater uncertainty.

Clear examples of compounds in this category are several of the antimicrobial agents currently in use or under trial. Typically, they are rather insoluble in water and are administered as feed additives. Such compounds may enter the sediment associated with waste feed, in faeces, or through adsorbtion onto other particulate material. A number of causes for concern have been expressed over the presence of antimicrobials in marine environments at fish farms. The main concerns have been summarised (Smith et al, 1994; Davies et al, 1996) as:

1. Development of drug resistance in fish pathogens
2. Spread of drug resistance plasmids to human pathogens
3. Transfer of resistant pathogens from fish farming to humans
4. Presence of antimicrobials in wild fish
5. Impact of antimicrobials in sediment on:
    a) the rates of microbial processes
    b) the composition of bacterial populations
    c) the relative size of the resistant sub-population of bacteria

Point 4 above is well established from observations in Norway, and is assessed/controlled from a public health viewpoint, and will not be discussed further. Point 1 is also well established, but the relative importance of antimicrobial compounds in sediments (as opposed to the same compounds in fish) is not clear, although it is likely that processes in sediments are of lesser importance than those in the farmed fish themselves.

Points 2 and 3, relating to the therapy of disease in humans and the development and transfer of resistant pathogens to man has been discussed at length by Smith et al (1994). They conclude that data to assess the risks are incomplete, but that the risk to

human therapy is small, and that the contribution of „R" plasmids to the frequency of resistance in human pathogens is probably very small, although there has subsequently been a report (Sandaa and Enger, 1994) of plasmid transfer in marine sediment.

The impact of antimicrobial compounds in sediments, as specified in the term of reference for this meeting, has been explored in series of reports of both field and laboratory studies from the Fish Disease Group, University College Galway, Ireland and from Dunstaffnage and SOAEFD Marine Laboratories, Scotland.

These reports have demonstrated that resistance can be detected in sediments treated with antibiotics. The factors influencing the extent of the development of resistance (in the small proportion of the microflora amenable to examination using current techniques) are complex, but the rate of cell division appears to be a particularly important factor (Davies et al, 1996). In systems where cell division is active, high proportions of resistant bacteria can develop in response to exposure to antimicrobials. If division is less rapid, resistance is either slower to develop or develops to a lesser degree.

There have been some measurements of the effects of antimicrobials on the activity of sediment microflora, using integrative methods such as the measurement of gas evolution rates from cores (eg Kerry et al, 1996, in press), or the rates of oxygen consumption and nutrient release (Davies et al, 1996, in press). Kerry et al found that the addition of fish feed with added antibiotic to sediment resulted in only a temporary reduction in metabolic activity, and a high degree of drug resistance. Samuelson et al (1992) showed that under field conditions the degree of resistance indiced by the use of oxytetracycline declined with time after the treatment had ceased. Klaver and Matthews (1994) reported that the same compound inhibits nitrification in artificial freshwater mesocosms. Wu and Knowles (1995) reported that chloramphenicol inhibited enzymatic denitrification in sediment and in bacterial culture. Davies et al (op cit) found that the addition of antibiotic (potentiated sulphonamide) treated feed to marine sediment cores resulted in a partial inhibition of oxygen consumption rates and ammonia release rates, which persisted for up to 3 - 4 weeks. Davies et al also reported a marked increase in phosphate release soon after the addition of treated feed to sediment cores.

Other similar experiments (P Provost, SOAEFD Aberdeen, unpub) have been carried out using amoxycillin, oxytetracycline, and oxolinic acid. The addition of antibiotics generally appeared to inhibit the onset of anaerobic conditions in surface sediments. Differences were found between antibiotics in their effects on oxygen uptake and ammonia release, but there was consistently a large release of phosphate by all treatments containing antibiotic. The mechanism behind this observation is not clear, but could arise from inhibition of microbial processes that would normally consume phosphate, or a movement of the redox boundary out of the sediment and release of phosphate from iron phosphates and/or interstitial water.

It may be concluded, therefore, that the concentrations of antimicrobial compounds in sediment that can result from mariculture will suppress the metabolic activity of bacterial populations in sediment. Many of the microrganisms present will be sensitive

to the concentrations of antibiotic present, even though a large proportion of the total concentration present will be biologically inactive. A resistant subpopulation will maintain its normal level of activity, but the overall rate will probably be reduced.

If cell division is occurring, the resistant population will be able to increase and restore normal rates of metabolism, with accompanying increase in the frequency of resistant bacteria. If cell division rates are low, the metabolic rate and frequency of resistance will remain low. Therefore, in addition to the concentration of antibiotic in the sediment, the response of the microbial population will depend upon the biologically active concentration, and the growth (cell division) rate of the microrganisms.

In general, the possible impact of antimicrobial compounds in sediment upon the rate of remineralisation of organic matter, or on the development of resistance in natural bacterial communities, are not taken into account during the authorisation/licensing of medicines, or in the design of monitoring programmes. Further, it is not clear that an adequate conceptual framework exists within which judgements can be made of the importance, or environmental significance, of the development of resistance, or of the interference with remineralisation rates. Resistance can, to some extent, be viewed as a response of the sediment microbial community to antimicrobials that works to restore remineralisation rates to pre-exposure values, and therefore may be environmentally benficial. Both the reduction of remineralisation rates caused by exposure to single doses of antibiotic, and the increases in the proportion of the bacterial population showing drug resistance, appears to be transitory responses (Samuelson et al, 1992), although the temporal scale of the response may be rather variable. The possibility of repeated recreation of the responses through periodic use of antibiotics must exist, but running contrary to this is the continuing input of fresh organic matter (faeces, waste feed) from the overlying farm, which will encourage the growth of the better-adapted component of the microbial communites (the resistant sub-population). It is commonly suggested that the possible effects of antibiotics on remineralisation rates, leading either to increased accumulation of solid waste, or encouraging hydrogen sulphide release, may be self-regulating through the potential for deteriorating sediment conditions to adversely affect the farmed fish. In view of the compensatory mechanisms outlined above, it is not clear whether this is a realistic and significant feedback process.

3.2.4 Discussion on future trends and development

A consequence of the above discussion for medicine regulation and fish farm monitoring may be that the effects of currently-authorised antibiotics in sediment are unimportant. Biologically active concentrations of these compounds in sediment are confined to relatively small areas of sea bed beneath and immediately around cages, which are probably heavily organically enriched from the input of waste feed and faeces. The sedimentary conditions, and the benthic fauna, will be strongly modified without any addition of antimicrobial compounds. The presence of such compounds may be a minor complication of the interactions between fish farms and marine sediments, which has insignificant consequences for the wider (eg sea loch, or fjord-scale) environment. However, there remains a lack of a thorough understanding of the significance of the processes discussed. There is clearly need for research to clarify, under field conditions, what are the consequences for the environment of (temporary)

reductions in microbial activity, or changes in the balance between different microbial processes, or the induction of varying degrees of drug resistance arising from the use of currently-authorised antibiotics in fish farming. At the same time, it will be necessary to make comparisons between the environmental impacts of antibiotic use in fish farming, with other uses of the same or similar compounds in agriculture and human medicine, both of which also result in the release of these compounds to the environment.

The above comments apply more strongly to new antimicrobial compounds that may be proposed for use in mariculture. The assessment of the environmental significance of the effects of one antimicrobial compound may not be applicable to another compound (although hopefully the emthod of assessment will be transferable). Drug resistance has historically been a significant problem in aquaculture, and strategies to combat this process may be attractive to the industry. However, the development of new active compounds with different modes of action against microrganisms, or formulations which incorporate controlled release rates or chemicals that inhibit the process of development of resistance (News and Comment, Science 270, 724) may present new questions, or at least similar questions with different emphases. If the potential new products can significantly inhibit the ability of microbial communities adapt to exposure to these compounds, the likely balance between processes described above may be disrupted, and different concepts of assessment of potential environmental impact may be required.

There is reported to be interest in pharmaceutical companies in compounds which are not themselves particularly active, but which are transformed by the target organism into compounds which may be both therapeutic and toxic to non-target species. The assessment of the environmental risks presented by these compounds is complicated, depending on rates of metabolism and depuration etc. Classic toxicity test may not easily detect this mechanism of toxicity.

There is also considerable interest in improving the effectiveness of antimicrobial agents in fish. Some current compounds are less than ideal, through relatively poor uptake efficiency (resulting in the „waste" of substantial parts of the dose), or through long depuration times (resulting in long withdrawal periods and loss of commercial flexibility). Commercially desirable properties of new compounds would include high bioavailability and rapid depuration of parent compound or (?toxic) metabolites. The combination of these properties suggests that the resulting concentrations of biologically active substances in the water phase may need additional attention.

There is a consistent pattern of reductions in the use of antimicrobial agents in well-established salmon farming industries. In Norway, Ireland and Scotland the absolute amount of antibiotics has decreased in recent years, even though the production of fish has increased considerably (cf data for Norway, Fig. 1). There are several factors contributing to this reduction of use. There is increased awareness of the need to ensure that disease-free smolts are used, and that vaccination against furnculosis and/vibriosis (and other diseases?) is applied wherever possible. Other improvements in husbandry practices have reduced the stress on fish in cultivation, as has the better control of sea lice infestation, and consequently fish are less susceptible to disease challenge.

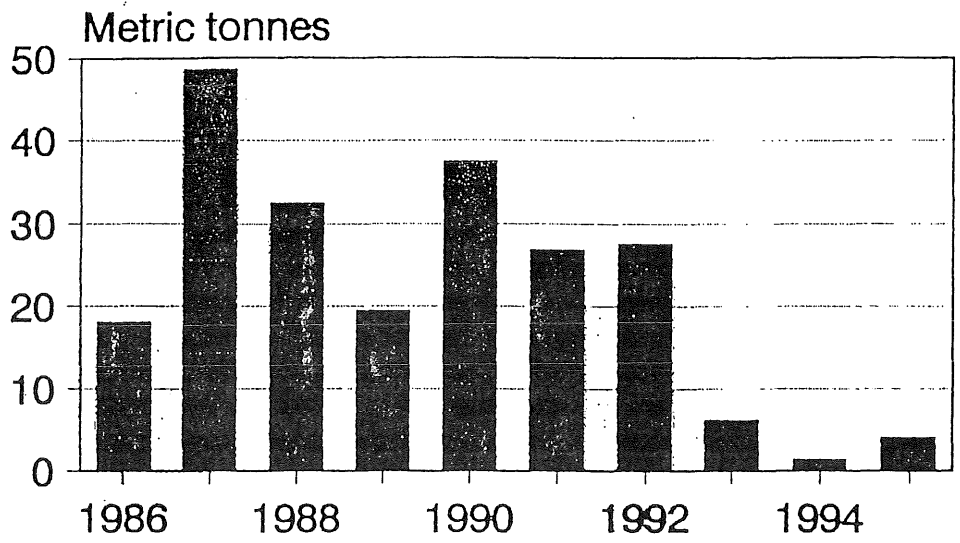


Figure 1: Changes in antimicrobial usage in Norwegian mariculture during the period 1986-1994.

3.2.5 Chemical control of sea lice in salmon and sea trout cultivation

One of the more controversial aspects of salmonid cultivation in the sea has been the need to control infestations by ectoparasitic sea lice. Until recently, the only authorised (licensed) chemical treatment has involved the use of the organophosphorus compound dichlorvos as a bath treatment, and the subsequent release of the compound to the marine environment. Dichlorvos is widely used in Norway, France, UK, Ireland etc. Further comments on dichlorvos are found in CRR 202, but, specifically, the compound is fairly soluble in sea water and is not found in sediment. The movement of dichlorvos in sea lochs can be successfully modelled on the basis that it behaves as a conservative dissolved substance (with a defined half life).

In the last two years, there have been considerable developments in the range of chemical treatments available, or coming available, for the control of sea lice. In at least France, UK, and Norway, hydrogen peroxide is now available for this purpose, and in some countries (including France and Norway) the organophosphate compound azamethiphos (in a commercial preparation) is authorised. However, hydrogen peroxide and azamethiphos also behave as dissolved substances (and hydrogen peroxide decays rather rapidly) and therefore neither are found in fish farm sediments.

There are other products under development, under consideration for authorisation, or undergoing field trials, containing active ingredients which are much are readily

associated with sediments. These compounds include cypermthrin (a synthetic pyrethroid), which is also licenced for control of midge larvae in drinking water supplies. Preliminary consideration of the bath treatment system and concentration suggests that cypermethrin should present only a small environmental risk in sediment.

A further group of two compounds are undergoing field trials at various locations. These compounds, diflubezuron and teflubenzuron, act upon the lice through the inhibition of chitin formation. They are rather non-toxic to non-chitinous organisms, and have little impact upon chitinous organisms unless they are moulting and require to synthesise new chitin. The procedures used to routinely assess the ecotoxicology of fish medicines do not immediately permit the effective assessment of compounds with such a strong, but discontinuous mode of action, and modifications are necessary to take these properties into account.The compounds would be used as feed additives (which is seen by the industry as preferable to the bath treatments that have been necessary with other compounds to date), at low dose rates. However, they are rather potent and likely to be slow to degrade in marine sediment, where they may continue to exert toxic effects on infaunal species. Data to assess the degree of hazard and associated risk are not yet available in the open literature.

There is some interest in the possible use of ivermectin, as a feed additive, to control sea lice, and some monitoring is carried out for this compound in fish tissue in UK and Ireland. Information on this substance is available from CRR 202. It is rather insoluble in water, and would be expected to be transferred to sediment. Field or laboratory studies of the toxicity of ivermectin in sediment are rare in the open literature. It is possible that the avermectin group of chemicals, of which ivermectin is a member, might provide some other potential compounds for the control of sea lice.

As in relation to the use of antimicrobial agents, various practical and research strategies can be identified which limit, or should in future limit, the need for chemical treatment. Improvements in general aspects of husbandry have significantly reduced the frequency of infestation. In many farms, the use of cleaner fish (wrasse) makes a large contribution to lice control, although generally it is found necessary to retain the possibility of chemical treatment as a back-up to the wrasse. There are also considerable efforts in hand to develop vaccines against lice. Unfortunately progress is not rapid, and an efffective commercial vaccine is probably still several years away, and the use of wrasse and chemical treatment will need to be retained for the foreseeable future. Meanwhile, there have been reductions in the use of dichlorvos in several countries, including Norway (see Table in country report) and Scotland, for the control of sea lice. This is due to various factors, including improved husbandry, the use of wrasse, and the increasing availability of alternative treatments.

In summary, while currently-authorised sea lice treatments are applied as baths and involve compounds which are relatively soluble in water, a number of the new compounds being considered for this use have rather different physico-chemical properties, and may well become incorporated into sediment. While the medicine authorisation/licensing procedures will include assessments of the environmental safety of these substances, there is currently little information on this in the open literature. There will therefore be a need, for both public reassurance and to provide an informed basis for environmental protection (eg through discharge controls), for appropriate information either to be published by the respective pharmaceutical companies, or to be obtained through new research programmes.

3.2.6 Anthelmintics

Farmed salmon can suffer from infestation by intestinal tapeworms, specifically Eubothrium crassum. Infestation can result in reduced efficiency of feed utilisation, reduced marketability and increased difficulty during processing, and in some cases reduction of growth rates. There is no general agreement on the significance of tapeworms for the fish. However, some companies do chemically treat the fish to reduce or eliminate the infestation. In addition to the compounds covered in CRR 202, two other compounds have been used. These are praziquantel (cf Mitchell, 1995) and fenbendazole (cf M Clarke, 1996, unpub), and both are used as feed additives. In both cases, the freedom to use the compounds will be reduced at the end of 1996 by the lack of MRL values.

There is little published information on the marine environmental impact of the use of either compound. However, recent work (M Clarke, SOAFD Aberdeen, unpub) has indicated that once fenbendazole becomes incorporated into sediment it presents a low toxic risk to benthic infauna. For example, the LC50 to Corophium volutator is greater than 400 mg/kg. In the aqueous phase, the LC50 to Mytilus edulis is greater than 260 mg/l, although a sub-lethal 72 hour EC50 for byssal thread attachment was estimated as 37mg/l. The therapeutic dose rates normally used suggest that the risk of toxic effects in the environment to non-target organisms is low.

3.3 Status and trends in mariculture and implications for planning and management of resource uses

3.3.1 Introduction

The WG Chairman established a subgroup under the leadership of Robert Cook and including Susan Utting (UK), Alain Febvre (France), Arne Ervik (Norway), Gunnar Aneer, (Sweden) and Jacqeline Doyle, (Ireland) to address the status and trends of mariculture development in member countries and access these in relation to environmental interaction issues including those not addressed previously by the WGEIM. Specifically this group was asked to address the WGEIM CRes 2:33 (c) and to analyse, document, and disseminate information of the status of mariculture, existing trends and future innovations in the culture of different species and concomittant resource requirements and implications for planning and management with due attention to trends in other coastal resources development and utilization. Many countries have developed, or are developing, national strategies which are addressing environmental interactions.

3.3.2 Trends for finfish

3.3.2.1 Production

Productions trends in the ICES area were discussed. This should have been substantiated by absolute figures tabulated from the Country Reports. However, all reports were not available and this task could not be done. The general upward trend of aquaculture output is reported from most regions with Norway being projected to reach 300,000 tonnes of salmon in 1996. In other member countries, such as Scotland

and the Faeroes, production increased only slightly. In France, Denmark, Ireland, Swewden and Canada, production levels in finfish mariculture have not changed significantly, although in Canada, considerable R&D is being focussed on marine fish culture. Along the German Baltic coast, marine cage farming has declined to negligible levels. It was noted that the production of sea bass and sea bream was increasing rapidly in the Mediterranean Sea, particularly in Greece. Currency devaluations in Greece, as well as Italy, has resulted in enhanced production in these countries somewhat to the detriment of the French industry where new site locations are very limited and the cost of production is relatively high. Tourism is a major competitor for space along the Mediterranean coast of France. This is prompting the development of land based systems with recirculation as the emerging method of choice. Also, in Nordic countries (particularly in Denmark) expansion in coastal waters is limited, due to competition with tourism. The number of trials using land-based recirculation systems reflects the need for new developments in response to the competition pressure for coastal resources.

3.3.2.2 Feed

A key trend in finfish mariculture is the attention to improved feeds and feeding techniques with increasing consideration to reducing nutrient inputs and consequently negative environmental impacts. For example, previous waste levels of 90 kg N/tonne has been able to be reduced to below 50kg N/tonne in salmon operations. This is achievable through higher digestibility feeds, improved diet formulations to meet metabolic requirements, the application of better husbandry practices, and closer environmental monitoring by fish farmers. The future trends will be to explore new sources of protein for feeds, eg. use of plant proteins, as well as testing new sources of lipids. The special concerns of geographic areas, such as the Baltic Sea where water exchange is restricted and eutrophication is a major problem, will continue to require innovative approaches to be developed to restrict nutrient discharges.

3.3.2.3 Practical issues

It was noted that the production of Atlantic salmon has developed from an initial low technology application to the complex production units in place today. Production cycles for smolts and adults have been shortened and they can now be produced all year round which helps to regulate the markets. Other production optimization techniques are being developed using innovative siting strategies to ensure the continuous supply of market fish. Economic savings have also been made with improvements in aquaculture practices. In Norway, production costs per kilo of salmon have decreased over the last ten years and in 1995 it was cheaper (cost per kilo) to produce than chicken or pork. Similarly, the production of market size sea bass and sea bream is possible within 16 months, rather than the previous 24 months, by using closed recirculation systems with thirty-fold savings in water requirements.

In the future, it is projected that there will be an increased use of land based recirculation systems for the culture of marine fish throughout the ICES area, particularly for species such as halibut, turbot and other flat fish. Depending on market conditions, onshore facilities for marine salmonid production is expected to be used as the competition for space within the coastal zone becomes more acute. Grow out trends for Atlantic salmon now include age class separation, fallowing of sites and better arrays of sea cages. The development of innovative cage designs which are

submersible could be used to take advantage of optimum water conditions, to avoid storm damage, and to be more predator proof.

3.3.3 Trends in shellfish and other species

The trends in the production of shellfish are expected to include the increase in the number of species that are produced from culture operations. For example, several species of scallops are being cultured using different suspended and bottom techniques. In itensively utilised areas, bivalve culture is governed by the carrying capacity of the growing area. Sometimes the carrying capacity is constrained by municipal, industrial and other adverse effects of urban development. Research to determine the optimum carrying capacity of shellfish growing areas and initiatives to control the release of ballast water organisms, particularly those with potential PSP implications protect the availability of productive areas. These are priority considerations. Improved depuration techniques need to be developed for purification from viruses as part of shellfish hygiene. Research into improved diagnostic techniques for disease identification continues and selection programmes for disease resistant strains are in progress. The cultivation of novel species such as abalone and sea urchins, the latter for roe production, is showing considerable opportunity.

3.3.4 Other developments

In Sweden, there are plans to assess the application of shellfish culture technology, such as mussel culture, in eutrophic areas as a method of mitigating the nutrients released from finfish culture operations or from other sources. The shellfish produced could not be used for human consumption but coud be put to other purposes (eg. fertilizer). Regardless of the fate of the shellfish produced an environmental quality objective would have been achieved.

The interaction of escaped farmed Atlantic salmon on wild stocks is a question that is receiving attention. Studies on the ecological implications of these escapees from salmon farms in British Columbia, west Canada, where this species has been introduced and where it has no genetic impact, has indicated limited effect on local stocks. The genetic implications of escapees in the natural range of Atlantic salmon is a matter of considerable debate and the subject of research in several ICES countries where wild stocks are perceived to be adversely affected. This is being addressed by other groups within ICES and NASCO. An ICES/NASCO Symposium is planned to be held in Bath, U.K., April 17 - 22, 1997, entitled "Interactions Between Salmon Culture an Wild Stocks of Atlantic Salmon: The Scientific and Management Issues".

A potential new threat to aquaculture is the presence of oestrogen-like compounds which are present in many of the plastics used for the construction of fish rearing systems eg tanks, pipework for water supply. The presence of these substances in recirculation systems has been implicated in creating sterility in cultured fish which are maintained in the systems for extended periods of time during the rearing cycle. This is a new example of compounds which can have a measurable effect on mariculture production and it shows the need for stringent testing and selection of such substances if they are to be used in mariculture.

3.3.5 Implications for management of the coastal zone

The subgroup suggested a trend of more individuals and groups wanting to use the coastal zone. This brings with it an increased pressure on coastal resources and potential conflicts of interest within and between user groups. It is unfortunate that environmental conflicts can often arise between users of the coastal zone through lack of appropriate information and data being available. A general trend for increasing dialogue between the various coastal zone users was identified and this is leading to a better understanding and balance between mariculture, other environmental groups as well as other users of the coastal zone. Potential problems can be minimised with better planning of the various activities in the coastal zone. There is now more awareness of a need for integrated coastal zone management both for environmental and socio-economic reasons. Action at local, regional and national levels will be needed to integrate the complex range of activities listed below.

Because of the competition for space in the coastal zone, future expansion of mariculture is likely to be constrained by many of these activities. Ultimately, environmental quality objectives will have to be established to integrate coastal zone ativities. In some ICES countries, strategies, objectives and standards have already been established (to some degree) for mariculture. For example, in Norway, the rapid development of the mariculture industry has caused pollution problems in the marine environment as well as conflicts with other users of the coastal zone. Research and practical experience have helped to identify the environmental problems caused by fish farming and have enabled the authorities to set up environmental objectives for Norwegian mariculture regarding escapes of cultured fish, diseases, medicines, chemicals and organic matter. The Norwegian strategy of Modelling-Operations-Monitoring (MOM) for the environmental surveillance of salmon farming operations may an appropriate method to assess the effect of organic loading. The data bases built up through the application of this program will provide useful guidance for future development of this industrial sector.

3.3.6 Other users of the coastal zone

3.3.6.1 Conservation

There are many more areas in ICES countries being identified as sites for conservation of unique and/or rare habitats and species (eg EC Habitats Directive, UNESCO biodiversity initiative, RAMSAR sites). This is limiting the availability of sites for mariculture and may also have a controlling effect on cultivation activity because new enterprises may be precluded. Sometimes, users' interests can appear mutually exclusive eg.the interaction of seals, otters and cormorants on mariculture are likely to remain as a contentious issue between conservationists and mariculture. The two groups will need to co-exist, develop a mutual understanding of the situation and agree on management practice.

However, there are instances where mariculture has a neutral or positive interaction with conservation interests. For example, Eider ducks and oystercatchers gain additional food sources in mussel farming areas.

Excluding one activity in the coastal zone may, however, have a negative impact on other users' interests. Some form of management plan has to be introduced. For example, low level fish culture is encouraged in lagoons on the French Mediterranean coast for maintaining the unique type of lagoon habitat that has developed there after several centuries of man's intervention and management. Without this low level management,it is likely that the integrity of the habitat structure could be lost eg through deterioration of drainage channels.

3.3.6.2 Recreation and tourism

With the continued worldwide trend in more leisure time, there is increasing pressure on the coastal zone from recreation and tourism. Leisure activities, such as sailing, water skiing, swimming, windsurfing, and camping, for example, as well as tourist developments could continue to reduce the area available for mariculture. Also, shellfish culture can be adversely affected by increased sewage input around tourist areas as well as by discharge of wastes from boating, due to problems with shellfish hygiene.

Several positive effects were identified between recreation/ tourism and mariculture. Markets for cultured fish and shellfish can be developed around tourist areas, as was demonstrated in the Baie de Bourgneuf, and mariculture sites may be tourist attractions. Improving the quality of bathing waters may be beneficial to bivalve cultivation in some areas.

3.3.6.3 Commercial fishing

With the downward trend in many of the commercial fisheries, there is an associated upward trend in developing mariculture within the locality so that commercial fishermen can remain within an area and diversify into mariculture to maintain their livelihood.

Traditional inshore fishery, fish spawning and nursery grounds are areas that cannot be used for mariculture but there are examples of beneficial interactions between mariculture and commercial fisheries. Mariculture sites provide protected areas for a range of wild species and there is an increase in benthic organisms which provide additonal food for other foragers. For example, in the Bay of Fundy, on the east coast of Canada, 15 years of lobster catch data show that there has been a steady increase in catches in the vicinity of the rapidly expanding salmon farming industry. Lobsters continue to be caught in pots near the salmon cages. In Annapolis Basin, Nova Scotia, lobster catches over the last two years have also remained stable for the same reason. Wrasse numbers can increase around cages which then provide a localised fishery. With such examples of beneficial effects on a fisheries resource, the adverse perceptions about mariculture are changing as more knowledge about interactions is acquired.

3.3.6.4 Shipping and navigation

In most countries, navigation channels will have exclusive priority for space over mariculture structures. All such structures and anchorages must be marked by navigation lights to avoid collision. The location of all mariculture installations should be identified on admiralty charts to avoid accidents and minimise risks of escapement.

Risks from shipping include the introduction in ballast water of pest species including toxic cysts of dinoflagellates carrying PSP. Studies on the effects of ballast water are being addressed. There is an urgent need for a Code of Practice for the discharge of ballast which is currently being addressed by IMO and ICES.

The use of antifoulants on large vessels, particularly TBT, continue to have a negative impact on shellfish cultivation in some areas of Ireland. The incidences of oil spills in areas with mariculture interests can have major detrimental effects eg Shetland Islands and Milford Haven, UK. Effects of such incidents usually result in mortalities of cultured animals in the short term and longer term contamination.

The situation in the La Rochelle basin, where resiting of shipping berths could release sites that would be ideal for bivalve cultivation, as well as being of benefit to the shipping industry, stresses the need for regular reappraisal of coastal development plans.

3.3.6.5 Urbanisation

With improved treatments for municipal waste,industrial effluents and sewage, new areas may become available for mariculture ..in the future. Protocols for best-environmental practice are moving towards minimising pollutant levels. Recommendations have been made in many ICES countries (eg EU Directive on Shellfish Growing Waters)but sstandards have still to be met in some ICES areas.

3.3.6.6 Agriculture and forestry

There is a positive trend towards minimising inputs from these diffuse sources within agriculture and forestry. The increased awareness of environmental impacts from fertilisers and pesticides, for example, are leading to a gradual move towards reducing these substances impacting in the coastal zone and is receiving attention within OSPAR.

3.3.6.7 Heritage

Protection of heritage sites, such as wrecks, and the need to maintain traditional activities may have implications for mariculture. For example, wrecks may prevent the establishment of new cultivation sites. Coastal communities with historically unique cultivation practices may preclude the application of more modern technologies.

3.3.6.8 Ownership of foreshore

In some localities (eg eastern Canada and Sweden),land adjacent to the foreshore is being bought by the private sector as summer residences. For aesthetic reasons, primarily visual impact on the scenery, many owners object to aquaculture developments in their immediate vicinity.

3.3.6.9 Military requirements

The subgroup thought that because of geopolitical changes, the current situation is unlikely to change and may in fact diminish as a result of decisions for the cessation of dumping of munitions at sea and a abandoned facilities become available for mariculture.

3.3.6.10 Mining and oil exploration/exploitation

No change in trend could be identified but exploratory tests for new gas and oil reserves are being carried out in more coastal waters in some ICES countries, eg the UK, and these might conflict with mariculture interests.

3.4. Interactions with other resource users

3.4.1 Introduction

The basic objective of the Working Group on Interactions of Mariculture is to stimulate ICES to promote improved integration of mariculture into policies, plans and management strategies for coastal areas that include the upstream users. This must be based on the principle that carefully planned and managed mariculture represents a form of sustainable natural resource development that can help nations meet social and economic objectives while protecting the integrity of natural ecosystems and the quality of the environment. However, to achieve the sustainable development of mariculture and to maximise the positive environmental, social and econmic benefits it can bring, it is essential that a broad perspective is taken concerning the interactions between mariculture and other forms of coastal development so that well informed decisions can be made concerning :

The socio-cultural acceptability of mariculture;

The economic feasibility of developing different forms of mariculture; and

The ecological sustainability of mariculture in different coastal areas where it may be acceptable.

For example, the coastal zone is the terminal reciever of the effects of environmental change in rivers and on land. As such coastal area planning must allow for the effect of changes upstream from the coast as well as changes directlt in the coastal zone. Institutions aware of possible changes in the coastal environment have a responsiblity to make upstream resource users aware of the impact their action may have.

Mariculture development represents a response to demand from society for specific products. In order to produce those products mariculture will require space in which to establish a production facility; for example a pond, cage, or pen, supported by capital goods, labor, management skills, a continuous supply of materials (water, seed stock, feeds, etc.) and energy. These requirements may cause a variety of positive or negative interactions with other economic and social activities. For example, the demand for sites to culture mussels may increase pressures on sheltered bays which may be used by artisanal fishermen or for recreational boating. At the same time, anti-foulants used on recreational craft may make cultured and wild mussels unfit for human consumption. The mariculture, artisinal fisheries and the recreational interests have a legitimate right of access to the coastal waters and the integration of their interests presents a challenge for policy makers, planners and managers in reaching an equitable, economically feasible and environmentally sustainable solution.

3.4.2 Description of various interaction scenarios

Table 1 provides examples of different forms of interactions between mariculture and other coastal resource users where the impacts can be grossly identified in both directions. Because of the multitude of combinations that are possible, the presentation of the user interaction matrix is restricted to the shellfish and finfish farming and the conflicts arising with selected other users.

Table 1: Interactions between mariculture and other coastal resource users.

The effects of fish-farming on :

	Positive effects	Negative effects
Shellfish:	addition of nutrients	contamination from medicienes and chemicals
Tourism	farm use as fishing ponds for tourists	the farm could ruin the sceenary for tourists; reduce the experience of unused nature
Fisheries	escapees supplement natural fish stocks	occupying fishing places, nursery grounds, catch confinement sites
Transport	(providing infrastructure)	occupying fairways
Industry	provide raw material for production	
Agriculture	use of fish waste as feed in meat or fur production	
Recreation		reduce the available area
Urban		

The effects on fish-farming by

	Positive effects	Negative effects
Shellfish:	use of feed waste, feces and nutrients from fish farms	
Tourism		disturbing the production - transfer of diseases
Fisheries	supply of food	competition of area
Transport		competition of area - transfer of diseases
Industry		release of pollutants
Agriculture		release of pollutants
Recreation		
Urban	contribution to better infrastructure	pollution

3.4.3 A problem that overlaps and exceeds

Problems in the coastal zone affect all users of ecological, economic and social services provided by coastal ecosystems. This includes activities such as aquaculture, fisheries, polluters and activities such as recreation and tourism. All these uses have in common:

-subtractability and interlinkage of resources; resource utilization by one user can be harmful to other coastal resource users;
- regulatory systems are generally inadaquate when faced with intensification and diversification of coastal zone use.

No technological fix

Solutions to problems in coastal area use cannot come solely from technological improvements. All coastal zone users operate within opportunities and the constraints formed by the ecological services provided by the coastal ecosystems in which they operate. For example, in shellfish culture, shellfish biomass must be kept within the capacity of the basin to produce the phytoplankton the shell fish use as food, and within the ability of the local environment to process the fecaes produced by the shellfish. Simularly, recreationalists cannot put excessive sewage into the basin.

Institutional Tools

Inadaquate institutional tools can be an obstacle to aquaculture development: captital investment in more productive systems is often prevented by the uncertianty of durable access to the resource or by privileges granted by precedence to a pre-existing coastal population. The result is that, within the frame work of existing institutions, administrations in charge of coastal zone management cannot renegotiate the balance of values of user rights amoung user groups as the value of these rights change.

Towards Integration

For coastal areas there is no general solution to the problem of intergrating coastal zone uses. Each solution must be adapted to the local ecological resource characteristics, technical systems, socio-economic organization of production systems, and scientific and administrative skills available. Evaluation of the benefits from introducing a new form of production of a good or service to the coastal area requires the ability to identify consequent changes and loss of value in the existing goods and services derived from that coastal area.

In that respect, it is necessary to describe and understand past and present relationships between ecological, technical, economic, social and regulatory aspects of RMR uses. The advantage of new institutional arrangements also have to be compared through the criteria of goods yield increase, efficiency in natural heritage conservation and acceptability or the ease of implementation of new regulations. Three strong influences have to be considered as priorities:

Integration of social factors

Within the access to RMR, the public opinion, social preferences and politic of factors linked to users play a dominant role compared to economic mechanisms. These social mechanisms must be studied as a priority. There are basically two types of users: local and non-local. There is a severe tendency in many coastal areas to displace the small scale local users because they are less powerful in economic and political terms.

Inter-use relations

Institutional options vary with uses, ie with resources and techniques that define production systems. However, answers have to be given concerning allocation between concurrent uses. They must be applicable to all uses within the same space.

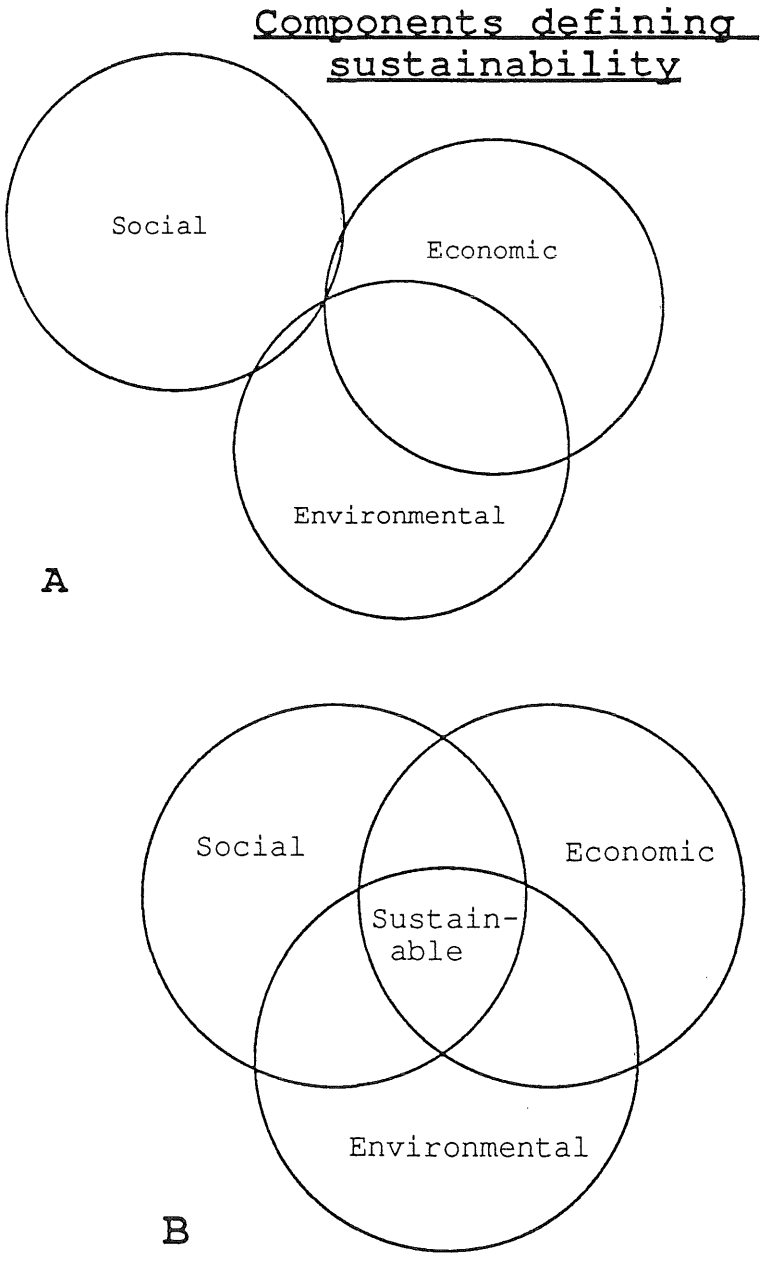


Figure 2. The interaction between social, economic and environmental conditions determine the degree to which aquaculture is sustainable in a particular culture. Figure A shows that even though environmentally and economically feasible, social requirements are not integrated with the other factors and can preclude development of sustainable aqauculture. Fig. B. represents the scenerio for sustainable aquaculture, where the three factors are integrated effectively.

Central position of the ecosystem

All these interactions take place within the ecosystems being developed. They are very complex. Modeling of these interactions through the different ecosystem compartments is required. Integrated management of multiple uses needs to be supported by the development of the quantification of interactions.

In conclusion, we can state that in each use, it is necessary to study the relationships among ecological, technical, economic and social processes in order to estimate their influence on institutional choices. Between uses, it is necessary to study interactions between ecosystems and exploited populations. These vertical and horizontal relationships determine the width of the studies that are to be postponed.

The matrix of integration

A matrix may be used as a tool for illustrating how mariculture and other activities may interact. Once important interaction among major users of the coastal zone have been identified, further matrices can be constructed that help to illustrate the social, economic or environmental factors influenced by those interactions. A policy maker, planner or resource manager can use matices to develop an analysis of potential interactions which are relevant for each local situation.

The information for the matrix analysis can be related to a Geographic Information System (GIS) to illustrate the nature of interactions for specific locations within the Coastal Zone or specific ecosystems.

Figure 2 illustrates the interelationships between mariculture and other social and economic interest groups.

Table 2. Interactions Matrix between mariculture and other resource users

Of\On	Fish Farm	Shell Fish Farm	Urban	Recre-ation	Tourism	Fisher-ies	Trans-port	Manu facturing	Agricul-ture
Fish Farm	*	+,-	0	-	+	-,+	+	+	+
Shellfish Farm	+	*	0	-	+	-,+	+,-	+	0
Urban	-,+	-,+	*						
Recreation	-	-,+		*					
Tourism	-	-,+			*				
Fisheries	-,+	-,+				*			
Transport	-	-					*		
Manufacturing	-	-						*	
Agriculture	-	-							*

Table 2 presents a matrix which illustrates the potential positive and negative interrelationships between mariculture and other coastal activities. There are two very important points illustrated by this matrix, namely:

1. There is a wide array of coastal activities which can have either a positive or a negative influence on mariculture. In turn, mariculture can affect a wide array of other activities;

2. There can be a substantial cumulative effect on mariculture from the additive impact of the negative effects of more than one activity, many of which may be located 'upstream'. However, there is little prospect of mariculture creating cumulative effects on other activities except in extreme conditions.

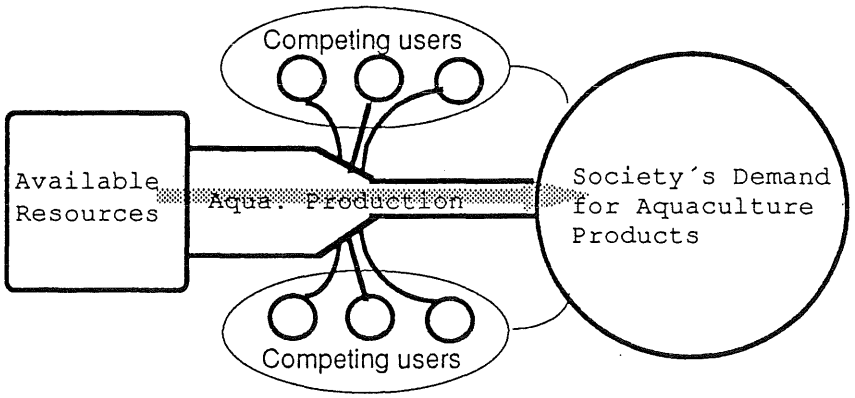


Figure 3. Diagramatic representation on how competing users affect development; not only as a constraint on the availability of factors of production, but also as part of the population which creates the demand for aquaculture products.

On the other hand, mariculture development depends also on a number of interacting economic factors of production, in particular when several users compete for the same resources their competition increases the demand for marine food products. This is briefly illustrated in figure 3.

It is very important to recognise that the interactions identified have **Social**, **Economic** and **Ecological** dimensions. Decisions concerning the sustainable development of mariculture will therefore require a comprehensive understanding of these factors and how they are interrelated. This will then provide a robust analysis of the issues affecting the sustainable development of mariculture and level of management required to resolve these issues.

Within the social component of the matrix, factors can be identified and integrated into the assessment of opportunities and constraints for developing mariculture. Two of the critical factors are social organisation and user rights.

Guidelines for the management of mariculture within a wider context depend on the social organisation of the rights to exploit natural resources in a region. Some societies have historically accepted private property rigths to natural resource exploitation, while others have managed the resources under the umbrella of public ownership.

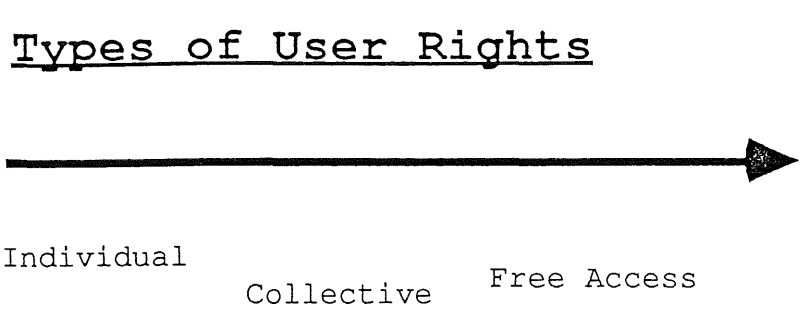


Figure 4. The range of types of user rights conferred in different societies.

The rights to exploit a natural resource are often tied to different forms of rights of access to and use of resources rather than "ownership". Individual property rights for use of resources may be given in conjunction with property rights to land. These rights may be modified or restricted by a legal or regulatory framework such as those required for environmental protection (i.e. exploit a fish stock in a privately owned lake or exploit an oil deposit under your property). Independent of land rights a personal license to produce or harvest a specified amount of a natural resource is also an individual right. This may or may not be a transferable right (bought and sold in the market place; i.e. fishing quotaes, pollution permit or sea cage farming).

A collective user right to a resource can be issued to an identifiable subgroup of individuals in a society which will share the right to exploit that resource. This group might be a community, a co-operative or another organizational or spacially differentiated group of people sharing a common economic or social goal. Such groups of people are often a precondition to participation in the self-management schemes of modern natural resource management practices. Under this scheme individual property rights and market forces cannot be concurrently employed in the management of the resources. (Many traditional distribution systems are built on collective user rights). Later developments, where Governments use their legal right to change these traditional systems has often led to degradation of the resource.

Basically all coastal and marine systems have common property features, as environmental goods and services are rendered continuously: no one can own- control -exclude anyone-else from benefitting from the benefits derived from natural systems such as "erosion control measures", the buffer functions of a coastal wetland system, or the nutrient exchange with adjacent areas, which can represent economically significant resource systems to the user at a specific site.

Free-access rights to exploit a resource means that all individuals within a society have a right to utilize the resource. Such a right of access may be employed where explotation does not lead to degredation of the resource (i.e. visual exploitation of unutilized scenery).

4. Environmental and other issues outside TORs

4.1 Identifying Pressure Indices for the Marine Environment & Coastal Zone

It has been brought to the attention of the Working Group that "The Commission of the European Communities" has issued a Communication to the European Council and Parliament on Environmental Indicators and Green Accounting (COM(94) 670 final, OJ

21.12.94). A core element of the Commission's initiative will be to establish a set of environmental pressure indices for the European Union's Fifth Environmental Action Programme "Towards Sustainability". It has been estimated that the about 50-100 pressure indicators will be necessary to give a sufficiently detailed picture of major human activities threatening the environment. The Marine Environment and the Coastal Zones have been included in order to define priorities for policy formulaton. It is intended to consider three major categories of negative environmental pressures, namely:

- habitat degradation and destruction
- deterioration in habitat quality through pollution
- damage to biological communities and living resources through non-sustainable harvesting practice.

Contribution to pressure indicators document

The Working Group noted that there were some parallels between the present aim to develop indicators of the scale/intensity of selected human activities, and early stages of the work of the Oslo and Paris Commissions (OSPAR). OSPAR (in partnership with ICES) prepared a thorough environmental quality status report (QSR) for the North Sea area, which integrated the location and scale of human activities with their chemical and biological consequences for the marine environment, ie included an assessment of the relative environmental significance of human activities. From the QSR, a series of priority issues of concern have been identified, and included in the framework of the new OSPAR Joint Assessment and Monitoring Programme (JAMP), together with the appropriate monitoring targets.

The OSPAR JAMP therefore provides a considered and internationally agreed statement of the priority marine environmental issues in the North sea (and adjacent sea) areas. The priority activities (in the current context of pressure indicators) should therefore be those which are most relevant to the JAMP issues of concern. In seeking to collate data on these activities in an EU context, care should be taken that duplication of activity with OSPAR programmes does not occur.

The concept of deriving pressure indicators was briefly discussed by the Working Group. It was generally agreed that, while it may be useful to have indicators to identify negative impacts of human activities on coastal ecosystems, there is little value in them as a stand-alone list in the context of coastal zone management. While human activities in the coastal zone may have negative effects on the environment, human activities may have beneficial societal effects if managed properly, in particular when working towards environmental sustainability. The Working Group felt that the GESAMP approach to an EIA should not only indicate the negative environmental effects but should also:

- Identify beneficial impacts of human activities,
- suggest mitigation strategies to reduce or prevent adverse impacts;
- identify residual adverse impacts which cannot be mitigated;
- develop strategies to track impacts regularly in an attempt to prevent environmental deterioration or improve management towards environmental quality objectives;

- aid the selection of the "OPTIMUM" alternative uses of natural resources while supporting the ecological functions that create the resources that maintain their integrety so that "sustainable use" can be achieved.

Aspects of a modern EIA should, therefore, include the understanding the use of EIA as a positive, improvement-oriented approach and as an interactive process (not a singly study), whereby consultation and public participation are included and socio-economic and socio-cultural issues are covered.

In this context of a more broadly based EIA, the proper development and identification of "Pressure indicators" should be seen as a tool ro raise awareness among policy makers of critical environmental presures and how they interact or cause synergistic and/or cummulative effects.

One of the objectives of the development of pressure indicators is to provide a mechanism which can be used to indicate changes in the pressure (scale and intensity of human activities) in defined areas, and possibly to make comparisons between these values of the indicators in different areas. These comparisons may be used to draw conclusions regarding the relative pressures in different areas, or whether the pressures within an area are increasing or decreasing with time. The repeated measurements implied by these objectives place the gathering of data on activities within accepted definitions (eg from ICES or GESAMP) of „monitoring".

ICES has recently prepared advice on monitoring strategies, particularly in relation to contaminants (ACME report 1995, sections 4.1, 4.2, Annexes 1 and 2). This advice emphasises the need for, and benefits that would accrue from, integration of chemical and biological effects measurements to obtain information on the degree of chemical contamination of the environment, and the impact of this contamination on biota, ie it emphasises the need to combine the measurement of deleterious effect with the measurement of exposure.

The document presented from the Statistical Office of the European Communities lists a series of three areas of deleterious impacts of human activities, and some of the types of human activities which may lead to these impacts. This is closely analogous to the relationship between the biological causes for concern, and the chemical contaminants described above. In keeping with ICES current policy, it is potentially wasteful and misleading to determine the scale of the human activities without simultaneously determining the actual impacts on the true causes for concern, ie on habitat degradation, habitat quality or living resources; the processes which we seek to prevent. The WG therefore recommended that, rather than collect information on activities alone, a more appropriate strategy would integrate the measurements of activities (as envisaged through pressure indicators) with the measurement of the impacts of the activities, in a coordinated programme.

Concern was expressed by the Working Group that :

(a) the unilateral consideration of Pressure indicators as negative impacts will not lead to "sustainable development" and as such are of little use for sound integrated coastal zone management.

(b) there exists a need for a more comprehensive and objective framework within which the different pressures are assessed.

This framework must consider:

1. the relative importance of different pressures,
2. the interactions amongst one or more pressures, and
3. risks associated with these pressures, taking into account local conditions.

There is also a need to address the question of whether there are environmental thresholds beyond which a benign factor becomes an adverse pressure.

The working group recommends that a broader approach be taken by the Commission that help guide ICZM policies towards envirinmenal planning and management for "sustainable" development in the coastal zone and therefore suggests that the Commission:

1) develops indicators to raise awareness while giving greater emphasis to the pro-active use of environmental information at the beginning of the process of policy formulation, development planning and management within the marine and coastal realm;

2) examine the ability of marine and coastal systems in different regions to to sustain these environmental pressures so that the relative importance of different pressures can be assessed. Reference could be made to the OSPAR JAMP and the relative importance assigned to key environmental pollutants.

3) consider the use of Coastal zone Management (CZM) as a positive framework for encouraging more environmentally, socially and economical rational patterns of development.

4) coordinate with the established programmes undertaken through the Oslo and Paris, and Helsinki Commissions to ensure dublication of effort does not occur.

4.2. Discusssion and concern on interpreting biodiversity in environmental assessment

The loss of biodiversity is often considered as an indicator of environmental degradation. Although the principle concept behind this assumption seems to be convincing, the issue is more complex than generally assumed. Bio-diversity is very divers. Diversity is the most typical character of life. It is the presentation of life in space and time. Systematic biology is a discipline which has explicitly been created to bring some order into this "chaos". How bio-diversity is defined is merely a matter of perception either of the scientist studying this phenomenon or the administrative using it a a tool in environmental regulation. For example, when considering marine biodiversity, the benthic ecologist and the planktologist may both look at number of species present while not being concerned about their biomass. As shown in figure 5, the commercially utilized species make only a minor fraction of the total marine biomass as expressed in organic carbon content, while bacteria and zooplankton are also not a major contributer to this biomass. In contrast, Phytoplankton provides over 90% of the ocean carbon. It is therefore necessary to always define the validity of the bio-diversity index being used and evaluate its validity in context of the concept being applied (e.g. locally or regionally). This is seldom done.

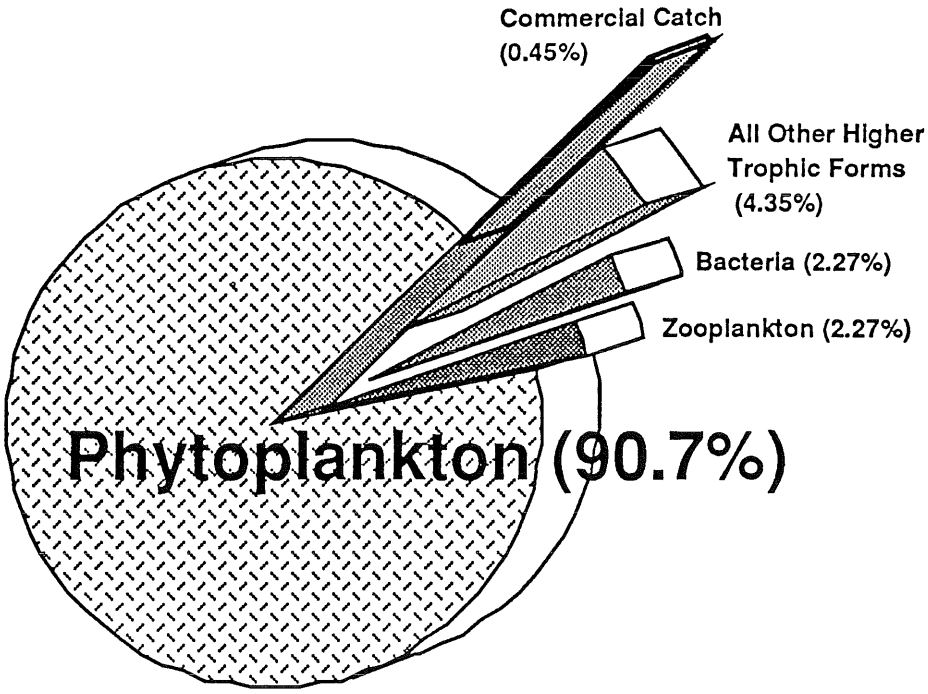


Figure 5. Total marine biota partitioned on the basis of carbon. Estimates are based on an extented literature survey.

There exists also another dilemma of a non-ecological interpretation and use of biodiversity in environmental assessment. The term "BIODIVERSITY" seems to be used in conservation biology almost entirely for FREE-LIVING ANIMALS AND PLANTS. PARASITES seem to be ignored or regarded as "THREAT" to the conservation of endangered species. Parasites and pathogens are among the most diverse of all organisms. Parasites and pathogens are a legitimate part of biodiversity. Almost all animals have parasites. Parasites and pathogens are among the most diverse of all organisms and are a legitimate part of biodiversity because almost all animals have parasites. Unfortunately, parasitology is taught usually from a medical or veterinary perspective and therefore parasites are rergarded as "nasty creatures" to be eliminated. All environmental agencies and almost all ecologists are equally concerned about species extinction. No concern is expressed that with its extinction, the parasites are also gone. With a loss of a parasite the interaction with other community members (intermediate hosts) may also be lost, causing community effects and changes in BIODIVERSITY. Because parasites and hosts co-evolved, the concept of a parasite-free host is an unnatural derivate of our human experience and perception. If a species is going extinct, it is always a "Co-extinction" as host-specific parasites and pathogen, are also gone. Disease agents and parasites provide a continuous "CHALLENGE" to host species thereby improving their fitness for survival (competitiveness, resistance, immune system). Large amounts of pesticides & antimicrobials are used in agriculture and medicine to reduce parasites and disease agents. This demonstrates how natural the host-parasite bond really is: like the chemical bond, we have to introduce a lot of energy to break it.

Even reproductive ecology has a disease and parasite component: "Sexual Reproduction" is also an attempt to evade parasites by starting life anew. Parasites have also diverse ecological functions. Parasite load, for exampel, is an over-whelmingly effective predictor of mate choice in some tropical fish and therefore affects reproductive success. Parasites regulate host populations and hosts regulate parasite populations thereby acting as a buffer-function in stabilizing biodiversity. By preventing some organims from becoming too plentiful, parasites foster biodiversity. One may even argue that because parasites appeared very early in evolutionary history, the enormous biodiversity wittnessed today has evolved.

The Working Group discussed these issues and concluded that greater attention being paid to the interactions of parasites and disease agents with other community members, when considering biodiversity as a tool in environmental assessment. Inappropriate management decisions may be taken when trying to foster biodiversity on the basis of free-living animals and plants alone. This also holds for bio-diversity conservation when considering site selection mariculture and environmental regulations imposed on mariculture and other coastal resource users.

4.3 WWW (World-Wide-Web)

The Working Group noted that there are presently a number of activites internationally that address CZM issues which are currently listed on the World Wide Webb (WWW). Some of these projects and activities had been brougth to the attention of the Working Group are listed below. It was also noted that the WWW is increasingly in use and may soon develop into a major information tool with a broad impact internationally. There is a rapid expansion of the use of WWW by environmental groups and many of the environmental agencies have responded accordingly. The Working Group noted this development and some members expressed concern about the total lack of quality control of this modern media-tool. As a consquence national and international organisations may have
AIDAIR (EUREKA EU1388) is a project that concentrates on urban and industrial air pollution aspects along the coasts of European countries and includes collaboration with a large group of European partners.

ECoSA stand for a project on "Education and Communication for Sustainability" in Africa. the project places major emphasis on extensive surveys of environmental conditions and makes educational provisions for visualisation of the information.
A Multi-media framework system has been developed by ESS (Environmental Software & Services GmbH, Austria). A similar activity is noted as EARSS which has developed with participation of UNEP for the Asia-Pacific region: a first prototype of the global system was presented at the NGO Global Forum during UNCED 92 in Rio. Basic elements of this prototype system are already available through WWW server: http//www.essaca.co.at.

EARSS is an interactive information and assessment system, designed to support environmental assessment and resource management tasks at a global, regional and national scale. It integrates a large set of environmental and related socio-economic data bases, a geographical information system, domain-specific simulation models

(e.g., water resources, air quality, soil/land management) and a rule-based expert system for the assessment of environmental issues.

Several other models are mentioned here that are exploited in expert systems in areas relevant to coastal zone issues:

a Gaussian air quality model, derived from the UNAMAP guideline series model ISC (Industrial Source Complex), a multiple point- and area source model for both short-term and long-term scenarios, including a pollution control optimization component.

a 1D dynamic water quality model based on STREAM - 1, including a waste load allocation component (developed in collaboration with IT bombay)

a 2D vertically integrated finite difference groundwater flow and transport model has also been developed.

a generic qualitative simulation method to address complex dynamic issues such as deforestation, land use change, urbanization, population development, etc (developed with CESIMO, Venezuela) is internationally promoted in South America. It is onknown to what extent coastal aspects are addressed. There may be opportunitie

a rule-based expert system for environmental impact assessment for resource management projects (developed for the Mekong Ssecretariat, Bangkok) show promises for wider application.

Because of its WWW orientation the project will use 'HTML 3.0, GIF, and MPEG as the basic file formats for browsers such as Mosaic and Netscape.

There are a number of new developments rapidly being promoted through WWW on internet. Some of them were briefly mentioned during the WG meeting and are listed as follows:

"Coastal Ecosystem Health" is a programme run by NOAA (National Oceanic and Atmospheric Administration, U.S. Department of Commerce (..//www.noaa. gov/coastal_ecosystems_health.html (03/14/96, 22:09:21h) which tries to create a coordinated management approach among its relevant programme offices, atttempting also to create partnerships with the states of other Federal agencies to implement the programme and coordinate management responsibilities. Existing and proposed efforts will be organized into five functional areas:
1. integrated management operations , 2. assessment, 3 monitoring,4 understanding education and 5 outreach.

The Working Group recommends to carefully check the available material while considering to prepare an own WWW Home page and seek approval by the Councel for release through the Secretary General.

5. Working Group Recommendations:

The Working Group on Environmental Interaction of Mariculture (WGEIM) recommends that:

(a) the Mariculture Committe recommends to ICES to take a pro-active role in promoting the integration of mariculture into the formulation of policies, plans, and

management strategies for sustainable coastal resource development through the organisation of interdisciplinary workshops with other users of the coastal resources.
Justification: Mariculture has a legitimate right of access to resources in coastal regions. At the same time every effort should be made to ensure the effective integration of mariculture with other resource users to achieve the maximum possible social and economic benefits while maintaining the ecological integrity of coastal systems and quality of the environment. This can be best achieved by ICES inviting experts from other walks of life to participate in ICES Workshops and Symposia, thereby providing a neutral forum for the exchange of information that would permit a more objective recognition and understanding of issues affecting the sustainable development of capture fisheries and mariculture. ICES has a wealth of technical information and expertise on capture fisheries and mariculture that needs to be more effectively communicated to policy makers, planners and the other resource users. The WG feels that the approach outlined above could achieve a "Clearing House"-function where ICES reaches out to other interested and affected parties and facilitates a positive dialogue.

(b) that ICES publishes the Proceedings of the Kiel Workshop (Editors H.Rosenthal, P. Burbridge, E. Black, H. Ackefors, M. Bilio, I. Davies) as a Cooperative Research Report after editorial review of the report and of selected papers.
Justification: The editorial Committee has undertaken major efforts to evaluate the material presented at the meeting and started to edit the manuscripts as well as the body of the report (see ICES Doc F:5, 1995) and will submit the final document for publication at the 1996 Statutory Meeting. It is anticipated this will be a concise document of no more than 100 pages.

(c) that a Symposium be organised on "Modelling the environmental Interactions on Mariculture" which covers a broad range of management, environmental and regulatory issues and includes expertise from outside the ICES area thereby providing a more global scope.
Justification: This Symposium was recommended by the participants of the Halifax Workshop and will address isssues that could not be covered at that Workshop and will carry forward the momentum generated by the previous workshop and by the cooperative research report under preparation. It was recognized that mariculture and coastal zone issues are increasingly considered in research and development projects outside the ICES area and that the effectiveness of improving the various modelling approaches within ICES would greatly benefit from such an inflow of expertise.

(d) that countries in the ICES area should be encouraged to establish environmental objectives for mariculture with defined targets and measurable results.
Justifaction: Reviewing existing and potential conflicts with other coastal zone users and noting the developments in Norway due attention should be given to trends in future coastal resource development. The priority topics for which objectives should be set include escapees, diseases, medicines, chemicals and organic materials.

(e) that priority should be given to updating the Cooperative Technical Report (No 202, 1994) on Chemical Use in Mariculture at the next meeting.
Justifcation: Recent changes in ICES member countries and the EU with regard to regulations as well as the recently published studies on the fate and effects of antimicrobials require adjustments and expansion of several sections of the report.

(f). that the Mariculture Committee and ACME seeks assistance from member states to provide information on chemicals presently under development and testing for use in mariculture so that WGEIM can fully prepare its TORs for the next meeting in order to review and update the CRR on Chemicals in Mariculture to take into account new developments in the range of chemicals used in mariculture in the ICES area.

Justification: There is a need for clarification of the conceptual framework within which the environmental significance of existing and new anti-microbial agents in sediments can be assessed, for example in relation to product authorisation/licensing and environmental monitoring programmes. It is for this reason that the WGEIM invites ACME to note that there are likely to be a number of new compounds licensed for use on fish which have modes of action and physico-chemical properties that suggest that toxicity of fish farm wastes in sediment must still be considered. OSPARCOM has expressed concern on the way in which chemicals used in Mariculture affect marine biota, in particular the concentrations (and quantities) used and their biological effects. As outlined in this report, a number of new chemicals are presently being tested for licencing, requiring an early update of the passed report.

(g) that advice been given through the Mariculture Committee and its Working Group on "Genetic Interactions of wild and escaped fish" on the subject with special emphasis being placed on the items outlined below:

(1) What is the role that natural selection plays in adapting salmonid populations to individual streams when those poulations are so small as to be unable to overcome the effects of genetic drift between generations?

(2) Are there data available that permit estimation of the minimum effective population size required to allow natural selection to adapt a population to a particular habitat?

(3) Does emprical evidence exist that indicates the population sizes required to maintain genetic diversity in a population of salmonids.

(4) What are the implications of enhancement efforts resulting in increased by-catch of wild stocks to the point that the genetic integrety of the wild stocks is threatened?

(5) What empirical evidence does exist that the practice of enhancing stocks based on genetic material taken from the river to be enhanced has successfully halted the deterioration local gene pools due the effect of the enhancement program?

The Working group discussed these aspects to some extent and felt that the subject is well within its TORs although the specific expertise is not available within the group. However, advice is needed to understand better the genetic principles involved in order to allow to better address the implications knowledge has on integrated coastal zone management strategies.

(h) that a Symposium be organised on "Modelling the Environmental Interactions of Mariculture" which covers a broad range of management, environmental and regulatory issues and includes expertise from outside the ICES area, thereby providing a more global scope.
Justification: This Symposium was recommended by the participants in the Halifax Workshop; it will address a broader range of isssues than could be covered at that Workshop on "Modelling Environmental Interactions of Mariculture". It will carry forward the momentum generated by the previous Workshops in Halifax in September 1995

and in Plymouth in October 1996, as well as by the cooperative research report which is currently under preparation. This proposal is based on the realisation that mariculture and coastal zone issues are increasingly significant in research and development projects outside the ICES area, and the effectiveness of modelling approaches within ICES would greatly benefit from such an inflow of expertise.
The Symposium will be organized in Bedford Institute of Oceanography in Halifax, Canada, in November 1997 for 5 days.
The co-convenors, Bill Silvert and Maurice Héral, will nominate (in consultation with the working group) a steering committee in order to prepare an outline of the intended programme before September 1996.

(i) That the Mariculture Committee approves the publication of a Cooperative Research Report on Modelling the Environmental Interactions of Mariculture, which is presently being prepared by the Modelling Subgroup of WGEIM, incorporating the Halifax workshop material, the document sections prepared during the subsequent working group reports and special invited reviews written by the editorial Committee as identified below.

Justification: Because of the rapid growth in modelling it is increasingly difficult to identify what work has been done and where to find it. Much of the relevant material has been presented at workshops and has not yet appeared in the primary literature. A cooperative research report summarising the state of the art in modelling the environmental interactions of mariculture will help alleviate this problem By gathering together information on modelling approaches from the primary and secondary literature, as well as from other sources available to members of the Working Group, a valuable resource will be created which will help scientists and managers identify the best approaches for modelling environmental impacts and will also contribute to standardisation in this field, which will further facilitate communication between different groups and countries.

A preliminary outline of this report is as follows:

Introduction: what and why are models?
Definitions
Techniques
- *Languages*
- *GIS*
- *Sensitivity analysis*

Space and Time Scales
Model Architecture
- *Physical submodels*
- *Biological submodels*
- *Water quality submodels*

Carrying Capacity
Holding and Assimilative Capacity
Evolution of effects
Decision Support
- *Classification of sites and areas*
- *Decision Support Systems*
- *GIS linkages*

EIM in the context of CZM
References

(K) That a Working group suggests a subgroup should be set up to outline the best management practices for integrating mariculture with other neighbouring coastal activities such as local fisheries, tourism, tourism and nature conservation. In particular agriculture has to be integrated with all other activities affecting water quality in the catchment area.

(L). The workig group suggests the parent committee ask the Consultative Committee to recommend multi-disciplinary integrated research to understand complex interactions of the coastal zone. This can only be achieved by means of examining alternative scenerios in order to arrive at the best practices for integrating coastal area management. This must involve a combination of social scientists, geographers, institutional economists, resource biologists, systems ecologists and planners with a view to intergration. Some of the particularly needed expertise relates to those oriented towards sysnthesis in Geographic Information Systems or for use in mathematical modeling.

(M) ACME are invited ICES to consider the implications of institutional biases which tends to direct monetary resources into selected fields of marine activities, emphasis should be placed on developing institutional knowledge which intergrates research tasks and otimise coastal management.

6. TORs FOR THE NEXT WORKING GROUP MEETING

The Working Group recommends that

the next meeting of the Working Group on Environmental Interactions of Mariculture to be convened at the Weymouth laboratory, UK, for 4 days in March , 1997 in order to fullfil the following tasks:

(a) to update the catalogue of completed, ongoing , and new research programmes on environmental interactions and related issues of mariculture in ICES member countries and identify research priorities

(b) to collect and evaluate material intersessionally on new chemicals used in mariculture with the aim to prepare an update (or Annex?) to the existing document on "Chemical Usage in Mariculture" (Cooperative Research Report no 202, 1994).

(c) to report on the problem of the utility of "biodiversity" in the context of environmental interactions of mariculture (i.e. Development of the EU Stress indicator in the context of the "Green Accounting and Sustainability" concept)

(d) to report on case studies concerning the incorporation of mariculture in coastal area planning and managment with emphasis on criteria and structures leading to success.

7. COUNTRY REPORTS

7.1 Canada (by E.A. Black, Victoria, B.C.)

7.1.1 Aquaculture production in coastal waters

Table 1 provides an overview on the 1994 production level for coastal aquaculture in Atlantic Canada and along the coast of British Columbia. The breakdown by provinces is indicated by the following abbreviations

Table 1: 1994 Canadian Mariculture Production Statistics (Tonnes)

	Salmon	Trout and Steelhead *	Char	Clams	Oysters	Mussels	Scallops
NFLD	46	334	15			400	12
NB	11,836	325			413	78	
NS		190		7	96	439	6
PEI		31	23		2,0352	5,950	1
Quebec		1,500				31	2
BC	20,000	115	5	390	5,223		19
TOTAL	32,426	2495	43	397	7,767	6,898	40

* Some undetermined portion of this is production in freshwater

7.1.2 Integrated Coastal Area Management

Initatives have been undertaken to built a basis upon which an integrated plan for multiple use of coastal resources may be derived. Present initiaties to inclde aquaculture in this plan have developed from past efforts to inventory areas considered most favorable to fish and shellfish culture as well as past efforts to identify coastal areas where aquaculture would be a preferred type of development. In addition there has been some development of mathematical models of environmental caring capacity for both salmon and bivalve culture. Attempts are also underway to allow for the effects of development watersheds draining into the coastal waters on proposeed uses of coastal waters.

Fish farming

Salmon farming on the Canadian west coast has been stable butwithout significant production growth since 1991. Contributingto this situation has been a desire by government to more fullyunderstand the role that fish farming will play an integratedcoastal area management scheme. To this end a literature reviewhas been done on the potential environmental interactions of fishfarming (The Environmental Effects of Salmon Netcage Culture inBritish Columbia by EUS Environmental Consultants Ltd. andHatfield Consultants Ltd., April 1996) . This is the fourth such reviews since 1987. It differs from pevious reviews in that considerably more information is now available on these interactions and, the study focuses more on data derived from studies in BritishColumbia.

While production has not significantly increased since 1991 there has been a marked shifts in what is being produced and where it is being produced. In 1991 Atlantic salmon constituted approximately 18% of production while the Pacific salmon constituted 82%. In 1994 66% of production was Atlantic salmon and only 34% was from the Pacific salmon species . At the same time there has been a relocation of farm sites. In 1980's the industry was heavily concentrated in Jervis and Sechelt inlets areas on the central eastern portion of the enclosed waters of the Strait of Georgia. Experience gained in this area demonstrated that many site initially occupied were less than ideal consequently there are almost no farms are left in this area. Most af the farms are now located on the west coast of Vancouver island or in waters contguous with the Queen Charlotte Sound area. Waters in these areas.

Shellfish Culture

Shellfish culture practices are changing due to a comibination of increasing production, urban pressure and climate change. Culture activities in Baynes Sound (a major oyster growing area) and in the Strait of Georgia generally, are suffering from the effects of an increased population base which has lead to inncreased coliform counts in culture waters and a consequent increase in the frequency of harvest closures. There is also concern that harvest closures due to red tides may be increasing in both frequency and duration. It is unclear if any trend in phytoplankton related problems is due to the effects of urbanization or if it is consequence of global warming. At the same time a lack of new sites expand production has meant that increases production capacity has been gained by moving more to intensive raft culture and the employment of FLUPSY (FLoating UPwelling SYstems). Such systems are both visually more apparent and acoustically more invasive thus increasing the potential for conflict with urban developmet and recreation. In addition the movement to more intensive culture methods increases the potential to impact on the carrying capacity of local waters for bivalve growth.

7.2 **Denmark** (by Eva Roth (DIFER) Nantes)

7.2.1 Production:

Trout in Freshwater:

Table 1. Production of rainbow trout in freshwater ponds, and number of plants

Year	Number of plants (approx)	Production in tonnes	Egg produc-tion in tonnes (of total)	Average unit price in DKK/kg	Value of total production in mill. DKK
1992	480	35,300	56	13.79	487
1993	490	34,200	60	16.07	550
1994	485	34,900	63	16.00	558

Source: Association of Danish Trout Farmers

Notes: Production is grown weight incl. dead fish during the production process. Number of plants are found in various public sources. Production value is estimated.

The fresh water trout farmers produce in ponds mostly using surface water supply. The feed conversion for trout farms have decreased from 1.25 kg feed per kg produced fish in 1989 till 1.00 kg feed in 1994.

Mariculture (sea cage farming):

Table 2. Production of rainbow trout in sea cages

Year	Production in tonnes	Number of sites	Value in mio.DKK
1992	6,798	30	182
1993	7,852	31	157
1994	6,793	30	NA

Source: Yearbook of Fisheries Statistics 1993, Jordbrug og Fiskeri 1994, Ministry of Agriculture and Fisheries, 1995.

In 1994 the average feed per production site was just under 200 tonnes and the average production was 165 tonnes. The average ration of feed per kg production was estimated as 1.18 (Ministry of Environment, Orientation on the Environment, no. 10, 1995: Point Sources 1994). The maximum amount of peopele employed is 320 and the mean number of employed during 1994 were 141.

Land based production using Seawater:

Table 3. Production of rainbow trout in land based seawater ponds

Year	Production in tonnes	Production in mill. DKK
1992	750	21
1993	1500	13
1994	1500	NA

Source, as table 2
Note: Production 1994 estimated from used feed 1800 tonnes and conversion ratio of 1.14.

The development of land based seawater ponds requires rather substantial investments.

Eel farming

Table 4. Production of eel and no. of eel farms

Year	Est. number of eel farmers	Production in tonnes	Value of production in 1000' DKK
1992	55	900	49,500
1993	40	1000	55,000
1994	37	1100 (prel.)	60,500

Source: Danish Association of Eel Farmers, interview.
Note: The value is calculated from unit price of 55 DKK/kg.

The individual production plant vary from 2 to 50 tonnes of production. Eel is considered a slow growing species. The industry employs approximately 100 people (1995). A major problem for the developement of the industry is the dependency of wild glass eel as input of production. Eel is also restocked in the Danish streams and rivers.

Mariculture - other species than rainbow trout:

Small scale trial production of other species for reseach purposes are carried out in Denmark. The aim is to use these species for restocking of lakes and streams, but also reseach into restocking of turbot and plaice is carried out.

Ministry of Agriculture and Fisheries has registred 2 farms as producing 3 tonnes of mussels and 20 tonnes of oysters.

7.2.2 National Policy and regulations:

Freshwater aquaculture require a production permit registered under the list of polluting industries. (Regulation no.358 of 6'th of June 1991)

The freshwater farming regulations incl. directives (1989) guiding production, maximum amount of feed per annum, the maximum differens in inlet and outlet water with respect to total phosphor, total nitrogen and suspended solids as well as oxigen saturation. Further specific water treatment facilities are specified inb the directive. (Order no.224 of 5'th of April 1989)

A permit to abstract water must be obtained from the County according to the Regulation of Water Supply (Regulation no. 337 of 4'th of July 1985). Most of these permits have to be reissued in 2005 which will be of crucial importance to the freshwater farmers.

Further changes on abstraction of surface water for production purposes are passed for 2005 and in reality no new plants are licensed for production implying wateruse from natural streams and lakes with direct outlet.

Establishment of mariculture in cages requires permission from Ministry of Agriculture and Fisheries, Ministry of the Environment and the County (Orders no 122 of 1'st of March 1991, no 306 of 4'th of June 1986, no 640 of 17'th of September 1990). Issuing new permits were suspended from 1986 to 1991 and all permits expired in 1992. At the moment 30 plants are in operation and it is unlikely that new permits be given.

Pollution permits, maximum allowabel feed, and site location is determined by the county but must be in accordance with the order for seawater based fish farming. For each farm the maximum amaout of feed, the quality of feed, maximum use of feed per produced kg fish, discharge of total P and total N are determined. Self control and reporting are part of the management system. Land based production using seawater is amnaged in accordance with the rules for the above.

Eel farming requirements are different as most Danish farms run in fully integrated recicling systems and do not directly influence the naturel environment.

The 2 mentioned permits for growing of mussels and oysters on Danish territory follow the Regulation of Seawater fisheries no 306 of 4'th of June 1986. The relevant Authorities have to be heard to safeguard the environment and other interests.

7.2.3 Support Measures for the Danish aquaculture sector:

In the period 1987 - 1990 there has been given support to the following projects according to Regulation 4028/86 and 222 of 22nd of April 1987 (EU Structural Fonds and Ministry of Fisheries).

Table 5. Support according 4028/86 during the period 1987-1990

Production category	Number of projects supported	Investment amount entiteled to support mill.DKK
Seawater cages	2	2.2
Land based seawater farms	3	40
Eel farms	16	71

Source. Developement programme for Danish Aquaculture 1992-1996, Ministry of Fisheries.

Through regulation 4020/93 9.17 mill ECU were granted to Danish aquaculture of FIFG fonds and 1.83 national fonds.

Table 6. Support according to 4020/93 during the period 1994-1996.

Year	FIFG support in mill. DKK	National support in mill.DKK
1994	3.9	0.9
1995	6.1	1.2
1996 (expected)	20	4

Source: Directorate of Structural Fonds.

Earlier the Ministry of Environment supported related investments but investments today are considered product oriented rather than environmentally oriented and therefore handled through the Directorate of Structural Fonds.

7.2.4 Expectations for the Future development of Danish Fish culture:

At present a Plan of Perspektive for the Aquacultural sector is being prepared by Ministry of Agriculture and Fisheries. It is expected June 1996.

Acknowledgement: Informations have been given from Ministry of Agriculture and Fisheries, The named Associations of Trout and Eel Farmers as well as internal material gathered by collegues at The Danish Institute of Fisheries Economics Research (DIFER)

Eva Roth (DIFER) Nantes, 27.3.96

7.3 England & Wales (by B.E. Spencer, MAFF, Fisheries Lab., United Kingdom)

7.3.1 Production

Flat oyster production is around 200 tonnes per year. The Solent Fishery is the only natural source of seed, which is used mainly for relaying on the east coast of England (in Essex).

Around 600 tonnes of Pacific oysters are harvested per year, cultivated from seed produced in UK hatcheries. In recent years there has been evidence of light spatfalls in British waters near to sites of commercial cultivation. There is no evidence that self-sustaining populations have developed, or are likely to in the future.

Reference:

Spencer, B.E., Edwards, D.B. & Kaiser, M.J., 1994. Spatfalls of the non-native Pacific oyster, *Crassostrea gigas*, in British waters. Aquatic conservation: Marine and Freshwater Ecosystems, Vol. 4, 203-217.

Production of Manila clams, which is also dependent on hatchery-produced seed, remains at 50 tonnes per year.

The production of mussels is approximately 3000 tonnes per year.

7.3.2 Research Topics Associated with Marine Aquaculture in England and Wales

Fisheries Laboratory, Conwy

1. A 4-year project on the environmental impact of intertidal clam cultivation in the River Exe is complete. The netting that protected the clams, rather than the clams themselves, resulted in an increase in the ground elevation of around 10 cm and encouraged higher densities of some infaunal worms. There was no change in species diversity relative to a control area. The impacts of harvesting (by dredging) were localised and not long-lasting.

Relevant references:

Anon, 1996. Clam cultivation: localised environmental effects. Results of an experiment in the River Exe, Devon (1991-1995). MAFF, DFR, Conwy, 10 pp.

Spencer, B.E., Kaiser, M.J. & Edwards, D.B. 1996. The effect of Manila clam cultivation on an intertidal benthic community: the early cultivation phase. Aquaculture Research (in press).

Spencer, B.E., Kaiser, M.J. & Edwards, D.B. An experimental investigation of the effects of Manila clam cultivation: observations at the end of the cultivation phase. J. Appl. Anim. Ecol. (submitted Jan. 1996)

2. Studies continue on the production and viability of triploid bivalves. Emphasis is on non-indigenous species that are cultivated in the UK and most of the studies have concentrated on the Manila clam. Triploids were produced using the chemical cytochalasin B but 100% triploidy was never achieved.

In 1995, a 3-year project was started on Pacific oysters assessing methods other than cytochalasin B for producing triploids. The aim is to produce 100 % triploid seed by cross breeding tetraploid and diploid broodstocks. The first target is to produce tetraploid oysters.

Relevant references:

Utting, S.D., Millican P.F. & Laing, I. 1996. The breeding potential and biochemical composition of triploid Manila clams (*Tapes philippinarum* Adams and Reeve). Aquaculture Res., 27: (in press).

3. One of the constraints to the further development of scallop farming in the UK is the availability of reliable supplies of spat for on-growing. Spat are collected from the wild during the summer and numbers are very variable from year to year. In an attempt to increase the supply of seed, the potential for the hatchery production of scallop (*Pecten maximus*) seed is being assessed.

A 4-year study on the hatchery production of scallop seed is nearing completion. Methods of conditioning animals to spawn in the late winter and early spring months have focused on the quantity and quality of micoalgae to feed in the diets in order to maximise the number and quality of eggs produced.

During the hatchery rearing of larvae and spat, major losses occur from the end of the larval phase through to 2 mm spat. A follow-on 3 year study will begin in April 1996 with the aim of improving survival of scallops through metamorphosis.

Other institutes

1. A 3-year study on the physiological and biochemical changes in seed scallops that occur as a result of their transfer from the hatchery/collecting site to the on-growing site was started recently (February 1996) at the School of Ocean Sciences, Bangor, North Wales. Improved transportation techniques will be developed and assessed since a major constraint to the development of scallop aquaculture in the UK, and elsewhere, is the significant losses of seed that occur both during and as a result of inappropriate transfer techniques.

List of Publications

Anon, 1996. Clam cultivation: localised environmental effects. Results of an experiment in the River Exe, Devon (1991-1995). MAFF, DFR, Conwy, 10 pp.

Child, A.R., Papageorgiou, P. & Beaumont, A. R. 1995. Pacific oysters *Crassostrea gigas* (Thunberg) of possible French origin in natural spat in the British Isles. Aquatic Conservation: Marine and Freshwater Ecosystems, Vol. 5, 173-177.

Howard, A. E. 1994. The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. Eur. Assoc. Fish Pathol., 14: 212.

Laing, I. 1995. Ballast water exchange at ports in England and Wales. MAFF, Directorate of Fisheries Research, Conwy. 24pp.

Laing, I. & Child, A.R. 1996. Comparative tolerance of small juvenile palourdes (Tapes decussatus L.) and manila clams (Tapes philippinarum Adams & Reeve) to low temperature. J. Exp. Mar. Biol. Ecol. (in press).

Laing, I. & Spencer, B.E. Selecting a site for bivalve cultivation. Laboratory Leaflet, MAFF, DFR, Lowestoft (in preparation).

Spencer, B.E., Edwards, D.B. & Kaiser, M.J., 1994. Spatfalls of the non-native Pacific oyster, *Crassostrea gigas*, in British waters. Aquatic Conservation: Marine and Freshwater Ecosystems, Vol. 4, 203-217.

Spencer, B.E., Kaiser, M.J. & Edwards, D.B. 1996. The effect of Manila clam cultivation on an intertidal benthic community: the early cultivation phase. Aquaculture Research (in press).

Spencer, B.E., Kaiser, M.J. & Edwards, D.B. An experimental investigation of the effects of Manila clam cultivation: observations at the end of the cultivation phase. J. Appl. Anim. Ecol. (submitted Jan. 1996)

Utting, S.D., Millican P.F. & Laing, I. 1996. The breeding potential and biochemical composition of triploid Manila clams (*Tapes philippinarum* Adams and Reeve). Aquaculture Res., 27: (in press).

7.3.3 Ballast water studies

1. A 6-month desk study was carried out by MAFF to assess how much ballast water was exchanged at ports in England and Wales. Questionnaires were sent to 127 ports of which 87% responded. The main findings were:

- Ballast water is discharged into 49% of ports and it is estimated from the information supplied that there are more than 36,000 ballast water exchange operations per year.
- Ports in England and Wales are net importers of bulk cargoes and approximately 1.6 times more ballast water is loaded than is discharged.
- An estimated 16.8 million tonnes of ballast water is discharged annually into ports with oil and gas tankers contributing 75% of the total.
- Only 4 ports reported discharge of ballast originating from outside continental Europe. By volume, ballast water from this origin accounted for about 11% of the total. These results should be treated with caution since accurate information on port of origin was not always available and ballast water may have been loaded at a location other than the last port of call.
- 79% of ports have no policy or regulations on management of ballast water discharge. Only 5 ports request compliance with IMO guidelines.

(From: Laing, I. 1995. Ballast water exchange at ports in England and Wales. MAFF, DFR, Conwy, 24pp.)

2. Following on from the desk study, a 3-year research project will be carried out by the School of Ocean Sciences, Menai Bridge, Bangor (contact Dr I Lucas) to assess further the risk of introductions of alien marine organisms into coastal waters of England and Wales. A sampling programme will be carried out to determine the number and type of viable marine organisms transported in ballast water into coastal waters of England and Wales. The strategy for the sampling programme will be based on the results of the questionnaire survey.

This research programme will complement studies being carried out in Scotland and a UK database on ballast water organisms will be developed.

3. The project on ballast water treatment using a commercial copper/silver electrode system which was sponsored by the UK Marine Safety Agency was completed. A report was prepared for the Agency.

BIBLIOGRAPHY

<u>Ballast water</u>:

Laing, I. 1995. Ballast water exchange at ports in England and Wales. MAFF, DFR, Conwy, 24pp.

Other:

Howard, A.E., 1994. The possibility of long distance transmission of *Bonamia* by fouling on boat hulls. Eur. Assoc. Fish Pathol., 14: 212.

OTHER BIBLIOGRAPHY RELEVANT TO WG

Anon, 1996. 'Metamorphosis' paper greeted with derision. New Scientist, 10 February, p6.
Anon, 1995. Mediterranean toxic algae growth fears. Fish Farming International 22(2): p. 40.

7.3.4 Institutions/ administrative organisations involved in coastal zone management

1. Shipping

Various - including Department of Transport, local port/harbour authorities, Marine Protection Agency.

2. Harbour planning

Various - including Department of Transport, local port/harbour authorities, Association of British Ports.

3. Coastal tourism development

Local authorities

4. Coastal resource management

Organised through estuary and coastal management plans involving a range of organisations.

Management plans (at various stages of development) are in place for most of England & Wales coastline e.g. Exe Estuary Management Plan, Wash Management Strategy Forum, Salcombe Kingsbridge Estuary Management Plan.

English Nature is a Government organisation that is monitoring all estuaries in England in relation to conservation issues. The Countryside Council for Wales and the Joint Nature Conservancy Council (Government organisations) also participate in coastal resource management in relation to conservation issues.

Non-governmental bodies and voluntary groups are active to varying degrees in coastal zone management, e.g. Marine Forum for Environmental Issues, Loo Voluntary Marine Conservation Area, Humber Forum, Morecambe Bay Conservation Group.

7.4 France (by: Kempf Marc, Michel Merceron, Antoine Dosdat, Maurice Heral, Jean Prou & Alain Ferbvre, IFREMER)

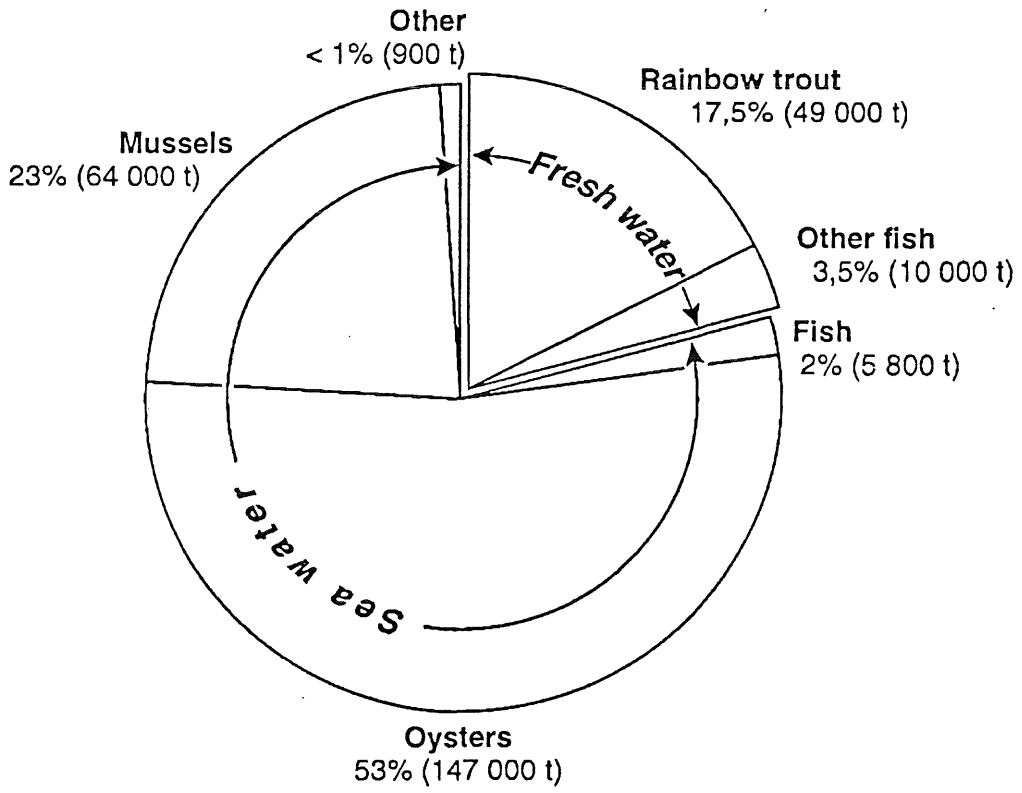
7.4.1 Brief picture of the french aquaculture

French aquaculture is characterized by a great diversity of species, as well as by the coexistence of traditional activities (marine shellfish, freshwater fish culture) with more recent and still developing ones (marine fish culture, new practices in shellfish growing, use of underground sea water, human food algae, new freshwater species, etc.). Traditional cultures are the main contributors to the tonnage produced. Another noticeable point is the importance of the Channel-Atlantic part of the country, which carries the main part of the production (> 80%) : coastal area for shellfish, and nearby rivers for freshwater salmonid farming. On the Mediterranean coast, marine fish farming of bass and bream as well as shellfish production by new methods (mussels on longlines in open waters) are developing.

7.4.2 Production

The significant numbers of the sector are summarized on the following figures, the present status and evolution appearing later on according to the species.

Main figures of French aquaculture (1994)
Distribution of gross production (tons)



Main figures of French aquaculture (1994, ultramarine not included). Gross production in tons, turn-over in million FF
Sources IFREMER (Ph. PAQUOTTE), FIOM, Ministry of Agriculture (fresh water)

	Gross Production tons	(%)	Turn-Over MFF	(%)	Exploitations number	(%)	Employment number	(%)
FRESH WATER FISH:								
Trouts	49 000	(17,5)	750	(22,0)	720 (1)	(13,0)	1800	(13,5)
Other	10 000	(3,5)	150	(4,0)	800 (a+b)		?	
Total	59 000	(21,0)	900	(26,0)	~1000	(18,0)	> 1800	(13,5)
SEA : FISH								
All sp.	5800	(2,0)	280(2)	(8,0)	60	(1,0)	350 (a)	(2,5)
SEA: OYSTERS & MUSSELS								
Oysters	147 000	(53,0)	1770	(51,5)	4500	(81,0)	8000 (a)	
Mussels	64 000	(23,0)	460	(13,5)			5000 (b)	
Total	211 000	(76,0)	2230	(65,0)	4500	(81,0)	~ 11 000	(84,0)
SEA: OTHER SPECIES								
Diverse	900	(0,5)	30	(1,0)	6 (a)+ 150 (b)	(<1,0)		?
SEA: TOTAL	217 700	(78,5)	2540	(74,0)	>4570	(82.0)	~11 350	(86,5)
GRAN TOTAL	276 700	(100,0)	3440	(100,0)	> 5270	(100,0)	>13.150	(100,0)

(1) 720 salmonid farms, i.e. 560 commercial firms and 160 restocking units
(2) Turn-over including sale of fry (self consuming not accounted for)
(3) Other marine species : manila clam, scallop, shrimp, algae (numbers partly concerning 1993)
(a) Main or single activity, full time
(b) Complementary activity, part time.

7.4.3 Molluscs

JAPANESE OYSTER

The Japanese oyster (*Crassostrea gigas*) dominates French aquaculture production. Almost all of it is consumed in France, which is thus the main oyster farming and consuming country in Europe.
Oyster farming is basically a traditional, artesanal, family scale activity. Because of this, it shows some structural difficulties which influence both market prices and management of farming zones. Attempts by the producers to obtain labels of quality and origin are aimed at improving the market price. Research is carried out to define

Marine fish farming production in France 1990-1995
(source IFREMER, SEM)

	Production (tonnes)					
Espèce	**1990**	**1991**	**1992**	**1993**	**1994**	***1995****
Atlantic salmon (*Salmo salar*)	1 000	980	950	240	455	500
Rainbow trout (*Oncorhynchus mykis*)				500	455	1 500
Brown trout (*Salmo trutta*)				175	890	
Turbot (*Scophthalmus maximus*)	35	100	150	440	630	800
Sea bass (*Dicentrarchus labrax*)	375	750	1300	1990	2190	2 300
Sea bream (*Sparus aurata*)				385	1160	1 300
Total	1 410	1 830	2400	3730	5780	6 400

* 1995 : Speculations based on stock estimates, to be confirmed

organoleptic and biochemical characteristics of both Japanese oysters and mussels, to enable connections to be made between products and their geographical origins and growing techniques. Some farming zones are overloaded, and consequently, oyster growth rates are decreasing. On the other hand, due to "remote settlement" techniques, use of hatchery-originated seed is increasing (presently 10% of seed production). In 1995, production suffered from some natural hazards, such as exhaustion due to early maturation after a mild winter, and severe toxic plankton blooms. As regards pathology, the appearance of herpes-virus is to be noted, mainly in hatcheries.

FLAT OYSTER (*Ostrea edulis*)
The farming of this species is still affected by parasitic diseases, which broke out in the '80 's (*Marteilia and Bonamia*). This explains the persistent low level of its production (about 2000 t in 1993 and 2600 t in 1994, mainly in Brittany). Progress is being made to obtain disease resistant strains with help of genetic programmes.

MUSSELS (*Mytilus edulis, M. galloprovincialis*)
The French market is much more open for mussels than it is the case for Japanese oysters. Mussel farming production (about 60 000t) only supplies half of the national consumption. The difference is covered by wild stock fishing and imports from neighbouring countries (Netherlands and Spain). Due to natural fluctuations in recruitment and lack of stock management, fishing yields are irregular and may disrupt the market equilibrium (e.g. 60 000 t landed in 1993).

OTHER SPECIES (clam, scallop)
Farming of the Manila clam (*Ruditapes philippinarum*), an introduced species, was strongly hit by the unexpected success of its reproduction in the natural environment (in 1993, the cultivated production was only 300 t). Now, the yields come more and more from fishing (3 000 t in 1995).
The scallop, *Pecten maximus,* is farmed up to the juvenile stage, as a support of a seeding-recapture activity on its natural fishing grounds (about 50 t were produced by this technique in Brittany, in 1993 and 1994). The technical feasibility of scallop culture

has been demonstrated, but its economical return in the present conditions is not encouraging.

MONITORING NETWORKS

Shellfish for human consumption are controlled according to the French and European regulatory requirements. Both the shellfish and surrounding water quality are monitored on the shellfish sites during the growing phase. Oysters and mussels also constitute a useful material for monitoring levels and trends of environmental quality parameters. Finally, the growth rates of the commercially exploited species are followed up on the main culture grounds, according to a standardized methodology; this was put in practice for the Japanese oyster in 1993, and for the mussels in 1994. A special monitoring of molluscs was also set up, for pathologic and genetic purposes.
All these networks are managed by IFREMER :

- REMI (microbiology) : faecal bacteria, *Salmonella*
- REPHY (phytoplankton) : blooms, toxic species, toxicity tests
- RNO (environment quality) : levels and trends of pollutants in water, sediment and living material
- REMORA (molluscs) : growth, mortality and flesh quality of molluscs
- REPAMO (molluscs) : pathology
- REGEMO (molluscs) : genetics.

As regards the monitoring of risks to human health, signs of toxicity of unknown origin have appeared on several shellfish growing sites since 1993-1994.

SHELLFISH GROUND CLASSIFICATION

The sanitary classification of the shellfish grounds was updated in 1995 by the French authorities, according to the European criteria set by the EU directive 91/492 (table : Sanitary regulation). This relied mainly on the results of the microbiological monitoring network REMI. A major difficulty arose with public users of natural grounds, because the collection of shellfish at low tide or in shallow water is a favorite spare-time activity ; an aspect largely underestimated. According to the new regulation, direct consumption is now limited to zones classified as A (at least for commercial products).

MANAGEMENT OF GROWING ZONES

A carrying capacity model has already been set up by IFREMER in order to improve the management of the Marennes-Oleron bay, the largest oyster production area in France, which is partly affected by overstocking. This model is now being applied to other sites and species (oysters + cultivated mussels + wild mussels). The results of the previous model are now being integrated in a GIS in order to analyse the multiple uses of the above region, including fishery, agriculture, tourism ... The model is also used to identify suitable sites for deep water shellfish farming zones in an area where the usable intertidal space is fully occupied.

SANITARY REGULATION OF SHELLFISH PRODUCTION ZONES French regulation after EC directive n° 91/492 (15/07/91) (classification criteria according to faecal coliform bacteria concentration per 100 ml mashed flesh, CF/100 ml)				
	Zones	**Limits** CF/100 ml	**Exploitation**	
			Farming	Natural grounds
A	HEALTHY	300	Authorized (direct consumption)	Authorized (direct consumption)
B	UNHEALTHY	6 000	Authorized after purification or restocking in a healthy zone	Authorized after purification or restocking in a healthy zone
C	EXPLOITABLE	60 000	PROHIBITED (unless special dispensation)	Authorized after purification and/or restocking in a healthy zone
D	UNHEALTHY PROHIBITED		PROHIBITED	PROHIBITED

7.4.4 Crustaceans

The Japanese shrimp (*Penaeus japonicus*) is cultivated as a complement to other uses of marine salt marsh ponds. This production is low (30 t) and risky. Two nurseries supply the necessary juveniles.

7.4.5 Algae

Undaria pinnatifida, a human food algae from Asia, is beginning to be cultivated (10 t), but the development of this activity is still facing serious market problems in France, Europe and Japon.

7.4.6 Marine finfish

Although moderate, marine fish production is gradually increasing for all the major species (1400 t in 1990 - around 6000 t presently). In recent years, this arises from improved performance of existing farms. In the best case, some of them are extending their installations on the same site, but no new projects appear. Although market problems should not be excluded, this is mainly due to the great difficulties encountered in obtaining new sites, and to potential conflicts with other users of the coastal zone.

Due to constantly falling prices, semi-intensive bass growing in Atlantic marsh areas is facing serious economic difficulties, and this is prejudicing the maintenance of these man-made water systems in fully operational condition.

Present fish farming involves only a small number of species, all subject to market problems and concurrence as soon as their production grows. So, professionals recommend research to test new species among the Sparidae and Gadidae families.
The two leaders in fresh water trout merged and also entered sea farming. Thus, a major european group was created (16 000 t), integrating all phases of trout production, processing and marketing, as well as some marine activity.

SALMONIDS
Because of the climate and the sites, as well as the northern European mass production, the classical species are only grown in small quantities (Atlantic salmon, rainbow trout; Pacific salmon, *Oncorhynchus kisutch* is no more cultivated). The brown trout (*Salmo trutta fario*), better adapted to local Channel-Atlantic conditions, appears now as a replacement species, whose production is continuously developing. It is mainly devoted to transformation industry (1993: Atlantic salmon = 400 t; rainbow trout = 600 t; brown trout = 200 t)
(1994 : Atlantic salmon = 450 t; rainbow trout = 450 t ; brown trout = 900 t).

BASS AND BREAM
Sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus auratus*) production is expanding, especially on the Mediterranean coast (1991 = 700 t; 1992 = 1300 t; 1993 = 2200 t ; 1994 = 3 350 t). Nevertheless, one important hatchery and growing farm is located in the North Sea/Channel area using heated water from an electricity plant. The development of these species is hampered by the difficulty of obtaining new coastal sites (land use conflicts and environment protection pressure), as well as by price lowering due to regional competition for a limited market (15 000 t produced in the whole Mediterranean in 1992), and currency devaluation in the main consuming countries. The economic difficulties extended to bass hatcheries. In 1995, French fry production amounted 18.10^6 units (35 millions FF). The tendency is now to grow bass of larger size (different market, better price), and to increase the tonnage of bream. As a reaction to concurrence, fishermen set up a trade mark to distinguish line fished wild bass from fish of other origins.
Noda-virus, present in several European countries, has now also appeared in French farms.

TURBOT
The turbot (*Scophthalmus maximus*), an Atlantic species, still shows a small but expanding production (1991 = 60 t; 1992 = 130 t; 1993 = 400 t, 1994 = 600 t), and has also to face the site and market problems as the precedent species. Wild stock fishery yields also contribute to the price fluctuation.

7.4.7 Underground Sea Water

In several Atlantic marsh areas, the use of underground salt water is developping. The constant temperature (14°) regulates fish farming water, both in winter and summer, the main consumer being presently turbot growing. The high nutrient content

stimulates plant growth of both plankton and macroalgae (the latter still experimental). Plankton production sustains shellfish nurseries and pre-growing, as well as final stage oyster fattening. The increasing use of underground salt water requires special management and control, in order to preserve the resource.

7.4.8 Toxic Plankton Events And Other Hazards

A toxic event of *Heterosigma akashiwo* (ex. *H. carterae*, Rhapidophyceae) occurred for the first time in France in 1994. The algae bloomed in coastal waters around western Brittany in late August and September, killing farmed salmon and trout. Some time later (Nov. 1994-Jan. 1995), the jellyfish *Pelagia noctiluca* proliferated in the same area and hit the same farms. This time, losses were due to irritation and stress, requiring preventive slaughter to avoid future complications.
A series of important blooms of the dinoflagellate *Gymnodinium cf nagasakiense* occurred in 1995 along the Atlantic coast from northern Brittany to Arcachon, between May and early September. They were associated with spectacular kills of wild fauna (worms, urchins, gastropods, bivalves and fish) as well as cultivated shellfish and fish. Losses were specially important on several shellfish grounds. They affected also hatcheries, and a trout farm in western Brittany.

7.4.9 Freshwater Fish

The freshwater production is much larger than the seawater one, and involves mainly the rainbow trout. This activity started intensive developing thirty years ago, and now represents the highest production in Europe (around 50 000 t in 1993 and 1994). Three western regions supply the bulk of this production : Normandy, Brittany and Aquitaine, the two latter being responsible for more than half of the total. Freshwater trout farming also has to face the general decrease of the salmon price. The response is a diversification towards large sized fish for the transformation industry (8000 t > 1 kg in 1993), as well as towards marine fish growing (brown trout, turbot, bass), at least for the major farming groups.
Freshwater fish farming is also being extended to new species : Siberian sturgeon (facing economic and market difficulties), European catfish.

7.4.10 Intensive Fish Farming And The Environment

Some information about the interactions between intensive fish farming and the environment are worth noting :

- The legislation concerning the so-called "classified installations", i.e. those able to pollute, was recently revised (Dec.1993). It applies to fresh and seawater fish farms. According to it, the marine fish farms producing over 20 t/year require a licence, which needs a previsional impact study. The extent of this study is open to local administrative practices. The threshold of 20 t/y is very low in relation to general environmental needs, European standards (100 t/y) and profit-earning capacity of the farms.
- A Working Group on "regulatory aspects" was constituted in 1993. It concerns both fresh and salt water environments and its members belong to public administrations, research bodies (lawyers, scientists) and professional organizations.

- An applied research programme on intensive marine fish farming and the environment is under progress at IFREMER, including collaborators. Three main items concern (1) the quantification of feed originated wastes from southern European species such as bass and turbot, (2) the environmental impact of the farming activity (especially by enrichment) and (3) the reducing of final wastes by means of integrated forms of mariculture in salt marsh ponds.
- Research on the effects of veterinary products in fresh and seawater is increasing. It is carried out mainly by the Veterinary School of Nantes.
- Applied research on land-based farm waste water treatment is also increasing, both for fresh and seawater. In the latter case, it includes recirculation. Two small scale pilot projects (2-5 t) are operating for turbot and sea bass, repectively on the Atlantic and Mediterranean coast. The following phase is being prepared, concerning two economic-scale pilots (70-80 t) and international cooperation (with a third pilot in Iceland).

7.4.11 Mediterranean Cooperation

A regional cooperative approach to aquaculture is being followed under the general authority of the Council for Fisheries of the Mediterranean. Four distinct networks succeeded the past MEDRAP Programme :
- SIPAM : data base (Tunis)
- TECAM : technological aspects (Saragossa)
- SELAM : socio-economic aspects (Saragossa)
- EAM : aquaculture and the environment (Split).

France, through IFREMER, is partly supporting these actions.
The last network, EAM (Environment et Aquaculture en Méditerranée) has somewhat similar objectives to those of the present ICES WG on Environmental Interactions of Mariculture. It is coordinated by the Regional Centre of Activity of Split, Croatia, belonging to the UNEP Priority Action Plan for the Mediterranean (UNEP-MAP-PAP/RAC), mainly concerned with coastal zone planning and management. Meetings or seminars are regularly held in different countries (e.g. Heraklion, Crete, Nov. 1995, co-organized by IMBC).

7.4.12 Conclusion

French aquaculture, all species together, constitutes an economically significant activity and represents the largest European production in gross weight. It is equally important for land use and management, both for the countryside and the coastal zone. Mariculture has its main productions directly in the sea. It is very sensitive to the quality of the latter and should be concerned by the environment for its own interest. So, mariculture itself is also an element for environmental monitoring and protection. These points should be brought more actively to the attention of public opinion and also be taken into account in the evolution of the legislation and its application.

7.5 Germany (by H. Rosenthal, IfM Kiel)

Mariculture activites in Germany continued to decline because of the public resistance against the development of coastal systems. A major conflict arises along the former east German coast from the rapid development of eco-tourism. New licences for cage farms were not granted along the coast of Mecklenburg-Vorpommern. Furthermore,

several of the existing farms have ceased production. In 1995 about 150 tonnes brackish water production of rainbow trout was left and this will further decline to an estimated 40 tonnes in 1996. Mariculture along the Baltic coast is practised at only 3 sites in Mecklenburg-Vorpommern and 2 sites in Schleswig-Holstein.

Mussel culture in extensive beds combined to be the largest production in German coastal waters with 12 licences granted. One farm on the island Sylt is involved in culture of the Pacific oyster (*Crassostrea gigas*), using seed oysters from an Irish hatchery, while grow-out during summer months is performed on racks in the tidal flats of the Wadden Sea with overwintering indoors in a cold water recycling system.

7.6 Ireland (by J. Doyle, Fisheries Research Centre, Dublin)

1994 - 1996

7.6.1. Production trends (tonnes)

Finfish	1992	1993	1994	1995
Atlantic Salmon	9231	12,366	11,166	12,500E
Rainbow trout sea cage	600	677	613	600E
Rainbow trout freshwater	700	906	854	850E
Shellfish				
Pacific Oyster C. gigas	1750	2014	1862	N/A
Native Oyster *0. eduJis*	334	450	590	N/A
Mussels Suspended *M. edulis*	5090	4773	3707	N/A
Mussels Bottom	8730	8884	9260	N/A

7.6.1.1 Finfish

- Fin fish production in Ireland is still dominated by Atlantic salmon. Production figures have remained static or reduced slightly due to the introduction, on an industry wide basis, of Single Bay Management strategies, single generation sites and fallowing after completion of one production cycle.

- The use of vaccines for control of furunculosis are proving very effective and have resulted in a remarkable improvement in survival at sea and no outbreaks were reported in 1995. Approximately 80% of salmon smolts are now vaccinated prior to

transfer to sea. Incidence of Pancreas disease has also greatly reduced. There has been a consequent drop in the level of antibiotic usage.

- Because of the collapse on the West Coast of the commercially important wild sea trout populations, associated with heavy burdens of juvenile sea lice, a major monitoring programme of all salmon farms has been in progress during the past two years. All farms are inspected 15 times per year with the aim of keeping lice levels under control. Lice levels on fish farms were generally much lower in 1994 and 1995 than in previous years.

In addition the practice of fallowing and maintaining single generation sites was seen to reduce the lice on farmed salmon smolts going into their first winter at sea.

- The interactions between wild salmon stocks and escapees from fish farms is being studied. In Ireland extensive sampling of catches in 1993 during tag recovery programme indicated low representation of farmed salmon (<2%) even in areas where farming is located. However because of the location of sampling and the fact that identification of farmed fish is based on external characteristics the analyses is probably an underestimate. The recorded tonnage of farmed fish in national catches in 1993 was 1.5 tonnese in a total of 550 tonnes.

7.6.1.2 Molluscs

- Oyster disease bonamiosis continues to cause serious losses of *O.edulis* in a number of bays. No evidence of disease was detected in Pacific oysters sampled. Major losses of *C.gigas* occurred on south coast during very warm weather in summer of 1995 and the cause is under investigation.

- The sale of *M.edulis* and other bivalves was seriously disrupted in 1994/95 due to protracted DSP toxicity from May 1994 to February 1995.

- Administrative measures include a major review of the legislative framework for Aquaculture focusing on more discrete areas for licensing having regard to other activities in the area.

7.6.2 Research Activities

Research priorities have been identifled as the fate of antibiotics and other chemicals in the marine environment Sea lice biology and treatment Interactions betwen farmed and wild fish. Studies in progress or completed are listed in Table 1 followed by the list of respective publications resulting from the studies.

Table 1 Studies related to environmental aspects of mariculture in Ireland

Project No	Project Description	Completion Date	Organisation	Status
1	Study of TBT contamination in areas of aquaculture or shellfish resources	1995	FRC D. Minchin	Published
2	Exotic species introduced with Pacific oysters from France	1994	FRC D. Minchin	Published
3	Exotic species introductions to Ireland by means of ballast water	ongoing	FRC D. Minchin	Published
4	Matters relting to intended and unintended species introductions	ongoing	FRC D. Minchin	Published In press
5	An aromatic dependant mutant of *Aeromonas salmonicida* as a live vaccine for furunculosis in salmonid fish (EU FAIR)	1996	TCD T. Foster	In press
6	Scallop seabed cultivation in Europe, Concerted Action (EU) with FR,IE,NO,GB	1996	UCC, FRC, Ind. M. Norman	In prep
7	Impacts of new focussed technology on bivalve mollusc fisheries and their environment (EU) with IE,SW,GB	1977	UCC G. Burnell	In press
8	Impact of Pacific oyster trestle culture on invertebrates	1966	UCC G.Burnell	thesis
9	Seabird activities in areas of aquaculture.	ongoing	UCC T.Kelly	Published
10	Study of the pathology of Pacific oysters	ongoing	UCC S. Culloughty	
11	Reproductive physiology and readsorbtion in Pacific oysters	ongoing	UCC S. Steele	
12	Investigations into the distribution and biota of maerl	ongoing	UCC S. deGrave	
13	Sea-lice infestations on salmonids	ongoing	TCD O. Tully	Reports In press Thesis
14	Study of the benthos in an are of intensive shellfish production, Bantry Bay (EU)	1994	FRC S. Neiland	Report
15	Studies relating to the larval stages of sea lice	1995	UCC	Report

16	Discrimination of salmon populations (wild and cultivated) using molecular markers	ongoing	UCC T.Cross	
17	Sea water acclimatisation and humoral antibody response in salmonids	ongoing	UCC P.Reilly	
18	Proliferative kidney disease in salmonids.	ongoing	UCC M.Mulcahy	
19	Bonamiosis in the native oyster, control and treatment	ongoing	UCC M.Mulcahy	
20	Vaccine development against sea-lice for farmed salmon	ongoing	UCC P.Reilly	
21	Studies relatining to oxytetracyclene and fish farms	ongoing	UCG P.Smith	Publication
22	Studies relating to *Aeromonas salmonicida*	ongoing	UCG P.Smith	Publication

Table 2: Studies related to environmental aspects of mariculture in Ireland include:

Project No	Project Description	Completion Date	Organisation	Status
23	Efficiency in the use of flumequine and its toxicity	1995	UCGP Smith	Published
24	Bacterial resistance to antimicrobal agents on fish farms	1995	UCG P.Smith	Published
25	Salmon farming and benthic microbiology in sea loughs	1996	UCG P.Smith	In press
26	Study on the genetic impact of introduced non-native salmon (EU)	1996	SRA P.McGinnity	
27	Genetic studies on Atlantic salmon	1998	SRA P.McGinnity	
28	Biochemical studies on smoltification of salmonids	1996	SRA M. Gogarty	
29	Study of furunculosis in freshwater and significance for cultivated salmon	1997	SRA D.Cotter	
30	Development of a management strategy for the reduction of sea lice larvae, *Lepeophtheirus salmonis,* parasites of farmed salmon and trout	1998	Costelloe Aquafact	Ongoing
31	The role of fish and marine invertebrates in developing a budget for antibiotics in aquaculture	1996	Costelloe	Ongoing

32	The biology and ecology of the sea louse *Lepeotheirus salmonis*	1994	Costelloe Aquafact	Published
33	Further aspects of the biology and ecology of the sea louse *Lepeotheirus salmonis*	1995	Costelloe Aquafact	Published

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7.7 Norway (by A. Ervik, Institute of Marine Research, Bergen & H. Kryvi, Ministry of the Environment, Oslo)

7.7.1 Production

The statistics of fish harvest in 1995 are presented in table 1. In 1994 the harvest of salmonids was 220.000 tonnes.

Table 1 Harvest of the most important fish in Norwegian mariculture in 1995

Species	Tonnes
Salmon	254 000
Rainbow trout	20 000
Halibut	50

7.7.2 Regulations

The trend in mariculture industry goes towards a more diverse one applying new technique such as production of smolt throughout the year, floating closed fish pen, artificial lightand single large fish pen lying at exposed sites. This does not fit well with the present regulations, which are therefore under revision In 1996 a system for adjusting environmental impact of fish farms to the holding capacity of the site (MOM) will be tested out in full scale in four regions in Norway. This system will be an element in the new regulation.

At the end of 1995 high salmon production necessitated a cutback to balance the marked. All fish above 2 kilo was therefore starved from December 5 1995 to January 15 1996. The estimated loss in production of this feeding stop is 45 000 to 60 000 tonnes. For 1996 feed quota are imposed from Februray 29 to December 31. This quota is 47 tonnes dry weight feed per 1000 m^3 rearing volume, which will give a total Norwegian production of about 300.000 tonnes.

7.7.3 Medicines

The health status in Norwegian Mariculture is good, which has resulted in a low usage of medicine. Sea lice still represent a main problem both for the mariculture industry as as for the wild stocks of sea trout and salmon.

Table 2 and 3 present the use of chemicals and antimicrobial agents in Norwegian mariculture in the period 1986 to 1994, source of information: Norsk medisinal depot. The statistics for 1995 is not yet finished, but the amount of antimicrobial agents is still low.

Table 2. Sales statistics for selected chemicals used in Norwegian mariculture in the period 1987 - 1994

	1987	1988	1989	1990	1991	1992	1993	1994
Anaesthetics								
Chlorbutanol	384	725	608	467	467	151	149	152
Metakain	6,6	1,8	5,3	22	109	51	66	81
Endo/ectoparasite agents								
Metrifonat (Neguvon)	7566	3262	3300	2408	2144	1946	1779	1227
Diklorvos (Nuvan)	1311	3210	3488	3416	3588	3115	2470	1147
Azametifos (Salmosan)	-	-	-	-	-	-	-	389
Pyrethrum	-	-	-	-	-	-	-	31,5
Praziquantel	21	51	72	177	188	86	79	119
Fenbendazol	20	50	104	60	56	10,1	2,2	1,5
Malachite green (oxalate)	279	151	26	39	114	69	56	63

Table 3. Total usage of antibacterial agents used in Norwegian mariculture in the period 1986 - 1994

	1986	1987	1988	1989	1990	1991	1992	1993	1994
Oxytetracycline chloride	15410	27130	18220	5014	6257	5751	4113	583	341
Nifurazolidon	1610	15840	4190	1345	118	131	-	78	0
Oxolinic acid	-	3700	9390	12630	27659	11400	7687	2554	811
Trimetoprim + sulphadiazine (Tribrissen)	1000	1900	670	32	1439	5679	5852	696	3
Flumequine	-	-	-	329	1959	3837	9833	2177	227
Florfenikol								56	14
Total	18020	48570	32470	19350	37432	26798	27485	6144	1396

7.7.5 Environmental objectves for Norwegian mariculture

In 1994, the fisheries, environmental, health and veterinary authorities in Norway presented a report on environmental objectives for Norwegian aquaculture. These included long-term environmental and short-term goals for five specific areas. In order of priority, these are: escapes, diseases, medicinal products, chemicals and organic matter.

A progress report was made in summer 1995. In general, the results show that many of the environmental objectives have already been met, or that there are positive trends indicating that they could be met by the end of 1995, which was the time limit set for most of the chort-term goals. Some long-term objectives were reached in 1994, and efforts must be made to maintain equally results in the future.

Most important results after two years:

goal			results/comments
escapes			
goal 3.1.1 (1994)	reduction of escapes to less than 400 000 /year	not reached	more than 645 000 escaped (hurricane). positiv trends
goal 3.1.2 (long term)	escapees should not represent a threat to wild stocks		too much farmed salmon in rivers (21 %). significant reduction last years
diseases			
goal 3.2.1 (end of 1995)	reduction of infection of wild stock	reached	health conditions much improved. few outbreaks
goal 3.2.2 (end of 1995)	reduction of salmon lice attacks		very much lice in 1993 and 1994. damage from lice reduced certain places
goal 3.2.3 (end of 1995)	elimination of *g. salaris* in fish farms		the number of restricted farms halved. the positive trend expected to continue
goal 3.2.4 (end of 1995)	no introduction of new diseases or parasites	reached	
goal 3.2.5 (end of 1995)	protection of specially valuable salmonids against diseases		furunculosis found in one river, bkd in two. significant improvement since last years
goal 3.2.6 (long term)	the risk of infection from farmed salmon should not constitute a threat to wild sp.		the threat is now primarily connected to salmon lice on migrating smolt and on sea-trout in the fjords and coastal areas

medicines	goal		results/comments
goal 3.3.1 (end of 1995)	50% reduction of the use of medicines (compared to mean values 1988-92)	reached	the reduction has been: antibiotics: 95.2 % dichlorvos: 66 % metrifonat: 53 %
goal 3.3.2 (end of 1995)	new medicines should be checked for env. effect	reached	
goal 3.3.3 (long term)	75 % reduction of the use of medicines	reached for antibiotics	new strategies to combat salmon lice might change the picture drastically the years to come
goal 3.3.5 (long term)	all medicines shlould be checked for env. effects		the tests have started. metrifonat is no longer permitted for use in fish
chemicals			
goal 3.4.1 (end of 1995)	the use of chemicals must be surveyed and the env. effects determined	reached	
goal 3.4.2 (end of 1995)	80 % reduction of the use of copper (1991)	not reached	31 % increase
goal 3.4.3 (long term)	reduction of the use of chemicals (not specified)		probably not changed the last years
goal 3.4.5 (long term)	termination of the use of copper		31 % increase

organic materials			
goal 3.5.1 (end of 1995)	recycling of the fish waste	reached	at least 88 % recycled
goal 3.5.2 (end of 1994)	env. quality standards must be established	not reached	will be tested in 1995 (mom)
goal 3.5.3 (long term)	the env. impact must not exceed the e.q.s		dependent on 3.5.2
goal 3.5.4 (long term)	95 % of the fish offal must be recycled, 75 % must be used as feed	reached	95 % recycled offal was used as feed

7.7.5 Coastal Zone Planning

There are 281 coastal communes in Norway. The extent of coalstal zone planning in these communes is demonstrated by the following figures (from R.Bennett, 1995).

	Approved plans	Planning in progress	Not planning
1992	22 % (64)	30 % (80)	48 % (137)
1995	36 % (101)	27 % (75)	37 % (105)

The planning activity tends to be concentrated in the skerry belt and outer fjord districts, which are most densely populated and intensively used. Data from R. Bennett, 1995, indicate that the combination of fishing and fish-farming implied a strong imperative to plan, due to both economic dependence and conflict potential.

A large majority of communes (83%) point to the need to regulate the use and the conflicts in the coastal zone as the prime reason for planning. Environmental concerns are the next most important reason (63%) with economic development and the need for employment opportunities running a close third (61%). The environmental motive is prevalent among communes in the east, south and southwest. In Central and Northern Norway the economic motive takes second place, but iit is almost non-existent in the south (Vassdal 1992).

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7.7.6 A Norwegian Programme On Development Towards A Sustainable Industry (The Technology Programme)

«Cleaner Aquaculture Technology Programme» is a part of The State Pollution Control Authority's programme on development towards a sustainable started in 1992. The aquaculture programme is divided in the following main activities:

- feed and feeding technology
- medicines
- antifouling treatment
- closed and landbased farms
- effluent treatment
- information
- miscellaneous (escapes)

The summary financial table for the period 1992 to 1995 is:

Area	SPCA mnok	SPCA %	Industry mnok	Industry %
feeds and feeding	9.120	34.11	18.074	40.4
antibiotics	3.377	12.6	6.969	15.6
chemicals	2.502	9.36	4.057	9.07
closed systems and cleaning	8.931	33.4	13.140	29.3
information	0.194	0.73	0.570	1.14
miscellaneous	2.614	9.78	1.983	4.43

A list of all the projects is included in this report (Appendix 4).

Several specific goals have been set up for the programme. Some of the goals and the achievements are:

GOAL	RESULT
- reduce the feed consume to 1.1 kg dry feed per kg fish produced	+
- reduce nutrient discharges to less than 35 kg n and 8 kg P per ton fish produced	+
- develop closed cages which is environmentally preferable and econ. profitable	(+)
- 50 % reduction of antibiotic effluents (16.5 tons)	+
- develop less env. hazardous antibiotics	-
- 50 % reduction of the amount dichlorvos used (compared to 1991)	(+)
- 80 - 100 % reduction of the amount of antifouling agents containing copper	-

It has been estimated (Leffertstra, SPCA) that the programme has contributed to about 70 mill. NOKs in savings for the fish farm industry, while the corresponding cost of the programme have been about 50 mill. NOKs (of which SPCA has given 24 mill. NOKs, and industry itself the rest). Beside this economic profit, the programme has also lead to a closer and improved cooperation between the industry and the governmentall management. It is decided that the program also will continue this year.

THE TECHNOLOGY PROGRAMME

MAIN ACTIVITIES:

- FEED AND FEEDING TECHNOLOGY (16)
- MEDICINES (19)
- ANTIFOULING TREATMENT (9)
- CLOSED AND LANDBASED FARMS (6)
- EFFLUENT TREATMENT (14)
- INFORMATION (4)
- OTHER (6)

SFT'S PROGRAMME FOR CLEANER AQUACULTURE TECHNOLOGY:

7.8 Scotland (by Ian Davies, Aberdeen)

Addition to the Scotland country report.

In 1994, the Scottish Office published a report, prepared by consultants, on the major coastal issues facing Scotland at that time. It contained a detailed review of the legislative and regulatory framework within which coastal activities must take place, and suggested a number of ways in which the exploitation of the coastal zone could be better managed, with a view to long term development and sustainability. The following text is taken from the summary of that document. It is not to be taken as a statement of Scottish Office policy on coastal issues, but as an indication of the complexity of the interactions that can occur, and of the current interest among regulators and the public in developing ways of taking a more holistic view of the coastal zone.

Review of Scottish Coastal Issues

by

P R Burbridge and V Burbridge, 1994

7.8.1. Introduction

The Coast of Scotland has formed the focus for development for many years. This is clearly demonstrated by the well established concentration of urban settlements, industry and commerce in coastal areas. Exploration for and production of oil and gas, rapid expansion of fish and shellfish farms in sea lochs, large coastal quarries, recreation and tourism and proposals for the development of tidal power and other forms of renewable energy resources are examples of the most recent forces for increasing land and water use in relatively undeveloped coastal areas. Apart from oil and gas and coastal quarries, the sustainable development of the newer forms of development depends heavily upon the availability and effective management of renewable natural resources and maintenance of the quality of the coastal environment.

The objective of this review is to draw together existing material on the Scottish Coast and to provide an appraisal of the current range of issues affecting the sustainable development of coastal areas and resources. The review aims to provide a basis for

the initial assessment of major issues and consideration of the relevance of different approaches to a management strategy for the Scottish coast. As a first step in the process, it provides:

i) a brief description of the extent and scope of the coastal resource and a review of the current range of issues;

ii) an inventory of relevant data and information sources, and a commentary on recent and current research on the coast of Scotland;

iii) an outline of the main agencies involved and the divisions of responsibility;

iv) an inventory of relevant legislation;

v) discussion of existing initiatives in the public, private and voluntary sectors.

7.8.2 Executive Summary

The review of coastal management in England and Wales undertaken by House of Commons Environment Committee (1992) stated that " We believe there is no panacea for resolving all the problems experienced in the coastal zone; different areas will require quite different treatment. We also believe that some of the problems can be tackled within the present system, for example through the provision of Government guidelines and support. .... We believe that Coastal Zone Management delivered through a cascade of national, regional and local Coastal Zone Plans is the key to sustaining the present uses, enjoyment and ecological richness of the coastal zone into the future." Based upon the findings of this review, the authors observe that these same observations are pertinent to Scotland. The following paragraphs summarise the findings of this review relating to the uses of the coastal zone, current concerns, and the principle means available to plan for and manage development and protect the environment:

7.8.2.1 The Coastal Zone

There is no official definition of the Coastal Zone of Scotland. The coastline of Scotland is estimated to be 6,287 km long. Some 12% of the mainland coast is classified as developed and 88% is classified as undeveloped. If the House of Commons Select Committee's definition of the Coastal zone is applied to Scotland, the coastal zone would encompass all major cities and centres of industrial development and international trade, the best agricultural lands, the major fisheries including marine fish farming, major tourism and recreation areas and a large number of sites of archaeological, landscape and nature conservation value.

7.8.2.2 Data and Information Sources

There is a great deal of published and unpublished information available on the Scottish coast but it is recorded in many different forms, at different scales and is often contained within wider data sets collected and held by a plethora of different agencies. Until recently the coast has not been a focus for policy and hence for data collection at regional or local level.

The most comprehensive and integrative data bases have been developed by nature conservation interests. At the national level the British Oceanographic Data Centre's UK. Digital Marine Atlas provides an opportunity to create a comprehensive and easily updated geographically referenced information system for coastal planning. This could allow integration of disparate databases. Further development of this centrally held database could provide a focus for material from a wide variety of agencies, allow the integration of data necessary for management purposes and provide a framework for locally generated data and information.

7.8.2.3 Agencies and Responsibilities

There are 17 major central government departments and agencies which have some responsibility for activities affecting the Scottish coast. These do not include the Regional, District and Island Authorities with direct responsibility for the planning and protection of the coast, nor does it include voluntary local committees, other voluntary agencies or user groups who have an interest in coastal activities.

At a national level, the main responsibility for coastal matters is spread among: SOEnD, SOAFD, the Department of Trade and Industry, Department of Transport and the Ministry of Defence. There is no lead agency with a clear remit for guiding the sustainable development of the Coastal Zone in Scotland, although the SOEnD Rural Affairs Division has responsibility for the co-ordination of coastal policy. There are diverse consultation procedures in operation under which concerns over the sustainability of coastal resource uses and protection of the environmental could be more prominently addressed. However, many agencies do not have a specific remit to take into account resource conservation and environmental management issues. Strengthened research linkages among the SOAFD Fisheries Research Services, JNCC and SNH could help improve the scientific information base available for use with the consultation procedures to improve the management of coastal ecosystems.

The Crown Estate Commissioners have a major role in the allocation of coastal resources. However, their joint role as landlord and 'quasi-planning authority' is frequently criticised as is their ability to act as a 'competent authority' in relation to environmental assessment procedures.

7.8.2.4 Legislation, Designations and Controls

International legislation is largely concerned with nature conservation, marine pollution, safety, and the regulation of fisheries. National legislation is generally designed to guide development within sectors and was not designed specifically to foster the sustainable development of the coastal zone. Some legislation, such as the 1974 Control of Pollution Act, the 1985 Food and Environmental Protection Act and the 1981 Wildlife and Countryside Act have some integrative functions. However, generally it is EC directives which are providing the stimulus for a more integrated approach to the resolution of coastal problems and issues and protection of the environment.

There are numerous designations affecting the coast. These all pertain to specific aspects of the coastal environment and many have been criticised for failing to provide adequate protection of ecological functions or for areas below the low water mark. In several instances, more has been gained from voluntary agreements to protect the

coast than from statutory designations. The fact that planning and management systems do not cross the LWMOST mark is cited as a particular problem hindering the integrated management of coastal resources.

The Coastal Planning Guidelines for Oil and Gas Development produced by the SDD in 1974 provided a framework of advice for local authorities and are generally felt to have been beneficial because they were prepared in advance of major oil development. More recent draft guidelines on Marine Fish Farm Location prepared by the SOEnD to help strengthen those available from the CEC have been criticised for following after the main development had taken place. There is a danger that this may be repeated in the case of shellfish farming which is expanding rapidly. These points are discussed further in Section 9 of the report.

The 1974 Coastal Planning Guidelines were up-dated in the 1981 National Planning Guidelines to cover most major developments for port, industrial and power generation purposes. Further up-dating of these Guidelines would be useful to clarify responsibilities, and to provide more far-ranging guidance on environmental management issues.

Experience in Shetland under the Zetland County Council Act 1974 has shown the advantages of a local system of co-ordination and management control of activities affecting coastal lands and in-shore waters. The application of this type of approach in other coastal areas might be considered.

Bye-laws to control access to coastal areas and activities on the shore may be used under a number of acts, for example the Civic Government (Scotland) Act 1982, However, their application to resource management issues such as cockle fishing in the Solway Firth, suffers from problems relating to enforcement, the need for agreement of all interested parties, legislative complexity and the difficulty of using a 'local' tool to deal with a 'strategic' problem.

7.8.2.5 Major Patterns of Use and Emerging Resource Requirements

The coastal land and water areas of Scotland contain valuable economic and environmental resources which are subject to mounting pressures. It is difficult to present precise information on the use and condition of the coastal zone, or the extent to which our use of the renewable resources is sustainable. Concerns have been expressed by different groups relating to increasing competition for resources, conflicts between users of the coast, wise use of non-renewable resources and non-sustainable exploitation of renewable resources. It is suggested that if these issues are not adequately addressed, opportunities for diversifying and expanding economic development will be foreclosed, environmental quality will decline and Scotland will not be able to meet its international commitments relating to the conservation of habitats and species. Specific pressures of major concern include:

a) Fishing in Off-shore and In-shore Waters, and Fish and Shellfish Farming

Over fishing is producing a dual crisis for conservation of the resource base and the future of fishing communities who rely on this resource. Natural fluctuations in fish stocks compound the difficulties of setting sustainable levels for harvesting these stocks. The Multi-annual Guidance Plan (MAGP) targets set by the UK. Government in accordance with EC policy call for a 19% reduction in fishing effort by the end of 1996.

This will be achieved by reducing capacity and applying other control measures. The reduction in capacity hinges on an acceptable decommissioning scheme.

It has been suggested that strategies for conserving marine fish and shellfish in Scottish waters should logically focus on a two-pronged approach: the reduction of over fishing through a combination of technical measures and management options and the conservation of coastal habitats that sustain fish stocks. A number of spawning and nursery areas has been identified around the coast and it is important to find the means to protect these.

Control over the planning and management of fish farming is based upon permits issued by difference agencies. Apart from leasing and quasi planning functions undertaken by the CEC, there is no lead agency and many of the current guidelines, such as fallowing sea lochs, have been formulated by the operators themselves. The EC Directive on Environmental Assessment (EA) may be applied to fish farming applications . However, only one Impact Statement has been submitted out of a total of 446 registered business operating 721 sites in Scotland. Shellfish grown in the sea are not covered by existing legislation.

Environmental groups have identified a number of concerns with respect to fish farming. These include: 1) the lack of a strategic approach, 2) the effects of the use of toxic chemicals and antibiotics on fish farms, 3) risks to the genetic integrity of native salmon populations, and 4) the introduction of non-native species (particularly with respect to shellfish farms). Other factors which are considered to have a bearing on the appropriateness of a development include the visual impact of the site, ecological sensitivity of the proposed location, and the creation of hazardous conditions for navigation.

A number of factors make it difficult to objectively assess the environmental effects of individual fish farms, to measure the potential synergistic and cumulative effects of all fish farming operations, or to separate potential adverse effects on water quality generated by fish farming from environmental impacts created by other forms of activity.

b) Superquarries, Marine Aggregate Extraction, Non-Renewable Resources, Sand and Gravel Etc.

The proposed development of further superquarries has raised issues related to the need for a strong national strategic framework within which to consider the national and international supply of and demand for quarried materials as well as the protection of areas of high landscape and nature conservation value. Issues such as the potential adverse impact of ballast water discharged by large bulk carriers have illustrated the difficulties of applying planning legislation and the EC Directive on Environmental Assessment at a local level for individual applications for large-scale developments which could have with a significant influence on both terrestrial and marine environments.

Exploitation of sand and gravel around the Scottish coast is presently at a low level responding to a local demand by small-scale quarrying and beach extraction. Only one consent for the extraction of marine aggregates in Scottish waters has been given and it has not been implemented. However, demand is expected to rise and

exploration activities are increasing. Environmental issues may become more critical as demand for marine aggregates continues to grow.

The excavation of maerl, and the exploitation of algae for the alginate industry raise substantial concerns on the part of nature conservation and fishing interests. Maerl is, however, treated as a mineral resource and therefore may be covered by the 'Government View Procedure'.

The 'Government View Procedure' on the extraction of marine aggregates is currently under review. An issue that remains to be resolved is the Crown Estate Commission's role as lease-holder and its 'quasi-planning' status and position as 'competent authority' in relation to Environmental Assessment procedures.

c) Oil and Gas Production, Shipping and Marine Safety

The impact of oil and gas production in the north Sea is monitored through the international conferences on the Production of the North Sea and the Paris Convention for the 'Prevention of Marine Pollution from Land-based Sources'. Regular monitoring of the changes to communities on the seabed within the vicinity of installations is carried out by SOAFD. The development of on-shore installations is dealt with through the town and country planning legislation. However, as exploration moves inshore, a number of related issues arise. The JNCC Marine Conservation Branch and environment groups see an increased threat to marine sites from oil and gas exploration. They expressed concern at the decision by DTI to offer a fourteenth offshore Round of Exploration Licensing including a number of blocks in sensitive areas for nature conservation. The Round has involved consultations with other Government departments, JNCC and various local interest around the UK. As a result of these consultations, many licenses will include strict conditions, including seasonal restrictions to protect the environment and important fishery interests.

In general, planning authorities have not developed any statutory policies towards hydrocarbon development in the estuaries or coastal waters adjacent to their areas of jurisdiction. The lack of policies is a reflection of the recent nature of such possibilities and the uncertainty surrounding the issue of the responsibility of planning authorities for such waters. It has been suggested that further consideration should be given to the procedural arrangements and responsibilities in estuaries and other areas nearshore where planning controls do not operate.

The sinking of the Braer oil tanker has focused public attention on the danger of oil pollution and general problems of safety and pollution at sea. In recent years there have been great advances in navigational technology, however, these have not heralded corresponding declines in accidents at sea. Progress on matters relating to shipping and safety will have to be made within existing international legislative frameworks. Follow up work to the Joint Councils' consideration of the European Commission's Communication on 'A Common Policy on Safe Seas' suggests the need to look at the feasibility of a penal system for civil liability for environmental pollution, to consider how to achieve more efficient control of marine environmental pollution and to identify environmentally sensitive areas. The identification of environmentally sensitive areas would need to be consistent with international law, balance environmental and economic issues and linked with coastal zone policies.

d) Pollution

Research on public attitudes towards environmental issues in Scotland has shown that of twenty-two environmental topics considered, pollution of rivers, lochs and seas was the issue of highest concern to the Scottish public. However, where monitoring takes place, there does not appear to be significant levels of pollution of the seas around Scotland. Coastal areas of Scotland are affected by a number of different types of pollutants related to: 1) sewage disposal, 2) marine litter, 3) industrial wastes, 4) inorganic mine and particulate waste, 5) pesticides, 6) spoil dumping, 7) thermal discharge, 8) radioactive waste and 9) agricultural run-off. To date, no comprehensive assessment of the cumulative or synergistic effects of these forms of pollution on the coastal environment has been undertaken in Scotland although some attempt at assessment of the quality of the coastal environment has been made in the North Sea Quality Status Reports and in reports prepared by the North Seas Study Group.

Specific issues of coastal pollution are arising 1) as oil exploration and production activities move into estuarine and coastal areas, 2) in relation to shellfish growing areas under the EC Directive on Shellfish Hygiene and 3) in relation to the potential effects of ballast water discharged around proposed superquarry sites. More general concerns over pollution have been expressed by nature conservation interests relating to the decline of some species, and more localised concerns have been expressed in relation to recreational use of coastal waters.

e) Amenity and Landscape

Recent surveys point to relatively low levels of amenity and environmental standards on Scottish beaches. These include the results of bathing waters monitored under EC Directive 76/160/EEC and observations by persons associated with award schemes such as 'Keep Scotland Beautiful' campaign and the 'Norwich Union Coastwatch UK Survey'. Some progress has been made through voluntary beach cleaning exercises and experience in Ross and Cromarty suggests that more might be achieved. However, these schemes only address the end of the problem i.e. litter and on-shore cleansing. Much still remains to be achieved at source with regard to litter, sewage discharges and water quality. Schemes are in place which are designed to ensure that all designated bathing waters comply with the Directive, these are due for completion by 1997.

f) Landscape

Persons interviewed suggested that it is difficult to place particular stretches of coastline within their national or international context because there has been no comprehensive assessment of landscape quality in Scotland. National and regional landscape designations may include coastal locations and form the basis for planning policies. For instance many National Scenic Areas in Scotland have coastal frontage., however, the coast was not a strong factor in their definition. Under the Natural Heritage (Scotland) Act 1991 the designation of Natural Heritage Areas provides an opportunity to define areas within which SNH will co-operate with all relevant public authorities and private interests to produce a management statement setting out a basis for sustainable land use. These could provide a framework for the development of coastal policies. However, no NHA's have yet been designated and SNH is currently developing criteria for their designation.

g) Sport, Recreation and Access

There are no easily available figures for sporting or recreational use of the coast. However, increasing demand for access to the coast for sport and active recreation is clearly recognised. Three different types of conflicts relating to coastal water-based recreation have been identified, namely: conflicts between recreational users of water, between recreational users of water and conservationists and between recreational users and commercial and other activities. There are concerns that the planning system is not dealing adequately with development, such as marinas and it has been suggested that more guidance is required on access matters and on the control of wild fowling, etc. The direct involvement of user groups in the design and assessment of proposed developments and management schemes is also seen as of paramount importance.

h) Nature Conservation

The Scottish coast includes a wide array of unique and internationally valued habitat types. Most current issues with regard to nature conservation focus on estuarine and sea loch areas which are important areas for both conservation and economic development.

JNCC, RSPB and others have drawn attention to the international importance of Scottish estuaries for bird conservation. Fourteen Scottish estuaries have been identified for designation under international legislation but to date only two of the smaller sites have been designated as the process is complex. Current advise to local authorities in Circular 1/1988 requires all sites identified as SPAs to be treated as if they were designated. However, difficulties in dealing with areas below the low water mark remain. Current SSSI notification does not extend below the low water and therefore it is suggested that SSSIs are not able to provide protection for subtidal habitats.

i) Archaeology

The protection of on-shore and underwater archaeological sites is constrained by :
1) the absence of a comprehensive database which means that it is impossible to assess the whole cultural heritage quickly.
2) the lack of jurisdiction by planning authorities for activities below the low water mark. This restricts opportunity to make any comments on potentially destructive activities. The recent draft of the NPPG on Archaeology and Planning makes no mention of underwater sites, and
3) the absence of any reference to the marine environment in EA legislation pertaining to the study of impacts on archaeological interests .

It has been suggested that planning controls be extended to below the low water mark to allow new regional structure plans to incorporate an underwater archaeological component and improve awareness and communication between users and authorities. It has also been suggested that archaeological implications of coastal and offshore development should also be incorporated into EAs as standard practice.

j) Sea Defence and Coastal Protection
Over the next 50 years, sea level is predicted to rise due to global warming by a minimum of 5 mm per year. In Eastern Scotland land level rise appears to be keeping pace with sea level rise and most reconstructions of the more recent isostatic changes throughout Scotland suggest a symmetrical pattern with uplift in the west at rates similar to those of the East Coast. It is difficult to assess the risks to particular parts of Scotland. However, most authors agree that the Tay, parts of the Moray Firth, the Solway Firth, the Outer Hebrides and, possibly, part of the Forth and the Clyde, are all vulnerable to sea level rise. These areas contain the major urban centres and associated economic development, and support internationally significant features of significance for nature conservation.

The protection of existing settlements and economic activity will be a prime consideration. The implications of sea level rise taken together with factors such as increased incidence of storms resulting from climatic change suggest that policies will need to address issues relating to development in flood prone areas, the maintenance existing natural buffer zones and creation of new buffer zones, and control of surface water flows through watershed management .

Nature conservation interests point out that sea level rise will accelerate loss of intertidal habitats of mudflats, sandflats and saltmarshes. this, they consider, may be further exacerbated by sea defence works. More detailed inundation scenarios are required if threats are to be assessed and appropriately balanced measures are to be taken to relate and protect economic and nature conservation interests. The cumulative effect of coastal defence projects on conservation of coastal habitats and on amenity, landscape and archaeological values has often been criticised. Greater attention is now being paid to soft and hard engineering solutions and to consideration of policies of retreat.

The prospects of sea level rise and increasing pressures on estuaries for development suggest that these are important areas for major policy initiatives. In a UK. context, Scotland has relatively few current cases of land claim for number of estuaries but almost half of these are for rubbish tipping and spoil disposal. Potential sea level rise as well as nature conservation interests need to be fully incorporated into planning considerations of such activities at the local level.

k) Military Activities
Military activities affecting the coast include naval bases, facility of Coulport, NATO refuelling stations, land and sea ranges for firing, bombing, torpedo and missile practice as well as submarine exercise areas. Offshore military dumping is to cease in 1993. However, it has been estimated that a quarter of all hazardous items washed up on the beaches around the UK. has a military origin.

Access to military lands may present localised problems as may the visual intrusion of physical structures. However, a more strategic problem faced by some coastal communities is the closure of military establishments and the consequential reductions in population and local employment as on the Clyde.

There has been considerable concern for the safety of fishing vessels in coastal waters used by submarines. Experiments are taking place using warning systems attached to fishing nets but the potential conflict remains and the question of who should bear the

cost of such a safety system has yet to be resolved and other user groups e.g. yachts under sail remain at risk.

7.8.2.6 Initiatives in Management of the Coast

At regional and local levels within Scotland initiatives have been taken in response to different
coastal resource use problems, including the : Zetland Country Council Act 1974, Highland Region's Framework Plans for Fish Farming, the SNH Firths Initiatives such as the Moray Firth Review and the Firth of Forth Charter, and the voluntary Marine Reserve at St. Abbs Head. These examples illustrate the search for new means to 1) use different types of statutory and voluntary agreements, and 2) promote increased co-operation and collaboration in information gathering, monitoring and identifying potential conflicts and management options.

7.8.2.7 Significant Coastal Management Issues Which Suggest That New Initiatives in Coastal Zone Management Could be Appropriate.

A basic issue raised by the SOEnD in commissioning this Review is whether there is sufficient justification for instituting a major initiative to formulate and implement an integrated coastal zone management framework, of policies, strategies and guidelines. While this Review has not revealed a problem of such scale that the need for such an initiative is undeniable, there are certain problem areas which suggest that many forms coastal resources development are no longer sustainable and that a point has been reached where different management strategies are required. The obvious example concerns the problems facing the fishing industry where solutions are required to deal with declining fish stocks resulting from over-fishing and the degradation of coastal environments that help to sustain those stocks, and the consequent social and economic effects of declining employment on coastal fishing communities. In this and other cases, the wise and sustainable use of renewable coastal resources would help to sustain the fishery and offer alternatives for diversifying employment and income generation in rural areas.

Questions of sustainability and long-term benefit to coastal communities also arise in relation to proposals for superquarries and marine aggregate extraction. The wise use of finite resources cannot be successfully achieved through incremental planning decisions without reference to the balance of total supply and future demand or policies to promote the more efficient use of such materials.

The growth of shellfish farming has raised problems in relation to the maintenance of water quality standards and the effects of future plans for sewage effluent disposal. While environmental standards exist for managing both activities they are not necessarily compatible and any reduction of coastal water quality will have serious economic implications for the shellfish industry. This raises issues of minimum standards required to protect both the quality of the coastal environment and the economic viability of renewable resource dependent activities. This in turn raises issues of the levels of public and private investment required to accommodate increasing diversity and intensity of use of the coastal areas while maintaining the ability of coastal ecosystems to generate the resources being exploited and to provide the landscape and amenity features we value so highly.

The maintenance of water quality is a vital issue in the viability of most economic activities and in the conservation of coastal resource systems. The concept of

environmental standards needs to be broadened to encompass both economic externalities associated with poor land and water management and maintenance of the functional integrity of coastal ecosystems. These are not divisible and separate issues. Agreements need to be made among all users of the coast concerning standards of environmental quality to be reached in protecting the availability and use of coastal resources in relation to terrestrial and marine activities. These standards must also be sufficient to ensure the maintenance of the health and productivity of the coastal ecosystems that generate the economic or environmental resources these activities depend upon.

Such issues cannot be answered by land use planning concepts alone. They require the co-ordinated efforts of a variety of agencies. This is the essence of the problem we face in Scotland, we are relying very heavily upon a land use planning system to address very complex resources management and environmental protection issues that require specialised information, management skills and experience with both terrestrial and marine systems. A major obstacle to both the planning and management of inter-linked coastal systems and the resolution of conflicts in resources use is the use of the LWMOST mark to define the limits of jurisdictions over land and water areas.

7.8.2.8 Conclusions

A major conclusion of this study is that the quality of the environment and the potential of the natural resources derived form Scotland's coastal zone to support the expansion and diversification of the economy are too valuable not to invest time, manpower and capital to promote a more pro-active approach to their wise and sustainable use. While the achievements of the land use planning system in helping to guide sectoral development initiatives and protect environmental quality within the terrestrial component of the coastal zone in Scotland are laudable, land use planning systems need to be strengthened to better address issues in the marine component of the coastal zone. This is not a problem unique to Scotland. Environmental protection measures, such as pollution controls and environmental impact assessments together with the development planning process on land can help to maintain the quality of coastal waters. However, such measures are largely directed at controlling existing or proposed activities and do not necessarily ensure the continuing functional integrity of coastal ecosystems above and below the low water mark. If the health and productivity of these systems is not maintained, the flows of economic and environmental goods and services they generate will diminish. Once lost, the technical and financial costs involved in re-establishing such resources can be very great and their loss may prove irreversible.

7.8.2.9 Recommendations

We would therefore urge that further consideration be given to addressing a variety of complex coastal land and water management issues that require new and innovative solutions. Specific measures that could be taken include:

a) The development of coastal planning policies and guidelines that deal with the integration of coastal resources based activities at the local and regional level. Of particular importance is the need for improved guidelines to facilitate the integration of marine based resource uses in coastal areas. Some of these uses are compatible and

can be integrated in a spatial or temporal manner. Others require strict control to avoid negative economic and environmental impacts on other coastal activities.
b) Further attention could be given to establishing concepts, principles and techniques for coastal zone management in Scotland and training policy makers, planners and managers in their implementation. Basic issues of sustainable resources development and maintenance of environmental quality cannot be resolved on a project by project basis without some reference to broadly based and integrated economic and environmental principles and performance standards.

c) Consideration could be given to assisting agencies concerned with the development and management of coastal resources to :

i) Generate better data and information that will be of direct use to policy makers, planners and managers concerned with the sustainable development of coastal areas and resources;

ii). Gain improved access to appropriate information that helps to identify development opportunities and constraints directly relevant to planning for and managing coastal areas and activities;

iii) Use this information to formulate alternative development options appropriate to areas or resources under their jurisdiction;

iv) Assess the environmental, economic and social implications of alternative plans;

v) Implement planned development in a sustainable manner and monitor and evaluate the performance of the development activities in respect to the response of the coastal systems;

vi) Adapt plans and management policies where necessary to correct unforeseen and negative economic and environmental impacts before they lead to irreversible damage to the coastal environment.

These activities need to take place at national, regional and local levels and should aim to.:
1. Strengthen the information base for coastal management;
2. Provide encouragement and guidance on local and regional coastal initiatives;
3. Improve the integration of economic and environmental factors in sectoral policies affecting coastal resource allocation and management;
4. Strengthen inter-sectoral co-ordination of policies and the definition of agreed environmental quality standards;
5. Fulfil international commitments relating to conventions, treaties, and EC Directives.

7.9 Sweden (by G. Aneer, County Administrative Board of Stockholm)

7.9.1 Swedish Coastal Zone Planning

According to the Swedish Planning and building Act (1987) it is a municipal responsibility to plan the use of land and water areas (limnic and marine out to the territorial border, 12 nautical miles). Such planning must operate within the context of

the Natural Resources Management Act (NRMA) (1987). This act is an "umbrella" type act under which most conservation and exploitation acts are placed. The directions of the NRMA are to be applied to e.g.: the Planning and Building Act, the Water Act, the Environmental Protection Act, the Nature Conservation Act, the Mineral Act, the Electricity Act and many others. The NRMA also points out areas of national interest with regard to recreation, environmental conservation, etc.

The NRMA states that "Land, water and the physical environment in general shall be used in a manner that encourages good long-term management from ecological, social and economic viewpoints." It alos states "that land and water areas shall be used for that or those purposes for which they are most suited with regard to their nature and location as well as actual requirements. Precedence will be given to that use which encourages good management from the public's viewpoint."

The comprehensive plan is the vehicle in which the municipality must identify how it proposes to deal with land and water areas in the future taking into consideration national and other local public interests.

The County Boards are the regional authorities which shall develop an active "pushing" and coordinating role in the work with planning, management, environmental protection and other issues of importance for the regional development. The County Boards also have to support the municipalities in their work with planning. The County Boards also have to evaluate the comprehensive plans from the municipalities and to provide the evaluations as background documents to the Swedish National Board of Housing, Building and Planning (NBHBP) when the latter reports to the government. The NBHBP is the national authority surveilling the compliance of the Planning and Building Act.

Two recent publications present good descriptions of the Swedish system for coastal planning:
Johanson, L.1995. Coastal area management in Sweden. Swedish Environmental Potection Agency and Swedmar. 56 pp.

Ackefors, H. and Grip, K. 1995. The Swedish model for coastal management. Report 4455, Swedish Environmental Protection Agency. 83 pp.

Figure legends:

Figure showing the boundaries of the area of planning within the municipality of Lysekil on the Swedish west coast (from Johansson, 1995: Coastal area management in Sweden).

Figure showing areas of national interest with regard to shipping and navigation (from Johansson, 1995: Coastal area management in Sweden).

Figure showing the use of land and water areas in the Lysekil municipality. Areas suitable for aquaculture are indicated (from Johansson, 1995: Coastal area management in Sweden).

8 SPECIAL PAPERS PRESENTED AT THE MEETING.

ICES WorkshopPrinciples and Practical Measures
for the Interaction of Mariculture
and Fisheries in Coastal Area
Planning and Management

Kiel, Germany

Socioeconomic Survey of the Influence of Mariculture on the Resource Use in the Limfjord

by Eva Roth and Tove Christensen
March 1996
Danish Institute of Fisheries Economics Research (DIFER)
Niels Bohrs Vej 9
DK–6700 Esbjerg

Introduction

This paper briefly outlines the socioeconomic activities attached to the Limfjord. Especially the influence of mariculture on the planning and management of the Limfjord will be presented.

The ethical struggle as to the overall aim of environmental policy and the use of both marine and coastal areas is strongly influencing the debate on management of the Limfjord. A basic question in natural resource management is whether we sustain the environment to protect the future use-values or whether we protect the environment on behalf of the intrinsic values embedded in the Nature itself. This paper takes an anthropocentric view of the problem by evaluating the management in economic terms.

The importance of an economic assessment of coastal areas is due to the fact that environmental problems are most often rooted in the socioeconomic systems. The economic concept for evaluation of a natural resource is an assessment of costs and benefits of the resource - in casu the Limfjord. The assessment encompasses both the use and non-use values of the resource and includes both market and non-market values. The economic value of conservation of species/biodiversity is very difficult to estimate. The problem can be partly solved by narrowing the field where economic arguments should be applied. The extinction of species is not acceptable as it is an irreversible development and it is left to biologist to determine a biological sustainable level of population. The biological sustainable level of population is used as a bottom line below which the economic analysis does not apply. Over and above this level, however, the conservation management must include an evaluation of the direct and indirect costs and benefits of different conservation plans. This paper does not reach

an overall assessment of the economic activities, but the elements most visual to the interaction between different user groups are discussed.

The border area between the culture of fish and the fisheries is difficult to establish. There is no traditional intensive mariculture in the Limfjord, but other activities have traits of extensive mariculture and these are included in the present socioeconomic analysis. One kind of extensive sea ranching is the restocking programmes for trout and eel and the pilot schemes for restocking of marine species like turbot. Only the restocking programme for trout has been investigated further to be included in the socioeconomic survey. As a rule-of-thumb 3 out of 4 sea trouts caught by recreational fishermen stem from the restocking programme. This clearly indicates that the influence of restocking on the recreational fisheries is substantial. Another kind of sea ranching is found in the mussels fisheries. The maximum legal amount of undersized mussels (below 4.5 cm) in the catches were increased from 10% to 30% in 1993 under the condition that they are laid out for future harvest.

An integrated management approach has been introduced in the Limfjord. One dimension of intregration is a simultaneous assessment of all activities related to the Limfjord as a marine resource. Another dimension of integration is the vertical corporation between authorities of the local counties and the state.

The Danish Ministry of Energy and Environment is the authority that safeguards the water use and quality while the administration is decentralized to the local counties. The local counties are in charge of planning and monitoring/controlling pollution and land use in the coastal regions in accordance with the regulations of environmental protection. Aquaculture and mariculture are under the jurisdiction of the Ministry of Agriculture and Fisheries, but they are categorized and regulated as polluting industries. As water is the most essential production factor to the fish culture industry, the actual restrictions and regulations enforced on the industry are under the jurisdiction of the Ministry of Energy and Environment.

A working group consisting of the three counties in the Limfjord region and the Ministry of Agriculture and Fisheries, Department of Fisheries[1], have initiated and financed a statistical study of the socioeconomics of the fisheries in the Limfjord. The study was reported in 1995 [13] and 1996 [14].

A third dimension of integrated management in the Limfjord is a national scientific interdisciplinary research project aimed at establishing new strategies for "Resource Utilization in the Limfjord". It is a programme under The Danish Centre for Strategic Environmental Research.

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1 Arbejdsgruppen vedrørende myndighedsarbejdet om fiskeriet i Limfjorden

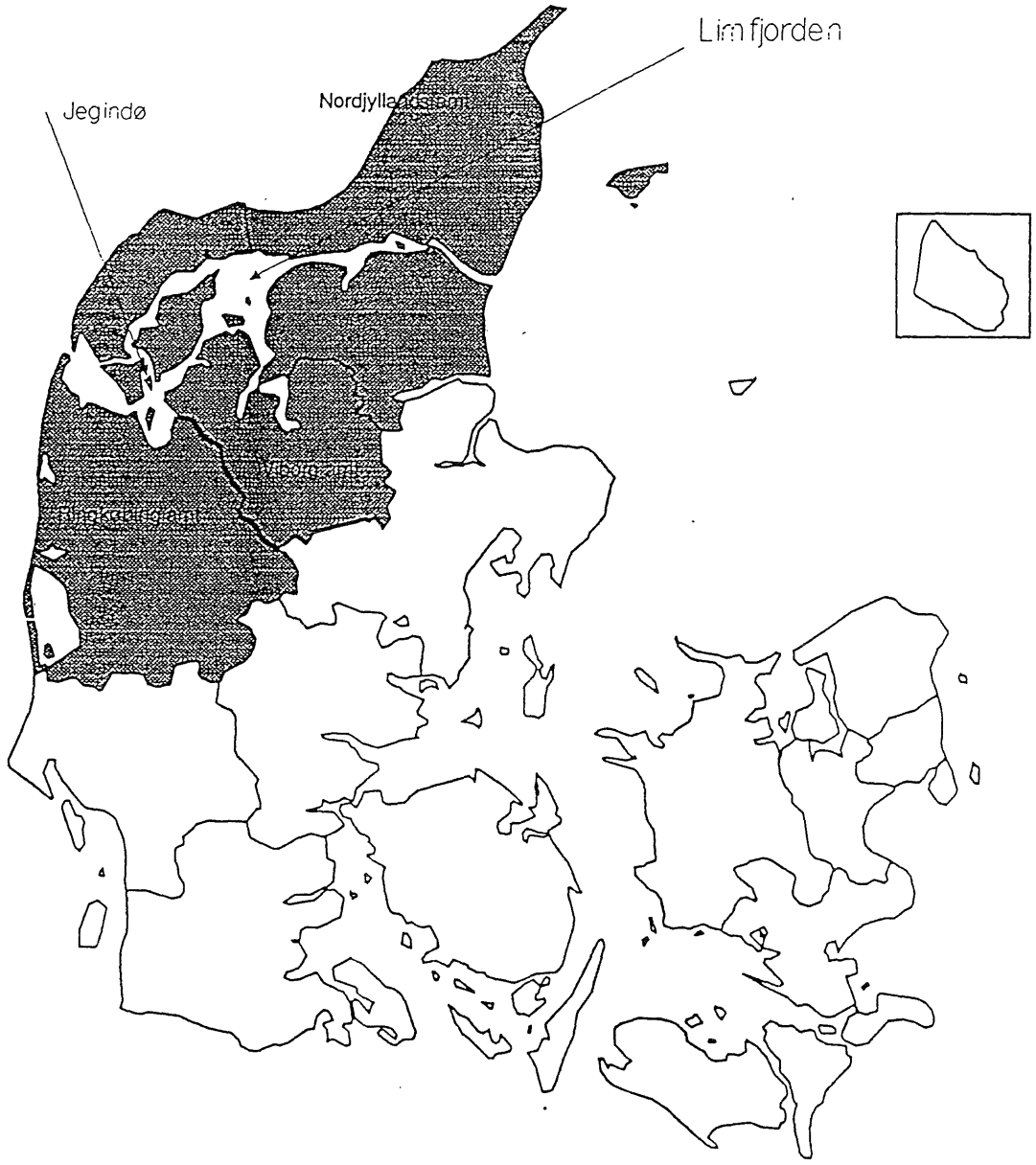
An improved understanding of the relationship between socioeconomics and the environment rests a with better knowledge of

1) the functioning of the ecosystem and the level of sustainable utilization of this system, both as sink of waste, water catchment, aqua/mariculture, households and waterconsuming firms, energy production and fisheries
2) the ability of the management system to cope with the problems arising from overutilization of the resource, as well as the conflicts between different user groups
3) the complementary utilization of coastal areas where par example existence of an authentic milieu by the small landings is of utmost importance to the tourist industry.

The paper is structured in accordance with the above - with focus on the economic implications of utilizing the fish resources of the Fjord. Section 2 gives a description of the Limfjord, its geography, utilization, and restrictions of its use. Section 3 describes how the importance of the commercial fisheries of fish for reduction and human consumption has decreased simultaneously with an increase in the mussel fishery. The economy in the mussel fisheries is describes as well as the use of mariculture through an organized outlay of undersized mussels. Section 4 describes the recreational fisheries in the Limfjord and includes an economic analysis of the restocking programme. The tourist industry and the use of Put-and-Take system is described in Section 5. Section 6 concludes on the general findings.

The Limfjord, its environmental condition and utilization

The Limfjord forms an estuarine fjord-system in the northern part of Jutland, Denmark (see the map on page 4). The Limfjord covers 1,500 km^2 where the mean depth is a little less than 5 m and the maximum depth is about 15 m. The salty water flows into the Fjord from the North Sea in the west and runs into the Kattegat in the east with a salinity ranging from 23 to 33 ‰. The salinity depends on the inflow of water from the North Sea (and to a lesser extent the Kattegat), a passage less than 200 years old, when the Sea evoke through the dunes in the west and created the system we know today. The low depth in the Fjord influences the entropication in the fjord. Summer temperatures vary from 16°C to 22°C and in the winter temperature drops to around 0°C often with ice cover on part of the Fjord.


Limfjorden
Jegindø
Nordjyllands Amt
Viborg Amt
Ringkøbing Amt

From ancient times the Fjord has supplied local people with fish and served as transport facility. Since Word War II, however, the socioeconomic activities connected to the marine resources in the Limfjord have resulted in large changes in the marine environment. The increasing number of activities have created problems of overutilization and internal conflicts because of externalities from one activity to another. The following Table 1 outlines the many different groups involved in the utilization of the streams and coastal regions in the Limfjord area.

Table 1. *Utilization of streams and coastal regions in Limfjord area*

Recreational use
– Nature viewer – Canoeing – Sports fisheries – Amateur fisheries – Small boat sailing – Hunting
Commercial use
– Farming (catchment, water gaining) – Fishfarming (water gaining, waste water) – Commercial fisheries (fisheries) – Tourist industry (sales of "Recreational use") – Sand and gravel extraction

The general trend for the marine environment in coastal areas and Danish Fjords has been a high nutrient load from both nitrogen and phosphorus that has resulted in changes in the fauna and flora and frequent incidents of oxygen depletion. The Limfjord is no exception. The big milestone for environmental protection of especially freshwater and coastal areas was the passing of the Action Plan on the Aquatic Environment in 1987. The main objectives of the plan were to reduce discharges to the aquatic environment of nitrogen and phosphorus by 50% and 80%, respectively, before 1994.

Nitrogen and phosphorus stem from different sources and influence the aquatic environment in different ways. Hence, implementing the action plan has resulted in large public investments and regulations to change the behaviour towards the environment of many industries, i.e. aquaculture, farming, and industrial plants.

Sewage water is the largest source of phosphorus while nitrate mainly stems from agricultural farming. Also fishfaeces contain phosphorus and due to the heavy load of nutrients in the Limfjord fish farming in cages is not allowed. The phosphorus contents

in fishfaeces would offset the effort by district and regional authorities to retain phosphorus in sewage-water-treatment plants. Environmental regulations on aquaculture plants in freshwater to decrease their outlet of phosphorus to the aquatic environment also speaks against allowing a future development of mariculture in cages.

A study of the effects of the Action Plan has been made by Kronvang, 1993 [7]. The annual nitrate nitrogen transport and runoff in Danish streams were modelled for the period 1967 – 1978 (for 6 streams) and 1978 – 1989 (for 62 streams). The analysis showed a significant 3.7% annual increase in the export of nitrate nitrogen during the period 1967 – 1978 in six Danish rivers draining mainly agricultural catchment areas. In contrast, no significant trends could be detected for the period 1978 – 1989. These general results are consistent with the situation in the Limfjord where a decrease in phosphorus has been observed while the runoff of nitrogen still is very high, primarily runoff from farmland. Fluctuations in nitrogen runoff to the Limfjord are primarily influenced by the annual rainfall which washes out nitrogen from agricultural land.

Apart from human activities the environmental conditions in the Limfjord are also very sensitive to weather conditions. Windy weather is favourable to the environment, whereas hot summer temperatures increase the frequency of oxygen depletion and bottom inversion and diminish light penetration necessary for rooted vegetation (eelgrass).

Erik Hoffmann, 1994 [5], discusses the consequences of high nutrient loads in the Limfjord on the production of mussels and fish and points out the following:

- primary phytoplankton production has more than doubled since early 70's which forms the basis of the large production of blue mussels
- the reduction in fish catches has provoked much discussion of the relationship between the increased nutrient load and the reduction in catches. But at the present it is not clear to what extent and at what rate alterations in the biological structure will take place in case of reduced loading

The large phytoplankton production also increases the frequency of anoxia conditions found in the Limfjord which influences fish and mussels. For oxygen contents in water below 4 mg/l the fish try to escape and below 2 mg/l the fixed bottom animals are threatened. Even though the blue mussels are more robust towards anoxia because they clamp up when exposed to low oxygen content, a higher mortality on blue mussels caused by low oxygen has been observed. The dry, hot summers of 1994 and 1995 have caused a very high mortality on blue mussels as 30% of the Fjord experienced oxygen deficiency.

In general, the research into the interaction between environment and fish mortality and growth is still lacking substantial input for an economic assessment.

The resource utilization of the Limfjord is subject to several regulations representing the regional, national, and international interests in nature conservation. The Ramsar Convention of February 2, 1971, contains international obligations to protect threatened bird species and safeguard feeding grounds of migratory birds (74 species recorded). The use of the Limfjord is further restricted by Danish regulations concerning conservation of

- marine biological interest areas
- protected marine areas (§ 60 in the Danish Conservation Act)
- scientific reserves
- seal protection areas
- closed areas for fisheries
- national protected areas
- national nature resort areas.

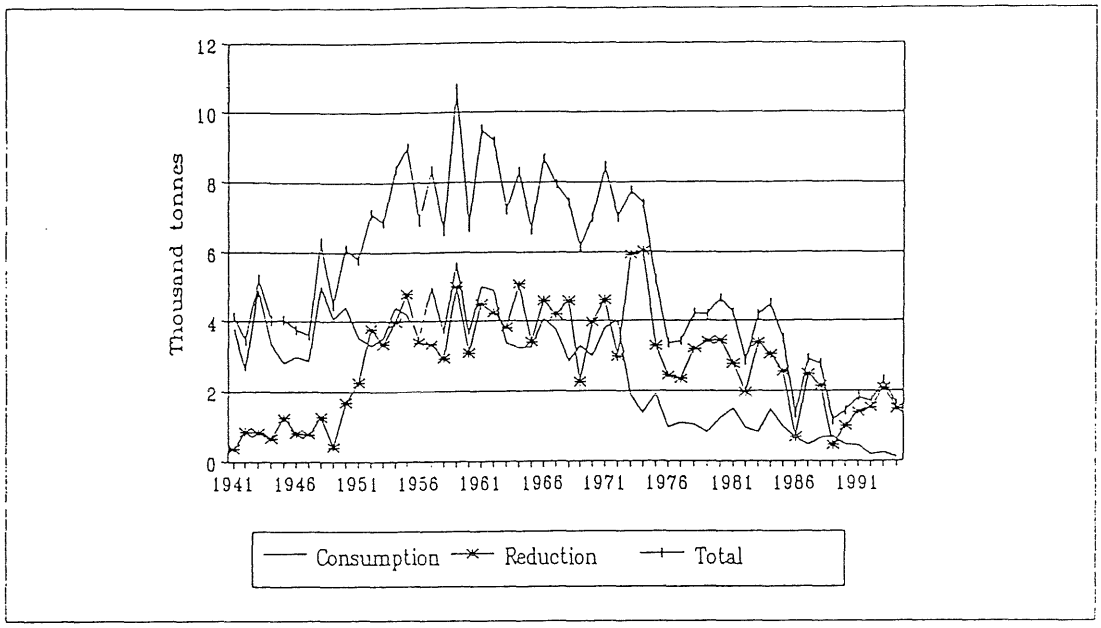
The conservation policy in Denmark often focuses on individual species instead of conservation of biodiversity in whole ecosystems. This lack of integrated management can unfortunately change a successful conservation plan dramatically. A resent example is the preservation of the cormorant which has resulted in a increase in population from 250 pairs in 1971 to 37,000 pairs in 1995. Due to very few natural enemies the growth of the cormorant population is only restricted by food. The influence on fisheries is substantial in the coastal zones. Also the protection of seals can turn out to be a problem for the coastal fisheries.

Commercial Fisheries

Fisheries of fish for human consumption and reduction in the Limfjord has historically had a large influence on the economy in the Limfjord region, but since 1975 it has decreased rapidly. The main fish species are i.e. eel, eelpout, flounder, herring, sprat and sea trout, where only sprat are used for industrial purposes (animal-fodder, meal and oil)

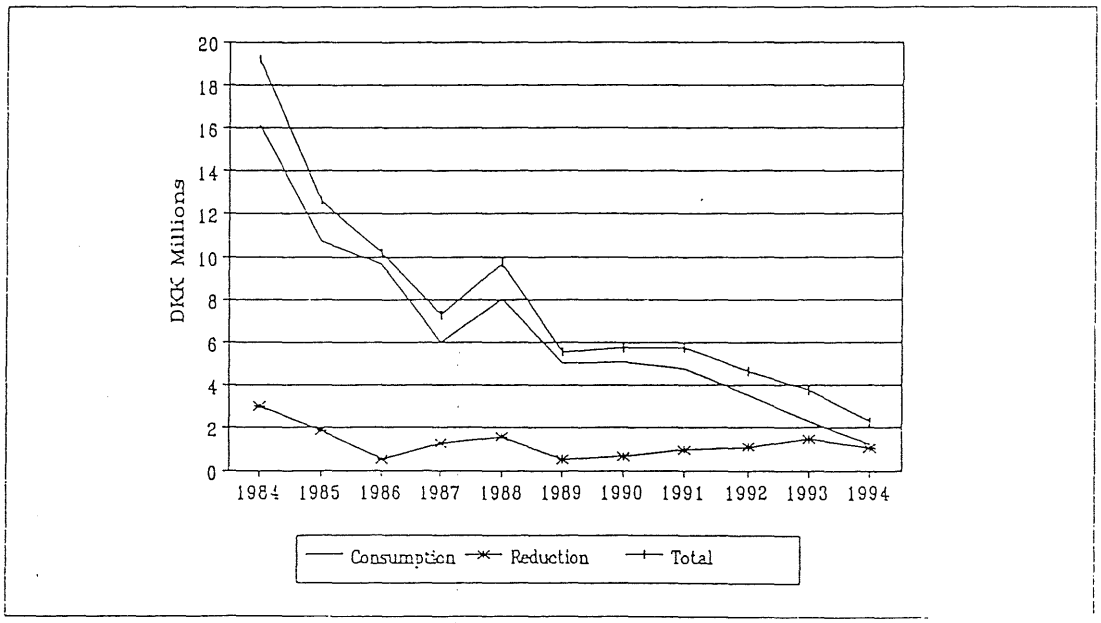
The total catches of fish for the period 1941-1994 are shown in Figure 1 and total turnovers for the period 1984-1994 are shown in Figure 2.

Figure 1. Total catches of fish in the Limfjord during the period 1941-1994, in thousand tonnes



Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: 1994 catches are preliminary

Figure 2:. Total catches of fish in the Limfjord during the period 1984-1994, value in million DKK

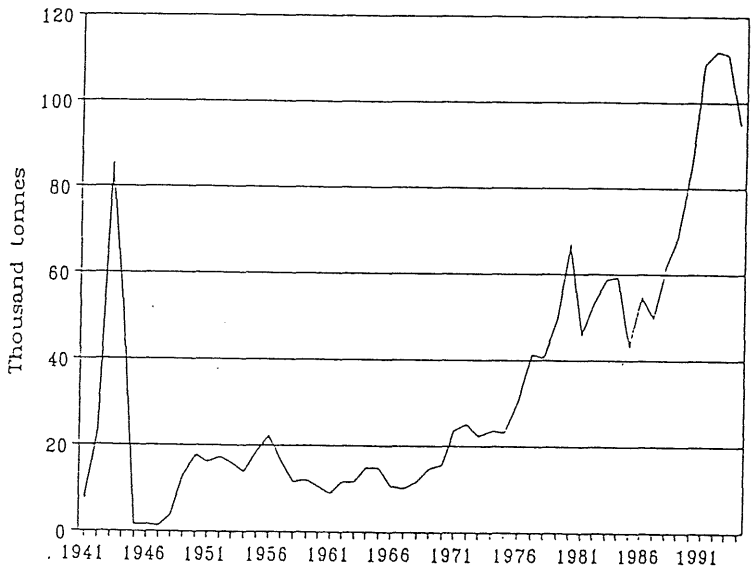


Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: 1994 catches are preliminary

It is noted that the value of the fisheries for human consumption and fish for reduction has dropped to around 1 million DKK each in 1994 and only 10 commercial vessels are presently engaged in this fishery (see Table 2.c below).

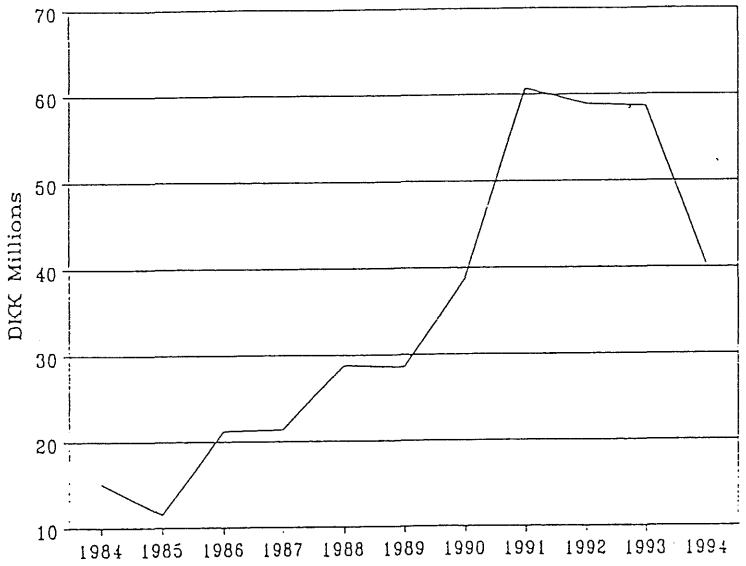
On the other hand the fisheries of blue mussels have increased significantly during the same period. There are 50 licences issued for dredging of mussels in the Limfjord. The catches of mussels for the period 1941-1994 are shown in Figure 3 and the turnovers for the period 1984-1994 are shown in Figure 4. For the last couple of years the net catch volume has been around 110,000 tons blue mussels with a catch value of around 60 million DKK.

Figure 3. Catches of common mussels in the Limfjord during the period 1941-1994, in thousand tonnes



Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: New methods for calculating the weight of mussels were introduced in 1994. There is no real drop in the catch of mussels between 1993 and 1994 (using the old calculation methods the 1994 catches are 107 thousand tonnes)

Figure 4. Catches of common mussels in the Limfjord during the period 1984-1994, value in million DKK



Source: Ministry of Agriculture and Fisheries, Department of Fisheries

The number of independent fishermen including their employees in the communities adjacent to the Limfjord is stated as 491 fishermen[2]. However, this number covers fishermen fishing in other waters and is not suited as a measure of the activity of the fisheries in the Limfjord. Enquiries to the Ministry of Agriculture and Fisheries brought about a segment of data covering only the vessels with log book data showing actual fisheries in the Limfjord. This separate run gives information about how many fishermen are actually involved in the fisheries in the Limfjord and how important is the fisheries in the Fjord compared to other catch areas. Only catches that can be associated with specific vessel are included. Hence, the figures are somewhat lower than the official catches for the Limfjord. However, the distribution of catch inside/outside the Limfjord are still valid for the analysis.

[2]Source: The Statistical Bureau of Denmark, The Central Trade Register

Table 2. Tables including catches from vessels involved with fisheries in the Limfjord in the period 1992 – 1994.

Table 2a. Fisheries in the Limfjord, 1992

Type of catch	No. of vessels	Catch in the Limfjord		Catch in other marine areas		Total catch	
		(tons)	(1000 DKK)	tons	1000 DKK	tons	1000 DKK
Consumption	36	44	948	427	5,386	471	6,334
Reduction	4	1,551	1,084	4,493	3,150	6,043	4,234
Blue Mussels	51	111,793	58,849	4,521	2,776	116,314	61,625
Total	91	113,387	60,880	9,441	11,313	122,828	72,193

Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: Only commercial fisheries included
Quantity measured as landed weight

Table 2b. Fisheries in the Limfjord, 1993

Type of catch	No. of vessels	Catch in the Limfjord		Catch in other marine areas		Total catch	
		(tons)	(1000 DKK)	(tons)	(1000 DKK)	(tons)	(1000 DKK)
Consumption	19	128	919	226	2,636	353	3,555
Reduction	7	2,062	1,442	2,392	1,440	4,455	2,882
Blue Mussels	52	111,026	58,609	1,161	4,376	112,-187	62,985
Total	78	113,216	60,970	3,779	8,451	116,995	69,421

Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: Only commercial fisheries included; Quantity measured as landed weight

Table 2c. Fisheries in the Limfjord, 1994

Type of catch	No. of vessels	Catch in the Limfjord		Catch in other marine areas		Total catch	
		(tons)	(1000 DKK)	(tons)	(1000 DKK)	(tons)	(1000 DKK)
Consumption	7	54	573	74	827	128	1,400
Reduction	2	586	429	1,320	790	1,906	1,219
Blue Mussels	51	107,382	40,281	59	22	107,441	40,304
Total	60	108,022	41,284	1,453	1,639	109,475	42,923

Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: Only commercial fisheries included
New methods on blue mussels in 1994 make the data less reliable
Quantity measured as landed weight; 1994 (preliminary figures)

Table 2d. Fisheries in the Limfjord, 1992 – 1994

Type of vessels	1992			1993			1994		
	No. of vessels	Catch in the Limfjord		No. of vessels	Catch in the Limfjord		No. of vessels	Total catch	
		(tons)	(1000 DKK)		(tons)	(1000 DKK)		(tons)	(1000 DKK)
Net	21	99	747	11	54	7	5	128	474
Dredges	49	105,540	55,537	50	107,656	56,875	50	104,858	39,342
Trawl	21	7,748	4,596	13	5,500	3,469	3	3,112	1,396
Unknown	0	0	0	4	6	72	2	5	72
Total	91	113,387	60,880	78	113,216	60,970	60	108,022	41,284

Source: Ministry of Agriculture and Fisheries, Department of Fisheries
Notes: Only commercial fisheries included
New methods on blue mussels in 1994 make the data less reliable
Quantity measured as landed weight
1994 (preliminary figures)

Knowing that the mussel dredgers have an average of 1.5 men on board, and the fishermen using set nets and pound nets usually work alone, and the trawlers often carry an employee – the total figure is more likely near 100 active commercial fishermen directly engaged in fisheries in the Limfjord. Compared to estimates on employment in fisheries in 1940 of about 1000, there is very few fishermen left.

The fisheries of fish for reduction must be considered a marginal activity in the Limfjord. The 2 boats participating in 1994 had 30% of their turnover in these fisheries. It cannot be established if these fisheries are a necessary condition for the economic survival of the boats. These smaller catches are most often used as mink fodder as they are landed very fresh.

The official legal landings[3] of fish for consumption were mainly landed to Jegindø in the western part of the Fjord (see the map on page 4). This officially licensed auction has a turnover of only 800,000 DKK a year which is not economically sustainable. With a sales commission of 6% and normal costs, the private auction master has an income of not more than 30,000 DKK a year. His personal comment to the question "Why he continued?" was an expectation of larger catches in the future. The expectation for future development of fisheries in the Fjord is connected to the reversed trend in nutrient loads in the Fjord brought about by the Action Plan on the Aquatic Environment in 1987, where the results are starting to show.

The fish is almost entirely exported as fresh fish to the European market. Two local fish exporters buy about 95% of the fish at the auction and two other fish exporters bid

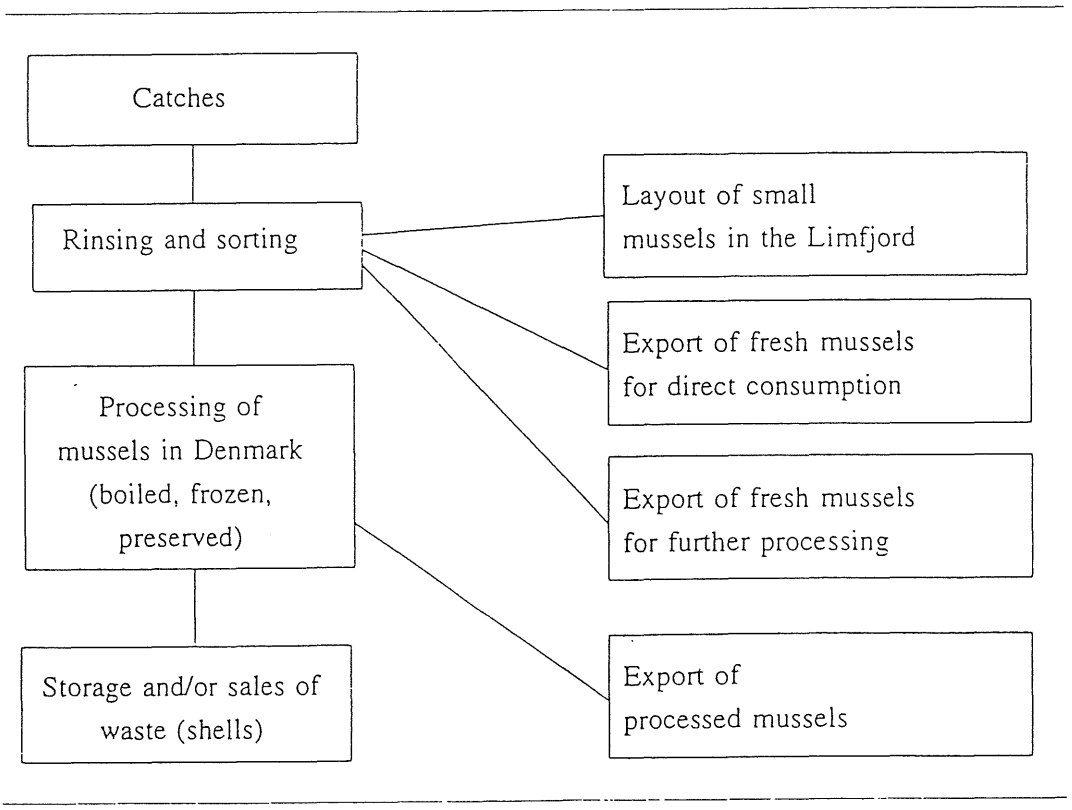
[3]Unconfirmed information of eel landed to a grey market

infrequently totalling about 100-120,000 DKK a year. The value added is about 100% of which wages, packing material, and transport are heavy costs, leaving the two main exporters with an income on fish trade of approximately 70,000 DKK each (compared to 50% of the maximum unemployment benefit in Denmark).

These very few people involved in the fisheries trade might be very valuable to society in the future as they upkeep the infrastructure necessary for a future growth in fisheries.

The catches of blue mussels give rise to further processing and export of blue mussel products and employ directly about 300 people. The following outline shows the production process of blue mussels in Denmark and Table 3 shows the value added in the production process of mussels primarily caught in the Limfjord.

Figure 5. Production and sales of common mussels



Notes: Special features of common mussels from the Limfjord
–Comparatively low meat/content
–Comparatively durable
–Danish marked for mussels is very small

Table 3. Value added in the production process for mussels

Table 3a. Fresh mussels

Fresh Mussels	DKK per kg
Raw material (paid to fishermen)	1.30
Wages	0.65
Packing material	0.15
Transport to border	0.55
Fixed costs and profits	2.20
Sales price at Danish border	4.50

Source: Interviews and telephone conversations
Notes: 3 major Danish suppliers of fresh mussels for the European market from the Limfjord
The total supply to this market is about 6 – 8,000 tonnes from the Limfjord

Table 3b. Frozen mussels

Frozen Mussels *(Production of 1 kg frozen mussel meat)*	DKK per kg
Raw materials (including packing and energy)	9.40
Wages	1.40
Sales costs	0.35
Maintenance	1.00
Transport at sales	0.60
Overheads/fixed costs + profits (-)	1.55
Average sales price	14.30

Source: Interviews and telephone conversations
Notes: The figures are partly estimated. Uncertainty on the informations obtained.
Raw materials for production of frozen mussels meat in Denmark are approx. 75,000 tonnes. Raw materials for production abroad are approx. 15,000 tonnes. 4 major competitors on the Danish market

Table 3c. Production of tinned and further processed mussels

Processed mussels i.e. preserved	DKK per kg	Share in percent
1 kg raw materials (fresh mussels with shell)	0,66	22,00
Wages etc.	0,45	15,00
Packing material	0,60	20,00
Transport	0,66	22,00
Fixed factory costs	0,45	15,00
Environmental costs etc.	0,05	1,67
Other variable costs + surplus (–)	0,13	4,33
Total revenue stemming from 1 kg fresh rinsed mussels	3,00	100,00

Source: Interviews and telephone conversations
Notes: Preserved mussels in cans and glasses and more specialized products
One Danish company process about 20.000 tons of mussels from Limfjorden into these products

The production of blue mussels is first and foremost governed by the availability of mussels, while the economic value added is dependent on the market situation.

The boats land on contract to the firms and prices are negotiated for a longer period of time. Price fluctuations per tonne landed mussels are thus due to changes in meat content and counts (number of mussels per kg). The mussel industry is characterized by an over capacity in the production units which has changed the traditionally strong ties between the fishermen and the processing firms into a competition among firms for resources. This has created a competition via prices for contracts with the fishermen.

The price formation of mussels in the Limfjord might be influenced by a joint production structure in other European countries (strong links between fisheries and processing industry). There is an example from Schleswig-Holstein where negotiations were carried out prior to the licensing of mussel dredgers in the Wadden Sea. Two licenses were granted under the implicit precondition of employment in the processing industry. The mussels in the Wadden Sea are often better suited for the fresh mussel market - hence imports of unprocessed mussels for further processing in the land based plants has created a higher demand from other sources (ie. the Limfjord). Furthermore, the licenses can be issued to firms that own the fishing vessels and hire the crew. This eliminates the price competition between fishermen and the firms as it is seen in Denmark.

The price formation in the factor market can thus be divided into conditions governing the supply:

- the natural environment for growth of mussels and the seasonal changes in mussel condition (and thereby meat content)
- the protection of the mussel stock has led to restrictions in catch and landings, which results in large fluctuations in volumes landed
- the licenses are not marketable and the size of the fishing vessels (tonnage and machine efficiency) is restricted in the Limfjord. Both of these management initiatives limit the incentives to invest in higher productivity (and thereby lowering the costs) in the fisheries,

and conditions governing the demand side:

- over capacity in the processing sector, which means that each plant is producing at a level, where the production costs are higher than under full utilization of the production capacity
- concentration of property rights especially with large Dutch Companies, as large companies theoretically have the market strength to influence the prices
- competition created by implicit preconditions for obtaining a licence in part of the Wadden See

The export price for processed mussels is dependent on the European market situation, as most of the Danish production is exported to this market. The total export value of fresh mussels was 53 mill. DKK and for processed or conserved mussels 193 mill. DKK in 1994.

As described in the introduction, changes in regulation of the mussel fisheries in 1993 led to opening up for lay out of undersized mussels and at the same time increased the ceiling for bycatch of undersized mussels in the catches from 10 to 30%. This new activity was introduced together with a relaxation of the very rigid zoning system, where Ministry of Agriculture and Fisheries decided which zones were open for mussel dredging. Today this has been changed to a self management system, where the fishermen cooperatively manage the zone-system - under the condition that 3 successive catches with more than 30% undersized mussels in one week automatically closes the zone for further dredging.

The consequences of these changes in mussel fisheries regulations together with the possibility of maricultural activities on the mussel banks have yet to be evaluated.

Sports fishermen and amateur fishermen

The largest group of direct users of the Limfjord is the recreational fisheries. The number of sports fishermen and amateur fishermen in the 24 districts adjacent to the Limfjord is shown in Table 4. The table includes both sports fisheries in rivers, lakes and fjords as well as the amateur fisheries (restricted number of fishing tackle including nets and fish traps for household consumption only). Taking into account that they are not all active fishermen (some of them might only have bought a licence for having the option to fish) and that some of the fishermen prefer the coasts of the North Sea or Kattegat - the numbers still indicate a large demand for recreational fishing activities.

In 1994 11,193 licenses were sold to sports fishermen (à 100 DKK) and 3,637 licenses to amateur fishermen (à 250 DKK) resulting in a revenue of around 2 million DKK to the Ministry of Agriculture and Fisheries, Department of Fisheries, for funding the restocking programme. The goals of the restocking programme are to aid the regeneration of the natural fish populations and to secure future catch possibilities for the recreational fisheries.

Table 4. Number of sports fishers and amateur fishermen per district next to the Limfjord in 1994

District no.	District name	Sports fisher men	Amateur fishermen
		1994	1994
665	Lemvig	332	116
671	Struer	539	178
673	Thyborøn-Harboør	42	71
675	Thyholm	68	56
683	Vinderup	270	112
773	Morsø	458	378
775	Møldrup	210	40
777	Sallingsund	298	197
779	Skive	1,251	292
781	Spøttrup	255	104
783	Sundsøre	7	42
785	Sydthy	194	90
787	Thisted	550	227
791	Viborg	1,379	144
793	Ålestrup	268	40
803	Brovst	114	70
809	Farsø	168	132
811	Fjerritslev	117	67
817	Hals	88	158
827	Løgstør	215	118
831	Nibe	252	257
837	Sejlflod	228	110
849	Åbybro	173	78
851	Ålborg	3,717	560
	Total	11,193	3,637

Source: The Ministry of Agriculture and Fisheries, Department of Fisheries, lists of sale of fishing licences

The two most important species in the recreational fisheries are eel and rainbow trout. Restocking of eel has only been done on a reasonable scale for the last few years so the results are still not investigated. Only the restocking programme for trout in the Limfjord is therefore investigated below in the socioeconomic analysis. The first part of the analysis consists of estimating the catches in the recreational fisheries because there are no official statistics. In the second part an economic value is associated with this catch.

The effect of restocking on the catch possibilities in the recreational fisheries are based on model calculations. As input to the model the following parameters are used: The annual restocking of various age groups and their cost prices together with the smoltification rates. The following table shows the estimated recruitment of smolt in the Limfjord stemming from supplementary stocking in 1994.

Table 5. Recruitment of smolt in the Limfjord stemming from supplementary stocking in 1994

Age of stocking	Number released	Percentage smoltification[1)]	Number of smolt	Price per fish in DKK	Total amount in DKK
Fry	159,200	2.5	3,980	0.22	35,000
1/2 yearlings	55,325	10	5,532	0.74	40,941
1 yearlings	68,750	25	17,188	1.74	119,625
"Large"	109,500	0[2)]	0	3.10	384,220
Entrance of stream	154,212	100	154,212	2.5	385,530
For coastal releases	40,000	100	40,000	_	83,000
Total	586,987		220,912		1,048,340

Source: The stocking information come from Peter Geertz-Hansen (IFF, Silkeborg)
Notes: 1) The percentage is taken from "Statusredegørelse om fiskeri i Limfjorden", 1992, Gorm Rasmussen (IFF, Silkeborg)
2) There are no "Large", that smoltificates, because they are already developed into river trout

The table reveals that the annual recruitment of trout from the restocking programme has a cost of 665,000 DKK[4]. Specific assumptions about the growth rate of a trout, the natural and initial mortalities, and the fishing effort have to be made in order to relate the recruitment of trout to the annual catch (the model is described in detail in Roth and Christensen, 1996 [14]). A scenario analysis is also found in the mentioned paper x

Table 6. Results from all the scenarios

Scenario	Mortality giving maximum quantity of catch[3)]	Quantity of catch	Biomass at maximum quantity of catch
1.1[1)]	(0.84,0.84,0.84,0.84,0.84,0.84)	0	141,567
1.2[1)]	(0.84,0.84,2.01,2.01,2.01,2.01)	23,696	91,502
1.3[2)]	(0.84,0.84,2.01,2.01,2.01,2.01)	11,848	45,751
2.1[2)]	(0.84,0.84,117.84,117.84,117.84,117.84)	17,987	40,363
2.2[2)]	(0.84,117.84,117.84,117.84,117.84,117.84)	17,044	22,248
2.3[2)]	(1.07,0.84,3.53,3.53,3.53,3.53)	11,928	33,928
2.4[2)]	(0.99,2.6,2.6,2.6,2.6,2.6)	11,667	22,950
2.5[2)]	(1.42,1.42,1.42,1.42,1.42,1.42)	7,496	23,964
3[2)]	(0.58,0.58,1.75,1.75,1.75,1.75)	23,854	70,528

Notes: 1) Mortality at release on smolt of 0%
2) Mortality at release on smolt of 50%
3) In scenario 2 only the mortality vector which corresponds to the maximum obtainable quantity of catch is mentioned.

[4]The cost of "Large" is not included

where the biomass and catch volume are computed against different mortalities (natural as well as fishing mortality) in order to analyse the effect of different regulation policies. Without going into further details the results from the different scenarios are listed in Table 6.

The results give rise to a number of concluding remarks. The biomass is sustained through the recruitment from the restocking programme, which makes the conclusions concentrate on the possible catch volume:

- if fishing mortality on 0-year trout is 0, the catch volume will only decrease marginally by starting fishing on 1-year olds instead of 2-year olds
- if fishing mortality is increased on 1-year olds and older fish, the total catch volume is increased (presuming recruitment is held constant). This means that there is no reason for restricting recreational fishing on the grounds of preserving catch volume
- free access to fishing on all year classes decreases the catch volume with almost 60%
- if natural mortality is decreased by 5%, the biomass would increase by 17% and the catch volume increased by 30% (ceteris paribus). As a decrease in the natural mortality can be obtained through a better environment this indicates, that improving the environment is the factor to look into, if an increase in catch volume for recreational fisheries is wanted.

The economics of the restocking can be approached in several ways. The estimated catch of 12,000 tonnes (corresponding to scenario 1.3 in Table 6) will be used through out the economic analysis. If the catch were to be sold through the official market it would result in benefits of around 300,000 DKK (assuming a price per kg of 25 DKK). Comparing this value to the cost of 665,000 DKK it does not seem to be profitable to restock for the commercial fisheries. However, in the recreational fisheries the actual catch is not the only measure for valuing a fishing trip. Also the recreational value by itself (and maybe the value of getting away from the domestic duties) should be included in the value of a fishing trip thereby increasing the value of 1 kg of fish caught in the recreational fisheries above the commercial value. A rough estimate of the value can be obtained by looking at the problem from the another angle. Assume that the cost of restocking of 665,000 DKK is actually what the restocking is worth to the recreational fisheries. That gives a unit price of 1 kg of trout at 55 DKK which is more than a double of the sales price (calculated as 665,000 DKK/12,000 tonnes).

Of course the actual figures are rough estimates but the analysis clearly indicates that a fish caught in the recreational fisheries is much more valuable than its commercial value.

Fishing tourism

Fisheries tourism is the overall designation for marketing of fisheries to tourists. Tourism in general is a very large industry in Denmark, primarily because of the availability of sandy beaches and a variety of accommodation. The tourist industry is selling recreational services as part of the sales of accommodation and meals.

The main reason for marketing sports fisheries in the tourist industry is to expand the tourist season, which in Denmark covers the three summer months. Fisheries are best in spring and autumn. The development of Put-and-Take fisheries in dams and artificial lakes are gaining momentum as an aquaculture based recreational activity. Offering this activity (often together with other activities like pony riding and canoeing) is also a way of expanding the tourist season.

The interaction between fisheries tourism and the environment has two sides. First of all, the reconditioning of freshwater and coastal areas, the restocking programme and marketing of green tourism create the potential for the development of fishing tourism. A sound marine environment and the fishing tourism are complements. On the other hand, the wear and tear from tourists on the nature cannot be overseen and external effects on local anglers are also present. Behavioral patterns when it comes to fisheries from different nationals do create friction.

The connection between fisheries and tourism is not clear, as the demand for accommodation might stem from either tourists who actually travel to fish either in freshwater, along the coastline in the fjords, or are simply attracted by the authentic milieu near the small landings – or the tourists choose fishing as a competing activity to other recreational possibilities (beaches, museums, etc.).

The number of fishing tourists can be estimated by the sales of fishing licences to foreign nationalities. It has not been possible to find any specific data on tourist fishing in the Limfjord area, but the total Danish sales of fishing licences to foreign nationalities in 1994 shows a total number of 26,000 of which Germans count for almost 25,000. Each of the 3 counties surrounding the Limfjord account for 6% of the sales of the fishing licenses sold to foreign tourists[5] which limits the potential number fishing tourism in the Limfjord to around 5,000.

The economic return of the tourist industry is difficult to compute. Different segments of the market have different patterns for spending. Many tourists bring almost everything they need from their home countries and are therefore not very supportive to the tourist industry. The following table shows the number of overnight stays by travellers in the

[5] Source: A survey made by the Danish Bureau of Tourism, 1994

three northern counties of Jutland. Most of these tourists enjoy the westbound beaches, but it is also popular to stay in holiday houses and apartment hotels on the islands in the Limfjord or along the coast of the Limfjord.

Table 7. Official Statistics on tourism in the three counties bordering the Limfjord (not conclusive), 1994

	Ringkøbing County		Viborg County		County of Northern Jutland	
	Danes	Foreig-ners	Danes	Foreig-ners	Danes	Foreigners
Hotels, holiday apartments etc. *1,000 persons/nights (1994)*	303.6	237.1	227.7	118.6	1046.0	1081.1
Camping *1,000 persons/nights (1994)*	389.7	358.5	603.1	160.6	1203.0	734.4
Youth hostels *1,000 persons/nights (1994)*	17.3	14.9	20.4	12.3	54.7	88.5
Summerhouses (private) *No. of weeks (1992/1993)*	4080	95007	1678	28682	8312	68223
Yachting etc., Visiting boats *1,000 persons/nights (1994)*	13.5	7.1	24.9	8.3	67.8	104.9

Source: National Danish Bureau of Statistics; Traffic and Tourism, 1994:6, 1994:34, 1995:14

The general trend for Danish Tourism is that 65% of the total tourism are Danes on vacation. The distribution of foreigners visiting Denmark is that 2/3 are Germans and the rest is almost distributed equally between Dutchmen, Norwegians and Swedes. Rent of holiday houses on a weekly basis is showing a different pattern, as 90% are rented by Germans.

The tourist industry has development very fast. A survey of attractive coastal areas in Denmark was made by The Danish Bureau of Tourism in [1]. Three specific areas in the Limfjord were listed as suitable for coastal fisheries of sea trouts but the survey mentioned critically that the fish population was too small and the infrastructure too bad. In general it can be concluded that a further development of the fishing tourism in the Limfjord requires both planning and investments and further studies of the patterns of spendings the fishing tourist and what services they demand might aid the management of marketing the fishing tourism.

Discussion

The long term trend of worsened environmental conditions for fish in the Limfjord area is naturally a reason for concern. Even massive public and private investments in pollution abatement have not changed the marine environment radically.

The aim of the regional authorities is to conserve the marine environment and safeguard (or reestablish to a natural level) the biodiversity in the marine flora and fauna. The reference to a natural environment with week influence from human activities is difficult to administer and for practical purposes the regional authorities classify the recipient and grant permits for outlets in accordance with the classification of the recipient, the historical outlet, and the improvement in abatement technology. A main obstacle the administration of the aquatic environment is, however, the insufficient knowledge of the functioning of the ecosystem and how it responds to changes in environmental conditions.

The change in the commercial fisheries is basically an adaptation to changes in the environmental conditions while the interest in recreational fisheries on the other hand follows from a general change in preferences in the society towards outdoor recreation.

The advantage of the process of viewing a coastal area as a socially integrated area, where both commercial and recreational activities are in demand, is its ability to identify the conflicts between different user groups. It should be mentioned that the field of assessment in the present survey is limited to cover the management of activities that are directly associated with the exploitation of renewable resources in the Limfjord. In practice the local authorities have to consider the social structure in the region and these social aspects have not been included in the present survey.

To sum up, the direct user groups of the fish and blue mussel resources can be reduced to:

- Commercial fisheries after fish for consumption and fish for reduction
- Commercial fisheries after blue mussels
- Amateur fisheries
- Sports fisheries (Danish residents)
- Tourism fisheries (Danes and international tourists)

The turnovers from commercial fisheries of fish and mussels respectively are about DKK 1,000,000 and DKK 60,000,000. The value added in the trade/processing industries vary with the production process. Fish for consumption is mostly exported as fresh fish and its value is doubled when it is delivered at the Danish border. Mussels have a value added for fresh and boiled/frozen mussels of twice the original factor price, whereas further processed mussels are added 3,5 times. The mussel fisheries have great economic value to the region.

Even though the commercial fisheries of fish have little economic value, they might be important in other ways. Firstly, the fisheries upkeep the basic infrastructure for the landings and trade and thereby preserve an option for the future fishermen in the region. Secondly, the fisheries have complementary value to the tourism industry.

It seems reasonable to assume that the restocking programme is administered economically rational implying that the benefits of restocking cover the costs. Under this condition the value of the fish caught in the recreational fisheries represents a value which is more than the double of its commercial value. However the programme might not be administered economically optimal in the sense that further improvement in the net benefits could be obtained by reconsidering

- the actual restocking procedure (maybe a change in the restocking procedure would result in higher smoltification rates)
- the volume of restocking (maybe the consumer surplus of restocking for recreational use could be increased by increasing the restocking).

Tourism fisheries cover a special segment of tourism and the potentials are developed in parts of Denmark. The Limfjord has been listed as an area with good potentials for future development of the fishery tourism and the possibilities are under investigation.

The foundations for these economic activities are the marine environment, the restocking programme, and the management of these natural resources (i.e. layout of undersized mussels) and last but not least the actual biological production in the Limfjord.

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Describing Benthic Impacts of Fish Farming with Fuzzy Sets: Theoretical Background and Analytic Methods

Dror Angel[1], Peter Krost[2], and William Silvert[3]

Abstract

Diver observations have been recorded over a period of several years at a site severely impacted by finfish mariculture. Logged data were analysed using fuzzy logic in order to address the problem of interpreting sometimes qualitative and subjective information. The underlying methodology based on fuzzy set theory is developed and described in this paper, along with the techniques used to quantify the relationship between the information recorded by the divers, which was usually of a verbal descriptive nature, and a numerical index of benthic impact.

Introduction

A three-year time series of more than 100 dive logs describing the status of the benthic environment beneath a net cage farm in the northern Gulf of Aqaba (Red Sea) has been collected and analysed. These logs cover the productive life of a fish farm site, including observations made after the cages were removed. Although the logs contain potentially valuable information about the benthic impacts of fish farming and about the process of recovery after removal of the cages, the descriptive nature of the data makes interpretation difficult. Fuzzy logic proved a valuable tool for translating the log data into quantitative form. Because of the novelty of this approach, this paper focuses on the underlying theory and development of analytic techniques for carrying out this analysis. The monitoring study of this site still continues, and more information on benthic changes following the removal and reconstruction of a floating fish farm is currently being collected. Those data will be used in a subsequent paper to test and validate the results of the analysis presented here. However, because the theoretical basis for the investigation involves a new methodology, it seems appropriate to analyse a subset of existing data in order to assess the value of fuzzy set theory for this type of problem

The original purpose of these logs was simply an informal collection of qualitative observations made during the frequent dives under the fish farm, which were performed during a geochemical and microbiological study on benthic implications of net cage aquaculture in the oligotrophic Gulf of Aqaba (Angel et al. 1995). Eventually it became evident that valuable information about the sediment dynamics and benthic processes involved in organic enrichment and recovery of the site

[1]Water Quality Research Group, National Center for Mariculture, P.O.B. 1212, Eilat 88112, Israel. Email: angel@agri.huji.ac.il

[2]Abteilung Meeresbotanik, Institut für Meereskunde, Düsternbrookerweg 20, 23 Kiel 1, Germany. Email: pkrost@ifm.uni-kiel.d400.de

[3]Habitat Ecology Section, Bedford Institute of Oceanography, P. O. Box 1006, Dartmouth, N. S., Canada B2Y 4A2. Email: silvert@scotia.dfo.ca

could be gleaned from the observations, so during this period the logs were refined to provide more comprehensive and quantitative data.

Although it was clear that the logs contained valuable information about how the site recovered after removal of the cages, it was difficult to interpret the data. It appeared that fuzzy logic might offer a way to deal with these difficulties (Silvert, submitted), so a pilot study was set up to analyse the logs in terms of fuzzy sets.

As far as we are aware, environmental data have never been analysed using fuzzy logic in this way before, so it was a learning experience for all participants. We have therefore decided to document the process as well as the results, since this is likely to be of use in deciding how to carry out future analyses of this type, as well as judging whether the methodology is likely to be useful in other situations.

Experimental Sources and Methods

Description of Study Site

The Ardag fish farm is located at the northern end of the Gulf of Aqaba, about 300 m offshore and close to the Jordanian border, over a sandy seafloor ranging from 20 to 30 m in depth. The farm was established in 1988 and consisted of two rows of floating net cages secured to a pontoon. From 1988 to 1991, annual production was between 60 and 80 tonnes of gilthead seabream (*Sparus aurata*). The cage system was modified and expanded in 1993, and annual fish production reached 250 tonnes by 1994. The natural, unenriched sediments near the farm consist of fine sand that support a wide variety of soft-bottom invertebrates (Fishelson 1971), seagrass beds (mainly *Halophila stipulacea*), benthic medusae (*Cassiopeia* sp.) and numerous demersal species associated with the seagrass beds. The surface of the sediments (upper 2 cm) directly below the fish cages was dark grey and fluffy in comparison to the compacted, yellow-to-light-grey sand in the natural unenriched sediments nearby. However, there were only minor differences in particle size distribution (the greatest variability among stations was in the 125 - 250 μm class) between sediments sampled below the fish farm and from clean sites. Microbial mats covered the organically enriched sediments under and adjacent to the pens throughout most of the year, and seagrasses did not grow in this region (Angel et al. 1992; 1995b).

Underwater observations of the seafloor

Field work was performed by SCUBA divers with varying experience in benthic ecology. Biotic activities and the physical appearance of the sediments were observed during dives and recorded as written descriptions. Observations included bioturbation by native fish, occurrence of epibenthic invertebrates, appearance and areal coverage of bacterial mats and organically enriched sediment, and visibility near the seafloor.

Visual observations were occasionally supported by still and video photography. In October 1991, a team from the NURC/NOAA group at the University of Connecticut conducted several video transects under the fish farm using a "Mini Rover" Remotely Operated Vehicle (ROV) in order to document the areal extent of disturbed sediments below the fish farm. In March 1993 a benthic survey was performed under the fish farm, using a REMOTS (Remote Ecological

Monitoring Of The Sea floor) and a video camera provided by the Institut für Meereskunde in Kiel, Germany. The first research dives were performed in fall 1990, but initially without a detailed ecological protocol to specify the observations required and to standardise how they were recorded. In spring 1991, after noting substantial changes in benthic bacterial mats, a standard form was developed to be filled out after each dive. This form contained technical details such as date, names of divers, exact location and the dive plan (max. depth and time) and visibility. In addition, all six of the participating divers were required to record a specified set of observations made at the seafloor. Later on, starting in April 1992, the sampling protocol was expanded and formalised to ensure more consistency between the logs.

Fuzzy Logic

Use of Fuzzy Sets for Environmental Classification

There are a number of difficulties in the analysis of these data which can be resolved by the use of fuzzy logic. The basic problem of assessing environmental impacts from incomplete and sometimes subjective data has been described by Silvert (submitted). The dive logs in this study contain many different kinds of observations, not all of which are quantitative, but which are of sufficient significance that we felt that they could not be discarded without loss of valuable information. For example, the thickness of bacterial mats is an important indicator of carbon loading, but the observations that were recorded at this site were descriptive rather than quantitative. Fuzzy logic lets us utilise these observations by relating impact categories to verbal descriptions such as "thick" or "thin". In this paper we focus on the analysis of qualitative data regarding fish farm impacts using this feature of fuzzy set theory, and the treatment of quantitative data such as organic loading and sediment oxygen consumption will be postponed to a later paper.

The decision to use fuzzy logic also resolved some other issues in analysing the data. One was the lack of uniformity along the dive transects. It was seldom possible to assign a single value to each variable measured along a transect, and using fuzzy sets to describe the heterogeneity of observations seemed more realistic than using means or other averaging techniques. For example, if there are thick bacterial patches along half a transect and no bacteria at all along the other half, a description such as "50% thick and 50% none" (meaning membership of 0.5 in each fuzzy set) is preferable to using an average thickness, which is equivalent to assuming uniformly thin mats along the entire transect even though no thin mats are actually observed.

Association Rules

The first step in deriving a fuzzy classification scheme from a set of observations is to associate each observation with different fuzzy sets describing the system. This is different from more traditional approaches which usually require an exact correspondence between observations and classifications. For example, a sediment redox potential (Eh) of 100 mv could be considered the dividing line between satisfactory and unacceptable degrees of impact, but it is difficult to assign a great deal of significance to the distinction between 99 mv and 101 mv. By using fuzzy sets we can associate each measurement with more than one classification by specifying the partial membership in each set, so that a redox potential close to 100 mv would have partial memberships in both the "satisfactory" and "unacceptable" fuzzy sets, and the distinction between 99 and 101 mv would be minor.

The correspondences between observations and fuzzy set memberships are called *Association Rules* and are used to convert data into lists of partial memberships for each variable. These are sometimes referred to as an *Association Matrix* or *Compatibility Matrix*, but the concept is more general than the usual mathematical definition of matrix, and can include qualitative and subjective observations as well as continuous mathematical functions. If we classify all benthic communities into just two sets for example, *healthy* and *damaged*, then typical rules might be:

- If there are dense kelp beds the bottom is 100% healthy and 0% damaged (i.e., membership in the set *healthy* is 1 and in the set *damaged* is 0).
- If only one species of macrofauna is present then the bottom is 10% healthy and 90% damaged.
- If Eh = 80 mv the bottom is 80% healthy and 20% damaged.

In the first case the observation is subjective, and presumably there is a range of observations including "sparse kelp" and "no kelp" that could be entered on the log. In the second case the number of species is a discrete variable, while in the third case Eh is a continuous variable and the partial memberships can be treated as functions of Eh.

To be more precise, these percentages are referred to as partial memberships, since the actual classification is based on evidence from several observations. If we observe both dense kelp beds and an Eh value of 80 mv, the corresponding partial memberships would have to be combined in some way to give a total membership of, say, 90% healthy and 10% damaged. The definition of appropriate *combination rules* is discussed in Silvert (submitted) and will be dealt with below.

The interpretation of fuzzy memberships sometimes leads to disputes, particularly on the part of those who take the view that fuzzy set theory is just another name for statistics and that all fuzzy set concepts can be expressed as probability measures. According to this point of view, partial membership of 50% in the sets healthy and damaged means that there is a 50% probability that the system is healthy, and a 50% probability that it is damaged. We take the view that environmental classifications are not totally exclusive, and that systems can straddle the borderline between two categories. This means that a system whose membership in the healthy set is 80% really is healthier than one whose membership is 20%, and not simply that it is more likely to be healthy. One of the advantages of fuzzy set theory is that we can use a limited number of discrete sets to create a continuous spectrum of categorisations.

The various association rules summarise the available information about the relationship between environmental observations and the condition of the system under investigation. The developmental aspects of the work described in this paper will be described in some detail because of its importance for understanding the application of this technique.

Definition of Impact Categories

Before developing the association rules one must define the categories to be used for the classification scheme, which means deciding to what fuzzy sets the system can belong. This is not a purely objective scientific decision, but depends on what kinds of results are needed and the kind

of resolution that is both necessary and appropriate. Too many categories usually prove impractical, but too few categories may not allow for a meaningful description of the system and thus might not prove useful. One extreme possibility is to define just two sets, say "good" and "bad", such that an unimpacted bottom has 100% membership in the "good" category and 0 in the "bad", represented by the vector (1.0, 0.0), whereas a heavily impacted site might have a membership vector more like (0.1, 0.9). In this case we felt that two categories would not provide sufficient resolution, and we concluded that four fuzzy sets probably provide the optimal number of categories to characterise bottom conditions at this site.

The four categories of impact defined for this project are "Nil", "Moderate", "Severe" and "Extreme". These are consistent with, although not directly based on, the characterisation developed by Pearson and Rosenberg (1978), and the observations that were made at this site were not chosen on the basis of the Pearson-Rosenberg model. Nil impacts are characterised by ambient levels of productivity and diversity, although these variables were not measured at the Ardag site. Moderate impacts show some effects of nutrient enrichment, usually through increased productivity and a shift in species composition. Severe impacts are associated with reduced productivity and low species diversity, while extreme impacts certainly include azoic conditions. Every observable was related to each of these categories by a set of association rules, which identified to what degree an observation was associated with each of these four categories. For example, anoxic conditions in the Gulf of Aqaba are always indicative of organically enriched sediments which are usually associated with extremely impacted bottoms. The corresponding association rule is $\mu_{Nil}=\mu_{Mod}=\mu_{Sev}=0$ and $\mu_{Xtr}=1$, represented by the vector (0, 0, 0, 1).

Development of Association Rules

Association Rules for this project can be expressed in the form of the matrix shown in Table 1. Each row of the matrix corresponds to one of the observations found in the logs; for example, the second row of Table 1 shows the associations corresponding to "patchy bacterial mats", and the matrix shows that this observation is most strongly associated with Moderate or Severe impacts, and less with an Extreme or Nil classification.

In this study one of the critical indicators of benthic condition was in fact the extent to which the seabed under the cages was covered by bacterial mats. In order to represent the relative importance of different observations, a weighting factor is assigned to each observation which is used in the calculation of the combined memberships. The importance of mat coverage is reflected in the high weight of 0.9 assigned to this observation. Several different types of observation were used to characterise the mats, including thickness, the percentage of sediment surface covered by mats, and their colour. The nature of the association rules is shown in greater detail by the following submatrix taken from Table 1:

Mat Thickness	Weight	Nil	Moderate	Severe	Extreme
thin	0.7	0.14	0.32	0.32	0.23
thick	0.7	0.04	0.29	0.29	0.38
massive	0.7	0.00	0.13	0.31	0.56

The weight of 0.7 shows that mat thickness is an important variable, but not quite as important as mat coverage (0.9). The four classification sets, Nil through Extreme, are associated with three values of the Mat Thickness, and each row of the matrix shows the extent to which each type of observation is associated with these four sets. The numbers in each row are normalised to add up to one. The numbers were obtained by a process of seeking a consensus among the scientists who had studied the region and consequently there is an element of subjectivity. The thicker the mats, the less the association with the Nil impact category and the greater the association with the Extreme impact category, as we would expect. The subjectivity is not so much a result of using fuzzy logic, as a basic problem of how one translates scientific data into an assessment of environmental impact; this issue is discussed in Silvert (submitted).

The association rules are often site-specific, as illustrated by the rules dealing with sea grass. In the Gulf of Aqaba the dominant macrophyte is *Halophila stipulacea*, which is sensitive to turbidity and vanishes rapidly under conditions of moderate impact (Pereg et al. 1993, Angel et al. 1995b). Since *H. stipulacea* is viewed as an important indicator species in this area, the presence of sea grasses on the seafloor was strongly associated with Nil or Moderate impact and the observation of extensive sea grass beds was considered incompatible with an assessment of Extreme impact, so the association of this observation with the Extreme category was set to zero. The situation in other areas can be quite different, since some sea grasses may thrive in polluted sediments with high organic content; cf. research in Australia (Larkum et al. 1989), Cyprus (Bayada, pers. comm.) and Malta (Chauvineau, pers. comm.), so the association rules for sea grass depend on location.

The use of fuzzy logic was extended to recording the actual observations, since there is a degree of ambiguity in the data due to local variations in bottom conditions. For example, along a sampling transect there can be a gradient in the thickness of the bacterial mats, so that it is best to describe the mats as belonging to more than one fuzzy set. In situations like this we use arithmetic averages. If one of the logs describes thick mats covering 30% of the area surveyed, and thin mats in the other 70%, this is interpreted to mean that the mats have membership of 30% in the "thick" set and 70% in the "thin" set, with resulting partial memberships for the impact categories calculated as follows:

Nil	Moderate	Severe	Extreme
.7*0.14+.3*0.04 = 0.11	.7*0.32+.3*0.29 = 0.31	.7*0.32+.3*0.29 = 0.31	.7*0.23+.3*0.38 = 0.28

This situation occurred most often with visual observations where the diver could sample the entire area and see patchiness in the properties.

It is important to note that averaging the fuzzy memberships in this way is not the same as averaging the observations without using fuzzy logic. Suppose we are given the observation that half of a transect contains a normal abundance of seagrass, while none is present on the other half. The Association Rules for seagrass (again from Table 1) are:

Seagrass	Weight	Nil	Moderate	Severe	Extreme
absent	0.8	0.06	0.29	0.32	0.32
few	0.8	0.70	0.30	0.00	0.00
normal	0.8	0.80	0.20	0.00	0.00

If we try to combine these results into a single observational category, it is reasonable to argue that on the average we should describe the situation as one with few plants, giving a membership vector of (0.70, 0.30, 0.00, 0.00). If on the other hand we average the two fuzzy sets as shown above, we get

Nil	Moderate	Severe	Extreme
.5*0.06+.5*0.80 = 0.43	.5*0.29+.5*0.20 = 0.24	.5*0.32+.5*0.00 = 0.16	.5*0.32+.5*0.00 = 0.16

so the membership vector is (0.43, 0.24, 0.16, 0.16), which is quite different and reflects the bimodal nature of the original observations. In particular, the existence of a region with no plants can be associated with a Severe or Extreme impact, whereas if we average the seagrass abundance over the entire transect we ignore this possibility.

Most of the variables in the logs were discrete observations, including some presence-absence data. Some were inherently continuous variables which were verbally described in discrete terms in the logs, and which would have been extremely difficult to measure objectively; for example, it is relatively easy to characterise the degree of bottom coverage by macrophytes in terms like "normal", "sparse", or "absent", but actual measurement of the degree of coverage by macrophytes would be difficult and time-consuming. The thickness of bacterial mats is another example, since it is easy to distinguish thin from thick or massive mats, but difficult to make precise measurements. It is possible to develop association rules that take the form of a function relating the partial membership to a measured quantity, but this approach was not seen as appropriate at this stage of the research program.

In this study we focus mainly on continuous variables which could in principle be measured numerically, but which were recorded in discrete terms. These include the areal coverage and thickness of the bacterial mats, amount of seagrass coverage, presence of visible epi-macrofauna and bioturbation by macrofauna and fish, and visibility. The colour of the bacterial mats was also recorded.

Association Rules

The association rules used in this study are shown in Table 1. Each row of the table, which is commonly referred to as an "Association Matrix", lists the partial memberships associated with that observation in the four fuzzy sets that are used for classification. In addition, a weighting factor is included to allow for differences in importance of the variables, as described earlier; for example, thickness and areal coverage of bacterial mats is considered a better indication of bottom conditions than their colour, so these variables have a higher weight than mat pigmentation.

In some of the rows all of the memberships are equal or similar in value; this means that the data represented by that row do not provide useful information about the state of the system. For example, thin bacterial mats are found under all conditions so their presence tells us very little about the degree of impact. Massive thick mats on the other hand are a clear indication of heavy organic loading and are highly associated with Severe and Extreme impacts. The distribution of partial memberships for each type of observation and the weight associated with it indicates how much significance it has in the final calculations.

The presence of bacterial mats is a strong indicator that the seafloor is both organically enriched and anoxic (Hall et al. 1990; Holmer and Kristensen, 1992; Findlay et al. 1995; Angel et al. 1995b). The thickness of bacterial mats and their areal coverage provide additional indicators of the extent of organic loading and the impact on the benthos, thus the relatively high weights assigned to these categories. The mats were generally white, however, green, brown and purple mats were also recorded (Angel et al. 1992). The light green colour was generally due to presence of euglenoids, while dark green, brown and purple mats were the result of *Oscillatoria* spp. in the mat communities. Increased intensity of the bacterial mat pigmentation (from green to purple) was positively related to increased organic loading and high sulphide (H_2S) concentrations.

The abundance of the seagrass *H. stipulacea* seems to be the most sensitive indicator of fish farm impacts. As stated above, seagrass beds are found throughout the region surrounding the fish farm but were usually not present below the fish cages; thus the variable *seagrasses* was assigned a weight of 0.8.

The normal, epi-macrofaunal community in the undisturbed sediments around the fish farm includes *Cassiopeia* spp., various decapods, holothurids, sea urchins, mound-forming polychaetes and many other species that were usually not observed below the fish cages. In the past, observations of macrofauna were rarely included in the dive logs due to their absence or oversight on the part of the divers, therefore this category has been assigned a weight of only 0.4, despite the fact that macrofauna are recognised as highly informative indicators of sediment health. In addition to the significance of macrofaunal presence/absence, we felt that bioturbation by macrofauna or fish is an important indicator of the status of the seafloor, since bioturbation will probably not occur if the sediments are highly sulphidic.

The last category included in the association rules is underwater visibility, which is directly influenced by the fish farming activities, but also depends on external factors such as resuspension and primary production. During stagnant conditions, visibility decreases because the input of particulates from the farm is not balanced by the cleansing action of the currents. This tends to bias observations by limiting vision to the immediate area, resulting in fewer observations regarding mat pigmentation, presence of benthic fish, macrofauna, etc.

Combining Observations

As mentioned previously, averaging the partial memberships for different conditions along a transect is a very different process from combining the partial memberships for distinct

observations, and in the latter case it is seldom appropriate to use arithmetic averaging. There are different ways of doing this, depending on the context of the analysis, as discussed in Silvert (submitted). Based on the discussion there, for the purposes of this paper we use the symmetric sum (Silvert 1979) to combine partial memberships.

In calculating the combined membership of the system in one of the fuzzy sets used for classification, the symmetric sum of weighted observations is given by

$$\mu/(1-\mu) = \{[\mu_1/(1-\mu_1)]^A[\mu_2/(1-\mu_2)]^B[\mu_3/(1-\mu_3)]^C\ldots\}^{1/(A+B+C+\ldots)} = \Lambda \qquad (1)$$

where μ is the combined membership, the μ_i are partial memberships for different observations, the exponents A, B, C, ... are the weighting factors, and Λ represents the right hand side of the above equation to simplify the following discussion. The meaning of this complex looking expression for the symmetric sum is simply that the value of $\mu/(1-\mu)$ is the weighted geometric mean of the ratios for partial memberships, $\mu_i/(1-\mu_i)$.

Since the memberships are normalised, all of the μ_i lie in the range between 0 and 1. In evaluating the symmetric sum a degree of caution is required. If all of the μ_i are less than one (i.e., none of the observations conclusively identifies the system as belonging to this classification), then $\mu = \Lambda/(1+\Lambda)$. If one (or more) of the μ_i is equal to one and the other values are all greater than 0, the value of μ is also one. In other words, if one of the μ_i is equal to zero or one, which means that the corresponding observation is not fuzzy, this clearly determines the combined membership. For example, if one of the impacts is totally unacceptable, then the combined effect when all other variables are taken into account must also be unacceptable. However, a mathematically unresolvable situation arises if one or more of the μ_i is equal to zero while another is equal to one, since in this case the expression for Λ is equivalent to 0/0 which is not defined. The interpretation of this situation is that one of the observations shows conclusively that the system is a member of the set ($\mu_i = 1$), while another observation proves equally conclusively that this is impossible ($\mu_i = 0$). The answer is not in the mathematics but in the original association rules or in the data, since the meaning of this result is that two absolutely incompatible observations have been made simultaneously on the same system. Unless there is an error in the observations, the existence of such a contradictory result means that the association rules are incorrect and must be modified.

Defuzzification

The final step in using fuzzy logic to classify systems is converting the vector of fuzzy memberships into a single numerical value. Although this is not an essential part of the process, in practice it is frequently necessary to provide a "score" to satisfy the needs of the decision-making process. This process is called *defuzzification* (Silvert, submitted).

The simplest way to defuzzify the membership vector is by simply forming a linear combination of the memberships. If we have just two categories, *good* and *bad*, then a simple way of defining a score is $\mu = 0 * \mu_{good} + 1 * \mu_{bad} = \mu_{bad}$, so the score is just equal to one of the memberships. In the present case we defined a score by the expression

$$\mu = 0 * \mu_{Nil} + 1 * \mu_{Mod} + 2 * \mu_{Sev} + 4 * \mu_{Xtr} \qquad (2)$$

which varies between 0 for an unimpacted seabed to 4 for one that is extremely impacted, assuming that the memberships are normalised so that $\mu_{Nil} + \mu_{Mod} + \mu_{Sev} + \mu_{Xtr} = 1$. The choice of coefficients is a largely arbitrary expression of the underlying consideration that the greater the impact, the greater the cause for concern. In cases where the membership in the Extreme category was non-zero ($\mu_{Xtr} > 0$), the value of μ_{Xtr} was usually the decisive factor in determining the score.

Results

The analysis of the logs was carried out without regard to data about external factors such as currents and storm events which might affect the seabed at the site. A final step was to examine the results of the fuzzy classification in terms of such factors as storms, bioturbation events, and changes in the management of the farm.

Figures 1 and 2 show the result of filtering the data on the basis of how extensive the observations associated with each log were. Each observable has a weight assigned to it as specified in Table 1, and the summed weight of all observations on a given date is a measurement of the completeness of the data. For these logs the total weights lie roughly in the range from 1 to 5. Figure 1 shows the partial memberships when all the logs are taken into account, and Figure 2 shows the results when only logs with total weights greater than 3.5 are included, which comes to 40% of all the logs. Although this filtering process greatly reduces the high-frequency variability of the data, particularly at the beginning of the time series, it does not affect the pattern, which indicates that logs with fewer observations do not appear to be biased.

The dominant patterns in the impact score as shown in Figure 3 are a short period of lessened impact during the spring of 1992, a gradual decline during the second half of 1992, low values throughout 1993, and a sharp increase back to high impact levels at the beginning of 1994.

The 1993 period stands out even more clearly when we look at the complete set of memberships (Figures 1 and 2). The measures of Severe and Extreme impact fall to low values during this entire period, largely due to the presence of abundant beds of *Halophila* which we consider incompatible with these impact categories. The presence of *Halophila* can be taken as a strong indicator of ecosystem health.

It is easiest to visualise these results by defuzzifying them and plotting the weighted score, as given by Equation (2). This is shown in Figure 3, and although a comparison of Figures 1 and 3 shows that most of the variation in the score is explained by changes in μ_{Xtr}, the membership in the Extreme impact set, some information is lost. The dominance of the Nil and Moderate categories during most of 1993 explains the low impact score, but the defuzzified score itself does not show that this is the cause.

The most pronounced trend in the data is the dramatic shift in the period between April 1993 and January 1994, which we shall refer to as "1993" for brevity. During this interval there was remarkable improvement in bottom conditions as indicated by a sharp decline in the impact index

and a change from a pattern with roughly equal memberships in the Moderate, Severe, and Extreme impact category to a mixture of Moderate and Nil.

These patterns, which coincide with a general consensus on the part of the divers that conditions during 1993 were markedly better than in previous years, can be attributed to changes in a few critical observables. Most important was the abundance of sea grass, since during this period there was massive plant recolonization. There is general agreement that the presence of *Halophila* is not compatible with a Severe or Extreme impact classification. In other words, the associations of "few" or "normal" seagrass abundance with these two impact classifications are zero. Other notable changes observed during 1993 included a rapid decrease in bacterial mat coverage and thickness and the appearance of bioturbating decapods.

Discussion

This paper deals primarily with the development of the fuzzy logic methodology, and a complete analysis of the data will be addressed in a later paper. We have however looked at these preliminary results in the context of potentially significant events over the period during which the site was observed, and these patterns seem to support the use of fuzzy logic as a means of extracting useful information from these observations.

When we look at the environmental history of the site, several events occurred that appeared to be reflected in the fuzzy analysis. During period B (see Figure 3) there were frequent storms and a period of heavy fish bioturbation, which appears to be reflected in the decline in the impact score during this period. At the end of period B there was a reduction in bioturbation by goatfish and rabbitfish which may have contributed to the worsening benthic score. We do not as yet have an environmental explanation for the decline in benthic score between May and November of 1992 (period C), although there was a major storm in May. The decline in fish bioturbation appears to be more strongly reflected in the decline in membership in the Nil impact set than in the total score.

During the winter of 1992-1993 the fish in the farm were removed, which clearly explains the decline in benthic score during this interval (period D) and the low score during period E when the farm was vacated. Severe and Extreme impact memberships fell to low levels during this period. However, recovery did not proceed as we might have expected. After the removal of the fish there was an immediate decline in μ_{Sev} and μ_{Xtr}, accompanied initially by rapid increase in bothμ_{Mod} and μ_{Nil}. The initial improvement in the status of the benthos was probably due to the massive settlement of bioturbating decapods that occurred in spring 1993. Soon thereafter, μ_{Mod} peaked and μ_{Nil} continued to rise, which is consistent with a picture of steady improvement once the source of carbon loading has been removed. The continuous increase in the μ_{Nil} membership was due to the appearance of seagrasses that indicate sediment "improvement". However, the abrupt decline in μ_{Nil} in August was due to the emergence of bacterial mats on the partially recovered sediments. This observation was quite surprising since bacterial mats are generally associated with sediments that are subject to organic enrichment, yet fish had not been stocked at this site for 6 months. We propose that undecomposed organic material buried within the sediment was brought up by bioturbating macrofauna and its decay created reduced conditions at the sediment surface, thereby enabling bacterial mats to form there for a brief period of time.

Restocking of the farm began in October and November of 1993, and this is reflected soon afterwards in the sudden increase in benthic impact score to previous levels. The Nil impact membership fell to zero and both the Severe and Extreme impacts increased dramatically.

A complete interpretation of the fuzzy scores will not be possible until additional data and environmental information can be collated and analysed. From the above discussion it is clear that plausible relationships exist between the fuzzy memberships calculated from the visual data in the logs, and environmental factors that are likely to affect benthic conditions. On the basis of this preliminary work we feel that the use of fuzzy logic to analyse these data appears to be successful and work on the project will continue using this approach.

Summary

In this paper we have sought to describe the fuzzy logic methodology in sufficient detail to let the reader fully understand not only the theory behind the approach, but also the developmental process and the problems which are being encountered in applying it to a practical problem. As with any new technique, whether theoretical or experimental, there are numerous difficulties and pitfalls along the way. We hope that by describing these in detail we can assist others in deciding whether fuzzy logic is applicable to their problems, and if so, provide some guidance in how to proceed.

The analysis of the logs described in this paper is under way, and this paper has shown that there are a number of issues to be resolved before it can be completed. It is also probable that after these issues have been resolved we will re-evaluate the earlier stages of the work, such as the construction of the association rules, and will repeat the entire analysis procedure. This will give us an estimate of the robustness of the approach and of its sensitivity to bias in the setting up of the initial computational framework.

A critical question underlying this work was whether the use of fuzzy logic contributed to the analysis or whether a simpler scoring system based on a few key variables might have worked as well. The influence of the various observations varied, and some were of crucial importance in determining the impact classification while others played a minor role. However, all contributed to the classification process in varying degrees, and we were not able to identify a small subset of observations which could be used reliably throughout the entire period of the study.

For example, the presence of seagrass was an important indicator of low impact when it was present, but its sensitivity to pollution is so great that its absence alone was not very useful in assessing whether the impact was Moderate, Severe or Extreme.

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Table

Table 1. Association Rules.

Variable	Value	Weight	NIL	MOD	SEV	XTR
Mat Coverage	none	* 1.8	.53	.26	.16	.05
Mat Coverage	patchy	0.9	.07	.50	.29	.14
Mat Coverage	many	0.9	.00	.25	.40	.35
Mat Coverage	complete	0.9	.00	.15	.31	.54
Mat Thickness	thin	0.7	.14	.32	.32	.23
Mat Thickness	thick	0.7	.04	.29	.29	.38
Mat Thickness	massive	0.7	.00	.13	.31	.56
Mat Pigmentation	white	0.2	.05	.30	.35	.30
Mat Pigmentation	light-green	0.2	.20	.50	.20	.10
Mat Pigmentation	white-green-brown	0.2	.07	.14	.43	.36
Mat Pigmentation	purple	0.2	.00	.07	.40	.53
Seagrass	absent	0.8	.06	.29	.32	.32
Seagrass	few	0.8	.70	.30	.00	.00
Seagrass	normal	0.8	.80	.20	.00	.00
Visible Epi-Macrofauna	none	0.2	.08	.08	.31	.54
Visible Epi-Macrofauna	few	0.2	.10	.35	.30	.25
Visible Epi-Macrofauna	many	0.2	.20	.40	.30	.10
Macrofaunal Bioturbation	none	0.4	.00	.07	.40	.53
Macrofaunal Bioturbation	little	0.4	.47	.33	.13	.07
Macrofaunal Bioturbation	heavy	0.4	.20	.40	.30	.10
Fish Bioturbation	none	0.4	.13	.07	.33	.47
Fish Bioturbation	little	0.4	.36	.32	.23	.09
Fish Bioturbation	heavy	0.4	.13	.25	.38	.25
Visibility	good	0.2	.32	.23	.23	.23
Visibility	mediocre	0.2	.19	.23	.27	.31
Visibility	poor	0.2	.13	.25	.25	.38

* When the Mat Coverage was "none", the thickness and colour of the mats were never recorded since the values were either redundant or not applicable, so in this case we assigned a total weight equal to the sums of the weights for thickness, coverage, and pigmentation.

Figure Captions

Figure 1. Partial membership scores for the four fuzzy classifications, based on observation of different benthic variables from 100 dive logs under fish pens. Values obtained by combining results from the Association Rules given in Table 1.

Figure 2. Memberships at the study site as in Figure 1, based on a subset of 40 logs with high total weights (> 3.5).

Figure 3. Weighted impact score over the period of the study, with significant environmental periods during the study period indicated. The periods are as follows:

period A - during summer/autumn 1991 there were no outstanding environmental events and impact scores were generally high;

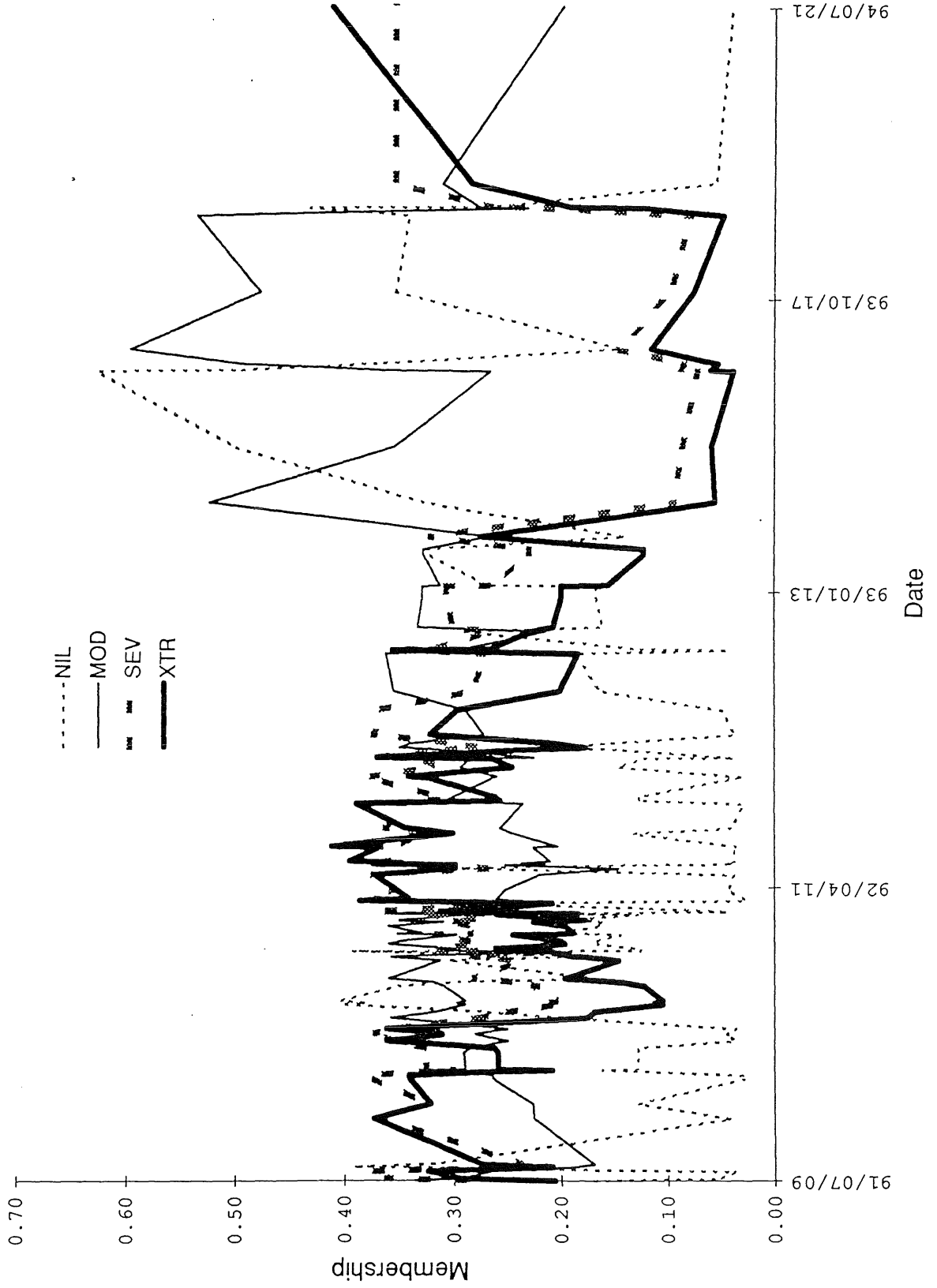
period B - in winter/spring 1992, there were strong storms and heavy fish bioturbation;

period C - during summer/autumn 1992, impact scores were generally high;

period D - during winter 1992/3, fish were gradually removed from the cages and the underlying sediments were colonised by massive numbers of bioturbating decapods;

period E - during spring/summer/autumn 1993, all cages were removed, fish farm was not active and impact scores were low;

period F - in winter 1993/4, fish cages were reinstated and stocked and impact scores rapidly increased.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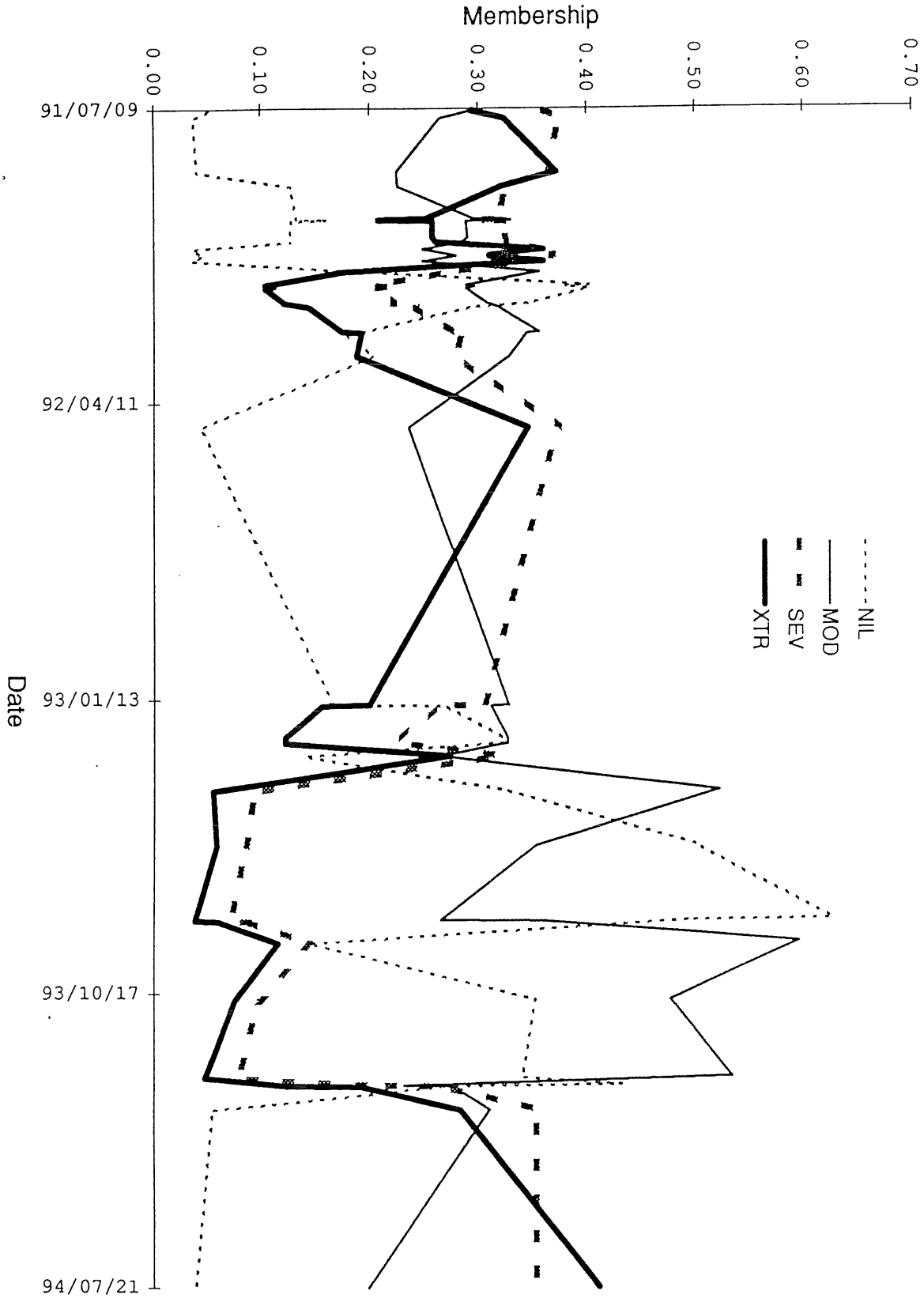
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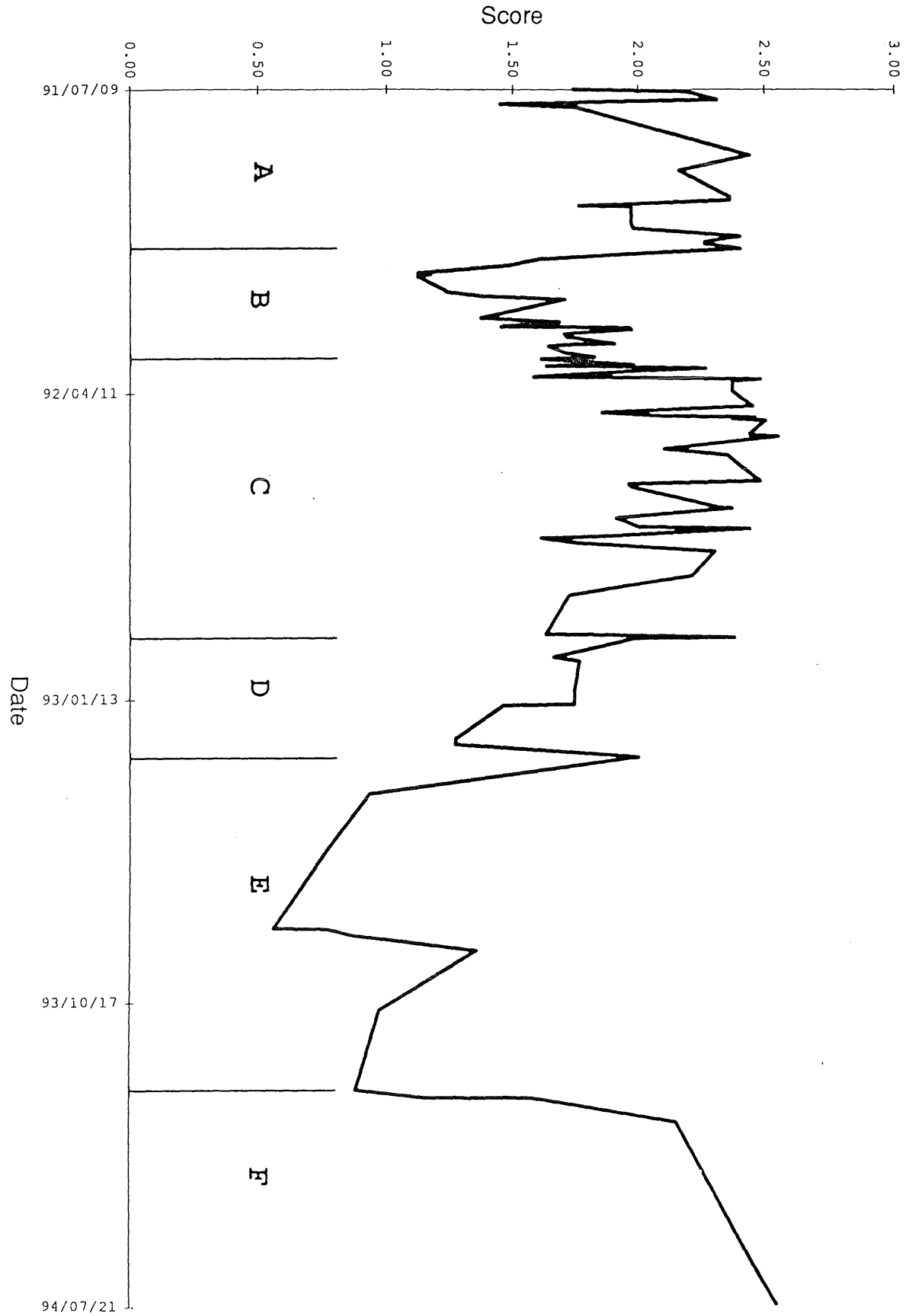
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Ecological Impact Classification with Fuzzy Sets

William Silvert
Habitat Ecology Section
Habitat Science Division
Science Branch
Bedford Institute of Oceanography
P. O. Box 1006
Dartmouth, N. S.
Canada B2Y 4A2
Email: Silvert@scotia.dfo.ca

Abstract

It is difficult to quantify the ecological impacts of human activities. There are often many different indicators that can conflict with each other, frequently important observations are lacking, and potentially valuable information may be non-quantitative in nature. Fuzzy set theory offers a methodology for dealing with these problems and provides a useful approach to difficult classification problems. This paper describes how fuzzy logic can be applied to analysis of ecological impacts.

Introduction

Attempts to classify ecological impacts are often thwarted by problems that are difficult to address by standard mathematical and statistical approaches. These include:

> Ecosystems are multi-dimensional. There are many kinds of observations that can be made on any ecosystem, and these observations may not paint a consistent picture of ecological impacts. Even individual observations may point to ambiguous or even conflicting conclusions; increased productivity, for example, may be good from a commercial point of view, but can also be evidence of hypernutrification. This leads to uncertainty in interpretation, which is difficult to represent by traditional methods of classification.
>
> Complete data are seldom available, so classification schemes that require complete information are of limited value. In particular, baseline data are often absent.
>
> Many types of ecological data are qualitative or use discrete categories and hence are difficult to incorporate into classification schemes designed to produce a numerical index of ecological quality.

Fuzzy set theory (Zadeh 1965) offers a way to address these problems. An important feature of fuzzy sets is that they provide a formalism for incorporating ambiguity and lack of quantitative data in a classification scheme. This does not preclude the possibility of using fuzzy sets to provide precise numerical grades if these are needed for statutory or other reasons, but the

process of going from fuzzy sets to quantitative indices, which is called defuzzification, can be carried out separately from the fuzzy analysis and does not conflict with the process of collecting and classifying data.

Classification with Fuzzy Sets

The input to any classification scheme is a set of observations. There can be many different valid descriptions derived from these observations, each corresponding to a different application. We can think of the classification process as one of filtering data, since once the observations are collected into a massive database, various interpretative reports can be generated for different purposes which use only part of the full set of data, as illustrated in Figure 1; this situation commonly arises in traditional fisheries management, where individual stock assessments are generated by a process which ignores data on all other species. Another common situation is weather forecasting; weather forecasters may construct a detailed picture of present and predicted conditions, but in order to decide whether aircraft will be permitted to land a limited set of specific criteria based on visibility and wind speed is often all that is considered.

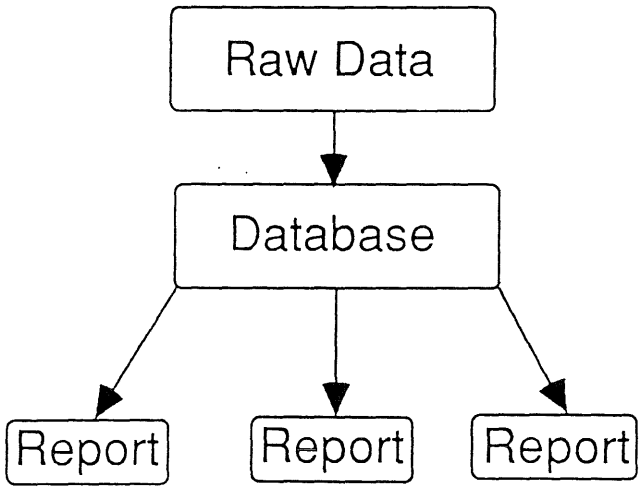

Figure 1

In ecological classification schemes the full set of available data may cover a wide range of factors such as usage, resources, impact, and so on. The process of classification involves coming up with a meaningful description for each ecological component so that we can produce useful reports describing the effects of human activities, the health of ecological subsystems, and so forth. It is seldom possible to do this without a high degree of conflict and ambiguity. For example, consider land use classification. A given plot of land might be very suitable for agriculture from the viewpoint of sunshine and rainfall, but may also have high acidity. This could reduce its general agricultural rating, even though it could be ideal for the growth of acid-resistant crops and may be a good investment for capital-intensive farming based on extensive liming. If there is no demand for this type of farm land, there would be grounds for zoning the plot for industrial development rather than agriculture. It is difficult to anticipate all of these considerations when carrying out an initial study of local conditions.

Fuzzy set theory deals with these problems of ambiguity by avoiding the constraint of associating each subsystem with a unique category. For example, instead of having to identify each plot or region as either agricultural or industrial, it is possible to balance conflicting observations in such a way that a classification like 80% agricultural and 20% industrial is possible.

Example: Classification of Factory Discharges

To illustrate the use of fuzzy logic to classify environmental impacts, consider the impacts of effluent discharges from a factory. For simplicity consider just two categories of impact, *acceptable* and *not-acceptable*, and two types of effluents, *nutrients* and *toxics*. The normal way to regulate the discharges is to evaluate them separately. This leads to outcomes that are not always reasonable and can lead to conflict and political pressure. For example, the difference between a factory that discharges 99% of the allowable level of nutrients and one that discharges 101% of this level is negligible and probably within the range of measurement error, but the former would meet the discharge criteria and the latter would not. If the former factory also discharges 99% of the allowable level of toxics while the latter discharges almost none, this would not affect the outcome even though the latter factory can legitimately argue that it pollutes less; this is illustrated in Figure 2.

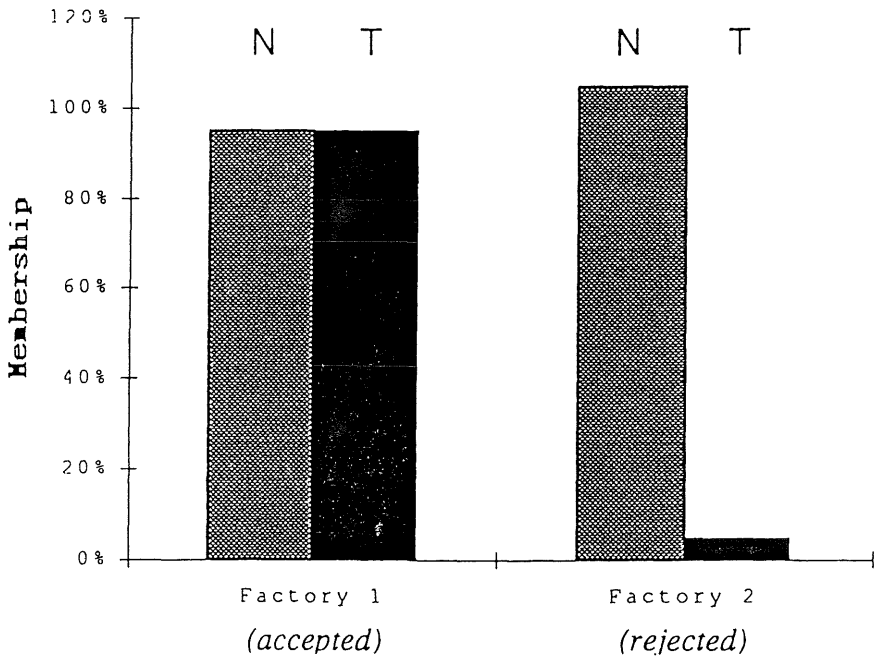

Figure 2

Fuzzy logic addresses these problems by treating the categories acceptable and not-acceptable as fuzzy sets. This means that instead of classifying a level of discharges as either acceptable or not, it allows for degrees of acceptability between 0 and 100%; in set-theoretic terms it replaces statements that a set of discharges is or is not a member of the set of acceptable discharges by statements about the degree of membership, which is a number between zero and one. Although this seems like a simple generalisation of the concept of set, it leads to a number of practical and

useful results. In particular, it lets us combine information on different discharges in a very flexible way. Instead of evaluating each discharge individually as either acceptable or not acceptable, we can assign fractional values for the acceptability of each discharge and then combine these numbers by a scoring rule to obtain an overall acceptability level.

The first step in this process is to assign an acceptability level to each rate of pollution discharge. Since this number is interpreted as the degree of membership in the set of acceptable discharges, it is commonly referred to as the *membership function*, represented by the symbol μ. A plausible membership function is shown in Figure 3. The level of acceptability (the degree of membership in the set of acceptable discharges) is a continuously decreasing function of nutrient loading, so a small increase in nutrient discharges leads to a small decrease in acceptability. This is quite different from the usual discrete approach, where changes in discharge have no effect on the acceptability unless they cross the allowable threshold, in which case a minuscule change in discharge determines success or failure in meeting the regulations. Although ultimately regulatory actions usually reduce to a simple yes-no decision, the use of fuzzy logic lets us base this decision on an assessment of the entire picture rather than dealing with each aspect independently. Since we are dealing with several distinct factors, the acceptability of each one is associated with a *partial membership function*, and the overall acceptability is obtained by combining these to generate a single *total membership function*.

In this example, the factory with the lower nutrient discharge might get a partial acceptability rating for nutrients (μ_N) of 51% and the latter 49%. These ratings could then be combined with acceptability ratings from the toxic discharges (μ_T) of 51% for the former, but 100% acceptability for the for the factory that does not discharge any toxic material, and the good ranking for no toxic discharges could more than make up for the small difference in nutrient discharges. These "acceptability ratings" (*membership functions*) are interpreted as degrees of membership in the set of acceptable discharge levels, as stated previously.

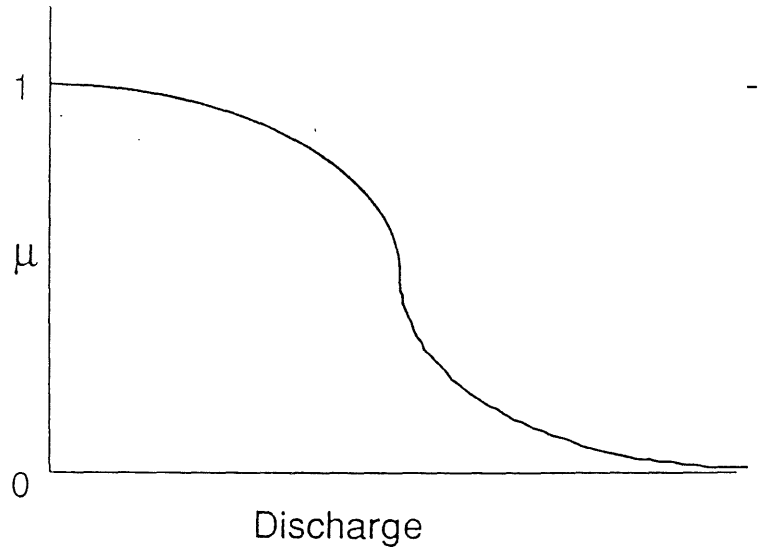

Figure 3

Once the *partial membership functions* μ_N and μ_T have been calculated we need to combine them in some appropriate way to define a *total membership function* μ. The proper choice of combination rules is a complex issue and will be discussed in the next section. For a situation like this, one reasonable way to combine partial membership functions is by using the geometric mean, so that if μ_N and μ_T are the partial memberships in the acceptable category for nutrients and toxics respectively, the combined membership is $\mu = \sqrt{(\mu_N \times \mu_T)}$. This is only one of many ways to combine fuzzy sets, but it has the important property that if one of the partial membership functions is 1, it partially compensates for a low acceptability in the other category, but a partial membership of 0 cannot be balanced by high acceptability in the other category and always leads to $\mu = 0$. In this case the combined acceptability ratings are $\sqrt{(0.51 \times 0.51)} = 51\%$ and $\sqrt{(0.49 \times 1.00)} = 70\%$, so the second factory clearly gets the higher acceptability rating despite the slightly greater nutrient discharge.

There is a potential problem with the fuzzy approach evident from Figure 4, showing the discharge levels that are acceptable. The rectangular area shows the results for the type of regulatory approach where each discharge is dealt with separately, while the outer rounded region is the result of using fuzzy logic. It appears that the fuzzy approach is more tolerant and would lead to more pollution if adopted, but this is the case only if the 50% acceptance levels are set to the same value as the individual thresholds. It would be more reasonable to reduce the 50% levels as shown in the inner curve, which would be more tolerant for factories that produce only one type of effluent, but less tolerant for those that produce several. In the previous example, if we reduce the acceptance level for discharges close to the original threshold value by one third the partial acceptance levels for factory A become 34% and 34% while those for factory B are 32% and 100%. The total acceptance levels are therefore 34% for factory A and 57% = $\sqrt{(0.32 \times 1.00)}$ for factory B, so the use of fuzzy logic lets us accept discharges that approach the previous threshold level for just one kind of effluent while rejecting discharges close to the limit for several types.

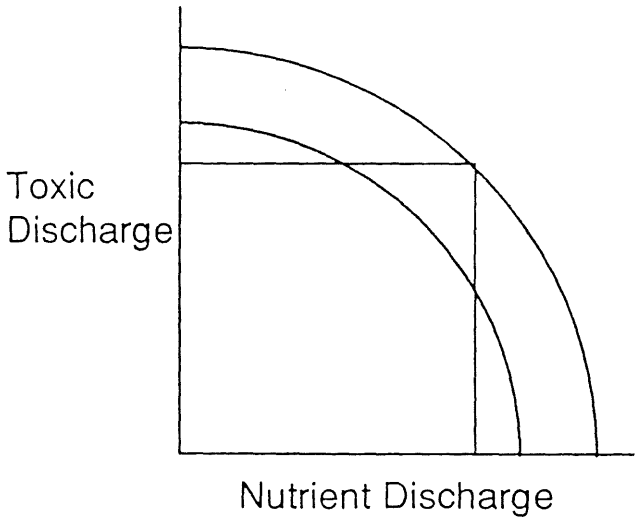

Figure 4

Combining Partial Membership Functions

The choice of the geometric mean as a way of combining partial membership functions in the preceding section is just one of many different ways in which several observations can be combined. The correct choice for any given situation depends on a number of factors and requires careful consideration in each case. However, there are some general considerations that can be used to narrow down the choice.

From the viewpoint of this paper, the most important feature of the combination rule is that it must be *compensatory* (Zimmermann 1991). This means that that a good score for one variable (high membership in the fuzzy set "acceptable") can partly compensate for a poor score (low membership) from another variable. The importance of using a compensatory combination rule is that it provides an objective method for dealing with the political reality that ecological impacts are inevitably balanced against each other and against social and economic factors in the decision-making process.

Most environmental standards are based on the non-compensatory combination rule

$$\mu = \min(\mu_1, \mu_2, \mu_3, \ldots)$$

which in the example above reduces to

$$\mu = \min(\mu_N, \mu_T)$$

(called the *fuzzy intersection*). This very conservative approach to classifying environmental impacts considers only the most unacceptable indicators; any measurement that falls below the threshold of acceptability is decisively negative, no matter how many favourable indicators there may be to counter it, and is equivalent to considering each factor separately and requiring that all impacts fall within the acceptable range. This approach has the disadvantage that a set of impacts which are all equally unacceptable is not distinguished from a single harmful impact, and although this might be reasonable from the perspective of some regulatory policies, it is not so useful in identifying cases where, for example, mitigation of harmful effects might be possible.

The geometric mean is an example of a compensatory rule and is a special case of the more general rule of combination

$$\mu = [\mu_1 \times \mu_2 \times \mu_3 \times \ldots \times \mu_n]^{\beta} \times [1 - (1-\mu_1) \times (1-\mu_2) \times (1-\mu_3) \times \ldots \times (1-\mu_n)]^{\gamma}$$

which reduces to the geometric mean when $\beta = 1/n$ and $\gamma = 0$, and to the *compensatory and function* of Zimmermann and Zysno (1982) when $\beta = \gamma - 1$ (the *compensatory and function* also includes the fuzzy *and* and *or* functions as special cases). This two-parameter expression, which we call the *beta-gamma* rule, is probably as general a rule of combination as would be needed for most ecological impact classification problems.

Environmental impacts are not always of equal importance, and one would not equate a major fish kill to discoloration of the water or to the production of unpleasant smells. It is generally necessary to introduce weighting so that different factors affect the outcome in proportion to their

importance. This can be done when combining fuzzy sets by weighting the partial membership functions. If we assign normalised weights A, B, C, ..., N to variables 1, 2, 3, ..., n, such that A + B + C + ... + N = 1, then the weighted version of the beta-gamma rule is

$$\mu = [\mu_1^A \times \mu_2^B \times \mu_3^C \times \ldots \times \mu_n^N]^\beta \times [1 - (1-\mu_1)^A \times (1-\mu_2)^B \times (1-\mu_3)^C \times \ldots \times (1-\mu_n)^N]^\gamma$$

There are some rules of combination which cannot be weighted, such as the fuzzy intersection

$$\mu = \min(\mu_1, \mu_2, \mu_3, \ldots, \mu_n)$$

The possibility of weighting is a consideration which should be taken into account in deciding how to combine partial membership functions, since it is rare for all environmental data to be of equal quality, or for all impacts to be of comparable severity.

Another important factor in selecting a combination rule is the concept of *balance*. A combination rule is *balanced* if high and low membership functions balance each other, e.g., if one observation gives a partial membership function of 0.9 and another gives a value of 0.1, a balanced rule would combine them to give 0.5. The symmetric sum (Silvert 1979) has this property, as does the beta-gamma function when $\beta = \gamma$. When the categories are purely descriptive, this is a desirable property.

On the other hand, when the categories have strong social or political overtones, an unbalanced combination rule may be appropriate. If the categories are *Acceptable* and *Not-acceptable*, then it may not be appropriate to let an acceptability rating of 0.1 be cancelled by one of 0.9. The minimum operator is the strongest example of an unbalanced operator, but the geometric mean also has this property (the geometric mean of 0.1 and 0.9 is 0.3 for example, not 0.5).

Most projects are evaluated in terms of the damage that they do to the environment, so an acceptable impact is generally interpreted as a minimal impact, while any major impact is usually seen as unacceptable. For this reason, membership in a set of acceptable impacts should be subject to the requirement that if any of the μ_i (i = 1, 2, 3, ...) is 0 the combined membership function is 0; in other words, if any of the impacts is totally unacceptable, the total impact is also unacceptable. The geometric mean, $\mu = (\mu_1 \times \mu_2 \times \mu_3 \times \ldots \times \mu_n)^{1/n}$, has this property. On the other hand, the arithmetic mean $\mu = (\mu_1 + \mu_2 + \mu_3 + \ldots + \mu_n)/n$ does not and permits a totally unacceptable discharge of, say, nutrients, to be cancelled by an acceptibly low level of toxic effluent.

The best choice of combination rule depends on several factors, such as whether we need to meet established regulatory standards or whether we are carrying out an objective scientific investigation, and whether we follow a liberal or conservative policy on environmental impacts. The geometric mean described above is suitable for many regulatory applications because of its inherent conservatism; although it is not as extreme as the fuzzy intersection given by the rule $\mu = \min(\mu_1, \mu_2, \mu_3, \ldots, \mu_n)$, a partial membership function of 0 for any variable, which means that the level of that variable is totally unacceptable, still forces the total membership function also to be zero. For other applications this may be considered too drastic. In particular, sometimes we have to deal with situations in which value judgements are inappropriate and we need a more

objective and balanced approach, since what is good from one point of view might be bad from another. This is typical of the adversarial conflicts that often bedevil environmental decisions, and a mechanism for balancing environmental damage against the potential benefits is often the only politically acceptable approach. The most appropriate way of combining partial membership functions for this type of problem is a balanced combination rule like the symmetric sum (Silvert 1979). As the name implies, this operation is symmetric under reversal of definitions, in that if we redefine our partial membership functions in terms of complementary classes — in this case the category "bad" instead of the category "good" — then the calculation leads to the same result.

The symmetric sum is defined as follows; if the various partial membership functions are represented by μ_1, μ_2, μ_3, etc., then the combined membership function μ (the weighted symmetric sum) is defined by the equation

$$\mu/(1-\mu) = [\mu_1/(1-\mu_1)]^A[\mu_2/(1-\mu_2)]^B[\mu_3/(1-\mu_3)]^C...$$

where the weights A, B, C,... satisfy the normalisation requirement

$$A+B+C+... = 1$$

or, more generally,

$$\mu/(1-\mu) = \{[\mu_1/(1-\mu_1)]^A[\mu_2/(1-\mu_2)]^B[\mu_3/(1-\mu_3)]^C...\}^{1/(A+B+C+...)}$$

This is similar to the beta-gamma rule with $\beta = 1$ and $\gamma = -1$ (a more general formulation is simply to require that $\beta + \gamma = 1$), but not exactly equivalent. One difficulty with the symmetric sum is that it is not defined if any of the μ_i is equal to 1. This is not a problem if all of the other μ_i are greater than 0, since it can easily be shown by taking limits that if any of the μ_i is 1, $\mu = 1$. If on the other hand one of the μ_i is 1 and another is 0, there is a real conflict. While this may be seen as a mathematical deficiency in the theory, one might better argue that if there are cases in which some of the effects indicate that the impacts are absolutely unacceptable, while others dictate that it is totally desirable, then one should not rely on a mathematical equation to resolve the issue. It is far better to let the mathematics break down in such cases in order to diagnose situations in which a human, rather than a mathematical, decision is called for.

A final problem that often arises in environmental science is that sets of measurements are not always complete. No matter how strict the monitoring protocol may be, there are often factors, such as bad weather, which make it impossible to collect a full set of observations. While this is always a potential source of inaccuracy and bias, it can at least partially be dealt with in the context of fuzzy set theory by omitting the membership function for the missing observation from the calculation. For example, if the sampling protocol calls for three observations to be combined by the geometric mean, $\mu = [\mu_1^A \times \mu_2^B \times \mu_3^C]^{1/(A+B+C)}$, and the second observation is missing, then we can use $\mu = [\mu_1^A \times \mu_3^C]^{1/(A+C)}$ instead. Zimmermann (1991) refers to the question of how the combined membership function depends on the number of observations as *aggregating behaviour*, although in this situation it might better be called *disaggregating behaviour*.

Calculating Entropy

In order to evaluate the utility of using fuzzy logic in analysing ecological impacts it helps to introduce a measure that can be used to determine how important the fuzzy aspects of the system are. If the analysis always leads to a classification scheme where everything is black and white with no shades of grey, i.e. the membership functions are always either zero or one, then the advantages of using fuzzy sets are dubious. On the other hand, if the classification usually involves a range of categories, this supports the use of fuzzy logic.

There is no standard definition of fuzziness[1], but a useful one can be derived from the Shannon-Wiener diversity index (Pielou 1975). This is basically an entropy measure of the form

$$F = -\Sigma\, \mu_i \, ln\, \mu_i$$

namely the sum over all categories of the product of the partial membership function and its natural logarithm, where the μ_i are normalised to add up to one. It has the properties that if one of the μ_i is equal to one (the rest must of course be zero), the value of F is zero, while if the μ_i are all equal, the value of F is *ln* n, where n is the number of categories. Since the number of categories is not a formal property of the system but rather a matter of judgement, it is best to normalise this fuzzy entropy index so that the maximum value is 1 regardless of the number of categories used, leading to the definition

$$F = -\Sigma\, \mu_i \, ln\, \mu_i \,/\, ln\, n$$

Entropy can be thought of as a way of checking the consistency of the different variables, a sort of crude correlation index. If all the indicator variables support classification in the same category, then the entropy is low. This is the easiest situation to deal with from a manager's or regulator's point of view, but there may be valid fundamental reasons why different indicators may conflict with each other and lead to a high value of entropy. In some situations high entropy seems inevitable; if one applies fuzzy logic to consumer purchases, most of the features that consumers are likely to find desirable will be associated with a high price, which of course makes the product less acceptable.

The interpretation of entropy requires a degree of caution. On one hand, it represents a measure of fuzziness as described above. On the other hand, consistently high entropy may mean that too many sets have been defined and there is a high degree of redundancy between them. If instead of classifying factory discharges as simply acceptable and not-acceptable we had defined ten or one hundred levels of acceptability that were difficult to distinguish, then the partial memberships in several fuzzy sets would usually be close to each other in value, and the entropy would be high.

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[1]Kosko (1992) has proposed the expression

$$\Sigma \min(\mu_i,\, 1\text{-}\mu_i) \,/\, \Sigma \max(\mu_i,\, 1\text{-}\mu_i)$$

In the formalism described here we always have $\Sigma\mu_i=1$, and for multidimensional systems it often happens that all of the $\mu_i<0.5$, so this almost always gives the uninformative result 1/(n-1) where n is the number of categories.

Thus a high value of entropy indicates that the system belongs to several different descriptive categories, but the significance of this depends on whether the categories are similar or very different.

Entropy is closely associated with uncertainty, since a fuzzy classification with high entropy implies a high degree of uncertainty about the true state of the system. The use of fuzzy set theory in classifying ecological impacts can be a valuable tool in developing strategies for management under risk. This is particularly true when the fuzzy memberships can be interpreted in terms of probabilities, which is frequently but not always the case. For example, the basic problem in fisheries management is to determine how much fishing pressure a stock can withstand. At a given level of fishing mortality it is necessary to know whether the stock is sustainable or endangered, and this can be a difficult decision to make. If it were possible to phrase scientific advice in terms of fuzzy sets, so that an assessment could be expressed as 60% sustainable and 40% endangered, this information could be used in risk-based management decision-making.

Defuzzification

The use of fuzzy sets for ecosystem classification provides useful information about both the degree of impact and about the ambiguity of the evidence supporting the classification, but sometimes this is more information than is needed. This is particularly true in regulatory situations, when there may be no mechanism for using expert advice beyond what is specified in statutes, as evidenced by the limited progress that has been made in incorporating risk factors in the management of natural resources.

Fuzzy logic can be used to provide a simple scoring procedure for classifying and ranking ecological impacts. The simplest approach is just to take a linear combination of the membership functions in different fuzzy sets with numerical measures of how serious the different impacts associated with these sets are considered to be. The general expression for this is

$$S = \Sigma \sigma_i \times \mu_i$$

where σ_i represents the severity of the impact associated with impact categories i. For example, if the only sets we use are *Acceptable* and *Not-acceptable*, represented by fuzzy memberships μ_A and μ_N such that $\sigma_A = 0$ and $\sigma_N = 1$, then a reasonable measure of the degree of impact is

$$S = 0 \times \mu_A + 1 \times \mu_N = \mu_N$$

which takes values between zero (no unacceptable impact) and one (totally unacceptable).

Defuzzification is not necessarily desirable, since it often represents a compromise between providing detailed scientific advice, and the desire of managers to have something simple to work with. Inevitably some useful information is discarded in the process of defuzzification, and it is generally better to find some way to use this information than to ignore it.

To illustrate the potential problems with defuzzification, consider the earlier example of using fuzzy sets for land use classification. Suppose that we classify the productivity of agricultural land as *High*, *Medium*, and *Low*, and that we defuzzify the result of classification with the score

$$S = 3 \times \mu_H + 2 \times \mu_M + 1 \times \mu_L$$

so that we get the same score S = 2.0 for the partial membership vectors (0.5, 0.0, 0.5) and (0.0, 1.0, 0.0). Although the scores are the same, the potential for exploitation is very different in the two cases.

This is a familiar situation, and the same problem arises when probability distributions (which can be viewed as a special case of fuzzy membership functions) are represented by mean values. While the use of fuzzy logic can provide valuable advice to managers, there is no guarantee that they will be eager to accept and incorporate all of it in the decision process.

Summary

The procedure described here may appear complicated, although part of that is due to the variety of choices that exist at each stage. Environmental decision-making is a complex process that involves trade-offs between conflicting values and interests, and a successful management strategy must involve determining what kinds of assessment procedures and weightings are appropriate for different problems.

The methodology involves three basic steps, as follows.

Score each Impact

For each kind of impact, such as release of a pollutant, a measure of acceptability must be assigned. This takes the form of a curve or function such as shown in Figure 3 that represents some measure of environmental effect as a function of loading. The resultant scores, represented by a number between 0 and 100%, are the partial membership functions of the impact in the set of acceptable effects.

Combine the partial membership functions

A method must be established for combining the *partial membership functions* (μ_i) for all the different effects. The most conservative approach is to take the minimum of all the μ_i, so that one very unacceptable impact cancels any number of favourable values, or a compensatory rule based on the symmetric sum can be used to enable acceptable and unacceptable impacts to balance each other. The geometric mean may be suitable in cases where low values of the partial membership function are especially significant, but in situations where a more objective classification scheme is necessary, a fully balanced rule of combination like the symmetric sum is appropriate.

Develop a grading scheme

Once a total or mean score is obtained, it needs to be translated into a practical tool for decision-making. This usually involves *defuzzification*. One option is to set

a cut-off value, and accept or reject proposals based on whether their acceptability falls above or below this level. However, fuzzy logic offers other possibilities. There is a move to controlling environmental impacts by taxation for example, and one possibility is to relate taxation for pollution control to the combined acceptability score.

I have tried to describe the fuzzy logic methodology in sufficient detail to let the reader understand not only the theory behind the approach, but also the developmental process and the problems that are being encountered in applying it to a practical problem. As with any new technique, whether theoretical or experimental, there are numerous difficulties and pitfalls along the way.

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A Modular Aquaculture Modelling System (MAMS) and its application to the Broughton Archipelago, British Columbia.

Chandler, P.C.P.[1] and Carswell, B.L. [2]

[1] Madeira Research, Sidney B.C., Canada, [2] Ministry of Agriculture, Fisheries and Food, Victoria B.C., Canada

Abstract

The British Columbia Ministry of Agriculture, Fisheries and Food has undertaken the development of a numerical model to enhance its aquaculture management capabilities. The purpose of this computer based system is to provide a tool for Ministry staff that can support the decision making process concerning the licensing of aquaculture sites by assessing the local and regional impacts of aquaculture operations. The modelling system has a modular structure and is comprised of three principal modules; the first is a pre-processor to establish the scenario to model; the second is a processor to coordinate the execution of the sub-modules that simulate a range of biophysical processes; and the third is a post-processor to display the results. These three modules are interconnected by a Windows based Graphical User Interface, a Geographic Information System, and an on-line support document. At present this modular aquaculture modelling system (MAMS) has sub-modules to simulate two-dimensional hydrodynamics, water quality, fish growth, and sedimentation. An assessment of the modelling system has been carried out for a region of important aquaculture activity in British Columbia, the Broughton Archipelago. MAMS can provide managers with a tool to examine and communicate the complex interaction of chemical, physical and biological processes that are relevant to salmon aquaculture in the Broughton Archipelago.

Introduction:

British Columbia has a successful salmon aquaculture industry that generated over $140 million in 1993 (Cdn) in annual economic activity, and provided approximately 1100 direct jobs primarily in northern Vancouver Island communities (ARA 1994). There are currently 83 active salmon farms in operation in British Columbia. , of these 21 farms are located in a region of approximately 5000 sq. km adjacent to northeastern Vancouver Island, which is referred to as the Broughton Archipelago (see Figure 1). The region is

characterised by rapid tidal streams, constricted passages and numerous shallow sills. The water is in almost constant agitation and rarely has the opportunity to settle into strongly stratified layers typical of water to the south in the Strait of Georgia (Thomson, 1981). Currently B.C. fish farming is producing approximately 19,000 metric tonnes (MT) of salmon, of which 4,800 MT are produced in the Broughton Archipelago. The Broughton therefore represents a significant proportion of the provincial salmon farm production.

The local salmon farm industry has been the subject of several reviews; including, the Gillespie Commission in 1986 and the British Columbia Ombudsman review in 1988. A key concern that continues to be raised about the industry is its environmental sustainability. In the Broughton Archipelago specifically, the assimilative capacity of the area for fish farming has yet to be resolved. This concern has prompted an additional review of the industry by the Environmental Assessment Office. This environmental assessment will, among many other things, review government administration of the industry. Salmon farms exceeding a specified production level may be subject to individual reviews under the Environmental Assessment Act. Pending the completion of this review no additional tenures for salmon farming will be issued in the Broughton.

The Aquaculture and Commercial Fisheries Branch of the Ministry of Agriculture, Fisheries and Food has responsibility to license and regulate salmon farming. These responsibilities include evaluating the biophysical characteristics of each site to ensure that it is capable of producing salmon at the licensed level without adversely affecting the environment. To meet these responsibilities the Ministry has developed a computer based modelling system that can be used by resource analysts and managers. Using a combination of field measurements and numerical models this system can analyze environmental loadings due to fish farms operations on both a site specific and regional basis. Managers are provided with a choice of display formats (animation, multimedia, electronic, and hard copy) to allow the effective presentation of the model results to a range of

audiences, including the government, the private sector, the scientific community, and the general public.

Overview of the Modelling System

The modelling system has been developed with a modular approach such that advances in computer technology, scientific understanding and management philosophies can be incorporated into the appropriate module of the system without disrupting its overall integrity. The approach follows that proposed for the Decision Support System for regulating finfish aquaculture (Silvert, 1994). The system has been designed to use hardware and software that is generally available in B.C. government offices. The processing platform is a desktop PC and uses both DOS and Windows software.

There are three major components to the system as shown in Figure 2. A pre-processor (written in Microsoft Access) establishes the scope of the simulation, selects the process modules required, and either prompts the user, or accesses the appropriate databases for the necessary input information. The processor is comprised of the sub-modules that simulate the hydrodynamics, water quality, sedimentation and fish growth. These process sub-modules are written in a variety of computer languages (Fortran, C, Pascal, Microsoft Excel) and the information flow is controlled by the GUI (dynamic data exchange).The processor has been designed as an open system to facilitate the future incorporation of additional process models. The post-processor presents the results of the model simulations by displaying the information in a user specified format.

The major modelling system components are linked using a Graphical User Interface (GUI), a Geographic Information System (GIS), and an on-line support document (hypertext mark-up language, HTML). The GUI (Microsoft Access) not only forms the basis of the pre-processor and post-processor, where operator input is accepted using point and click technology, but also organises the overall flow of information at all stages in the modelling system.

The GIS is linked to the model via the GUI and allows the model operator to access a series of B.C. government aquaculture related databases. The operator has the ability to view and utilise: geographic and bathymetric data of farms in the study area; the coverage of foreshore tenures; the most up-to-date data on farm operational status; background data on other resource activities in the region; electronic photographs of farms from overflights; and, video clips of the benthos under the farms collected using remotely operated vehicles (ROV).

Description of Process sub-modules

The Hydrodynamics Sub-module.

The spatial extent of the Broughton Archipelago, coupled with the paucity of current meter measurements, dictates the need for a hydrodynamic process sub-module in the model. The hydrodynamic regime in the area is a complex combination of driving factors including tides, winds, and fresh water from river runoff and precipitation. A two dimensional, vertically integrated hydrodynamic process model was chosen to simulate the flow field based on the limitations imposed by availability of data to establish initial conditions, the requirement to run on a PC, and the balance of resources among all the process sub-modules.

The hydrodynamic sub-module simulates the temporal and spatial variations in water level and the depth integrated velocity by solving the equations of continuity and momentum (Proudman, 1953).

Continuity:

$$\frac{dZ}{dt} = -\frac{d\,HU}{dx} - \frac{d\,HV}{dy} + E$$

Momentum:

$$\frac{dU}{dt} + U\frac{dU}{dx} + V\frac{dU}{dy} - fV = -g\frac{dZ}{dx} - \frac{C_d}{H}U\sqrt{(U^2 + V^2)} + K_x\frac{d}{dx}\frac{dU}{dx}$$

$$\frac{dV}{dt} + V\frac{dV}{dy} + U\frac{dV}{dx} + fU = -g\frac{dZ}{dy} - \frac{C_d}{H}V\sqrt{(U^2 + V^2)} + K_y\frac{d}{dy}\frac{dV}{dy}$$

where,

U and V are the depth integrated velocity components in the X and Y directions,
Z is the elevation of the water,
H is the total water depth (depth at rest plus surface elevation or h+Z)
h is the water depth at rest (often approximated by the mean depth),
E is a user-specified entrainment rate,
f is the Coriolis parameter, assumed uniform over the region,
g is the gravitational acceleration,
C_d is the bottom friction factor, and
K_x, K_y is the depth averaged turbulent eddy viscosity in the x and y direction.

The model domain extends over the Broughton Archipelago and consists of three nested rectangular grids; a 105 x 56 (1 km) grid throughout the entire domain, a 58 x 22 (250 m) grid centered on Fife Sound, and a 56 x 20 (62.5 m) grid in Deep Harbour. The timestep in the model is 1 s. The boundary conditions for each model run are determined by calculating the tidal forcing in Johnstone Strait (south) and Queen Charlotte Sound (north) based on the tidal constituents determined from water level measurements (Foreman, 1977). Cell drying and flooding due to the fluctuating water level is accommodated, and the equations are solved using a semi-implicit formulation.

The Water Quality Sub-module.

The water quality process determines the spatial and temporal variations of the water properties within the model domain. These may be material sources such as ammonia due to fish growth, or a concentration of pesticide used in farming operations. Similarly a deficit, such as oxygen depletion can be simulated. The source, or sink, may be situated at a farm site, or prescribed at any location within the model domain to represent, for example, an occurrence of Heterosigma bloom.

The fate of material introduced at any point within the model domain is modelled using the standard advection-diffusion equation to compute the depth averaged concentration.

$$\frac{d}{dt}(H \cdot C) = -\vec{\nabla}(\vec{v} \cdot H \cdot C + H \cdot (\vec{K} \circ \vec{\nabla}) \cdot C) + T + S$$

where

C is material concentration,
t stands for time,
H denotes water depth,
$\vec{v} = (u, v)$ is a velocity vector with the components u, and v in x and y direction, respectively,
$\vec{K} = (K_x, K_y)$ denotes a constant turbulent diffusion coefficient,
$\vec{K} \circ \vec{\nabla}$ denotes the vector with the components $\left(K_x \frac{\partial}{\partial x}, K_y \frac{\partial}{\partial y} \right)$
S is a source term,
T is a transformation term.

The transformation term is described by:

$$T = -A_1 \cdot H \cdot C - A_2 \cdot C$$

where

A_1 specifies the decay rate of the constituent (in units of day^{-1})
A_2 is the constituent surface exchange rate (in units of ms^{-1})

A_1 is a normal decay rate in units of inverse time. A_2 is multiplied by the depth to compute a depth dependent decay rate. The two decay rates are additive, A_2 is used to simulate fluxes through the surface (atmospheric exchange) or the bottom (settling for example); the units of A_2 are ms^{-1}.

The velocity field $\vec{v}$ can be obtained from hydrodynamic simulation, while H is computed from the continuity equation:

$$\frac{d}{dt}H + \bar{\nabla}(\vec{F}) = 0$$

where $\vec{F} = \vec{v} \cdot H$ is the volume flux vector $\left(\vec{F} = (Fx, Fy)\right)$.
Explicit formulation is used for all terms in the conservation equation, except for the transformation term T which uses an implicit formulation.

The Sedimentation Sub-module

The dispersal of particulate carbon introduced into the water column as a result of feed pellets not consumed by the fish is modelled using a conventional methodology (Gowan, 1989).

$$D = \frac{ZV}{S}$$

where

D is the horizontal displacement of the particle,
Z is the water depth,
V is the current, and
S is the settling velocity of the particle.

To resolve the fine scale fate of the feed pellets the sedimentation module uses a time step of 30 s and represents the sea floor on a 12.5 m grid. The grouping and orientation of standard 15 m cages are used to specify the input of the pellets. Using a Monte Carlo technique the trajectories of several thousand feed particles are tracked as they fall through the water column. The settling velocity is parameterised as 10 cms^{-1} (Caine, 1989, Findlay and Watling, 1994). The horizontal velocity (current field) is based on either the output of the hydrodynamic sub-module or measurements made at the specific farm site. Sub grid scale variability in the flow field is represented by assigning a variance of ± 10% to the horizontal and vertical velocities using a random number generator.

Fish Growth Sub-module

The modelling of fish growth is aimed primarily at determining the volume of material to be used as input to either the water quality sub-module or the

sedimentation sub-module. The fish growth sub-module is written to run as a Microsoft Excel spreadsheet.

The theoretical framework of the growth model is based on a water temperature dependent growth rate (Iwama and Tautz, 1981) where the estimated fish weight is calculated as

$$W_1 = [W_0^{0.333} + \sum (TGC \cdot MDT) \cdot t]^3 ,$$

where

W_0 is the initial body weight g,
W_1 is the final body weight g,
TGC is the thermal-unit coefficient,
MDT is the mean daily water temperature °C, and
t is time in days.

The TGC is set to 0.0033 following Einen et al., 1995 for salmon growth in Norway. The results from this formulation are normalised using fish growth data collected in the Broughton Archipelago (Stolt Sea Farms). The nutrient discharges due to fish growth are calculated as the difference between nutrient fed (a function of the type of feed used) and nutrient gain (assuming a constant concentration in the fish). Monthly feed conversion ratios are based on data provided by Stolt Sea Farms for three Atlantic salmon farms in the Broughton Archipelago. A constant feed wastage rate of 5% is used. (Findlay and Watling, 1994). At present the model calculates the monthly discharge of nitrogen and phosphorus, as well as carbon from fish feces and unconsumed feed pellets. The depletion of dissolved oxygen due to fish growth is modelled as a function of temperature following Washburn and Gillis, 1994, using values that consider physical activity (swimming) and metabolic activity (feed digestion).

Discussion

The modelling system has been configured to examine three scenarios in the Broughton Archipelago which are relevant to regulatory issues. These address site specific loadings (at existing farms or at proposed farm locations), interactions between neighbouring farms, and the assimilative capacity of the overall region.

A site specific loading scenario utilises the sub-modules of fish growth, sedimentation, hydrodynamics and water quality. Farm production is determined by specifying four parameters; the location of the farm (which specifies the water temperature data to use), the month in the year that the growing cycle commences, the number and size of smolts introduced to the farm, and the duration of the growth period. For example Figure 3 shows some results from a simulation at Deep Harbour, Broughton Island: specifically the time series of fish biomass, the particulate carbon in waste feed, nitrogen, and oxygen depletion.

The benthic footprint due to carbon is determined by the sedimentation sub-module and plotted as Figure 4. The loading from the final six months of farm production is used as input as this period represents the duration with the greatest on-site biomass and carbon discharge. Once provincial criteria for carbon loading from salmon farms have been established then results from the model can be used to regulate farm production and guide monitoring programs.

Figure 5 shows contours of oxygen depletion based on the maximum respiration at a fish farm in Deep Harbour. These contours are generated by the water quality sub-module using the currents generated by the hydrodynamic sub-module until a steady state is achieved.

Similarly to model the interaction between farms the fish growth sub-module is run for each farm site to generate input loadings to the water quality sub-module. Again the hydrodynamic sub-module is run until a steady state is established.

On a regional basis the resolution of the farm interactions is examined by prescribing a loading within each tenure based on the licensed or reported production. The primary concern in this scenario is to determine if and where the cumulative impacts of many fish farms may affect the water quality. This scale of modelling can also be used by regulators to assess the implications of various strategies in coastal zone management.

Conclusions

A computer based modelling system to evaluate and present information on the interactions between fish farms and the environment has been developed for the Aquaculture and Commercial Fisheries Branch of the British Columbia Ministry of Agriculture, Fisheries and Food. Its purpose is to provide managers with the information they need to regulate the aquaculture industry and plan its development. The modular structure of the modelling system, and the standard computer technology that is used, facilitates the incorporation of future advancements in both aquaculture science and management strategy.

The Modular Aquaculture Modelling system (MAMS) has been applied to the Broughton Archipelago, a region of important fish farming activity in British Columbia. Field data from several farms in the Fife Sound and Deep Harbour regions have been used to evaluate the hydrodynamics, water quality, sedimentation, and fish growth sub-modules. The modelling system has proven itself capable of using a graphical user interface to couple the process sub-modules with the pre and post processor components as well as with the geographic information system and the on-line help. Further work is on-going to verify the model output with additional field data, and to optimise the presentation formats.

Although often undertaken in the more remote regions along the British Columbia coast fish farming is closely monitored by an assortment of interested stakeholders. Having the ability to integrate the modelling of complex biophysical and chemical processes, and present these results in a variety of formats, it is anticipated that MAMS will provide a useful tool for government agencies to determine and communicate the decisions they use to manage the aquaculture industry.

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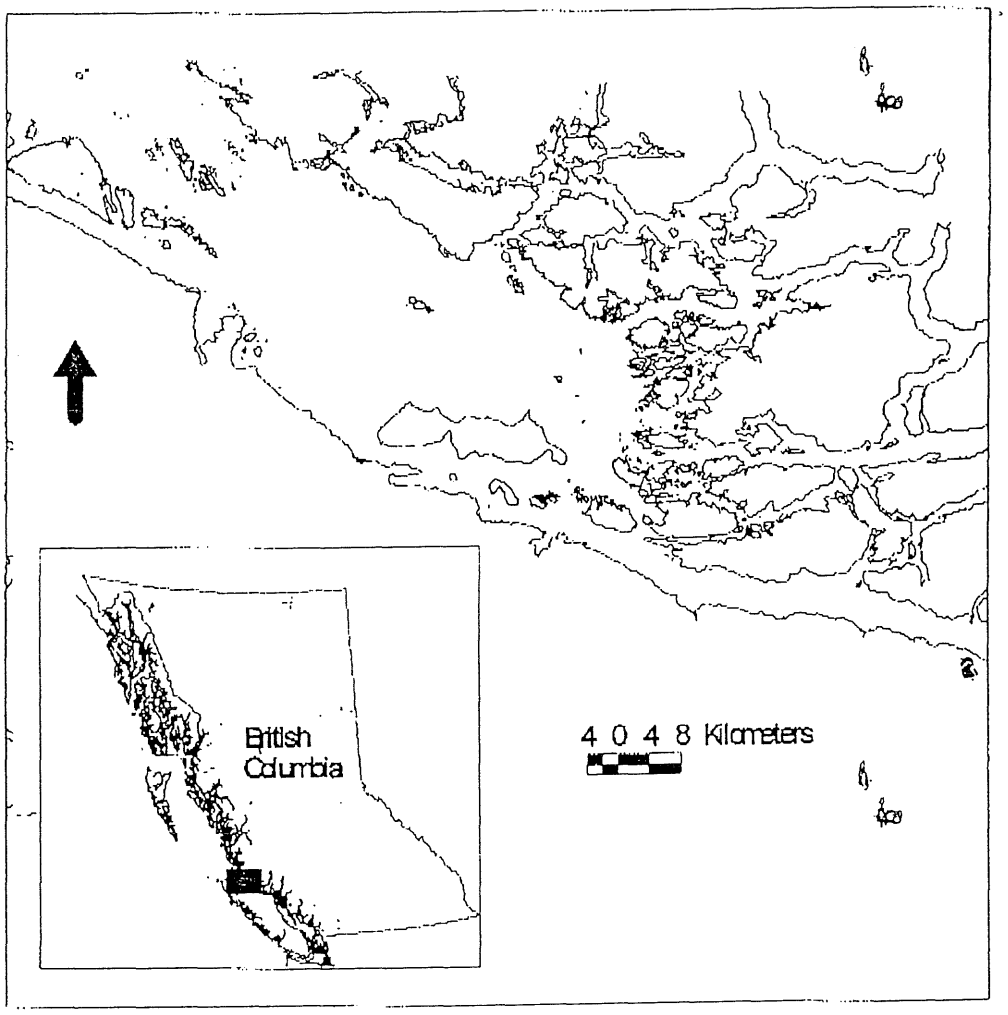

Figure 1. The Broughton Archipelago off the northeastern coast of Vancouver Island, British Columbia.

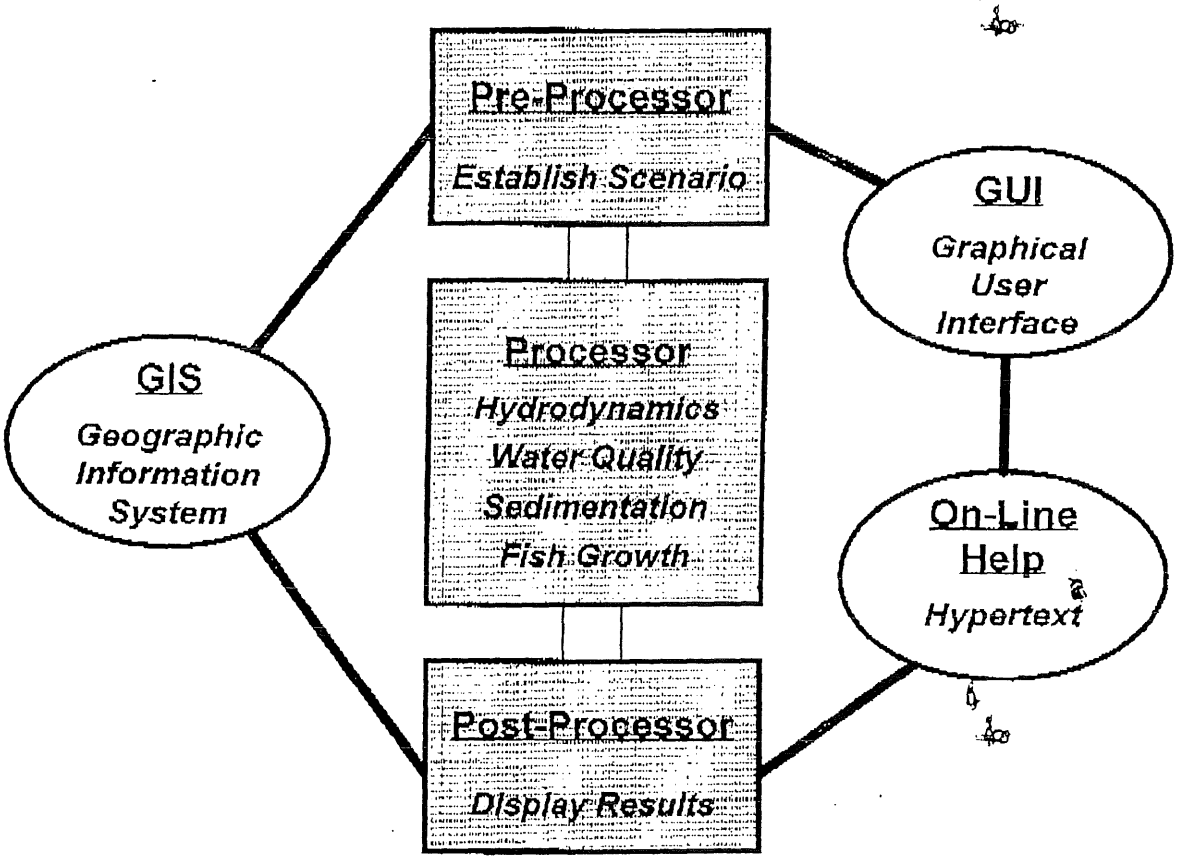

Figure 2. A schematic showing the structure of the Modular Aquaculture Modelling System

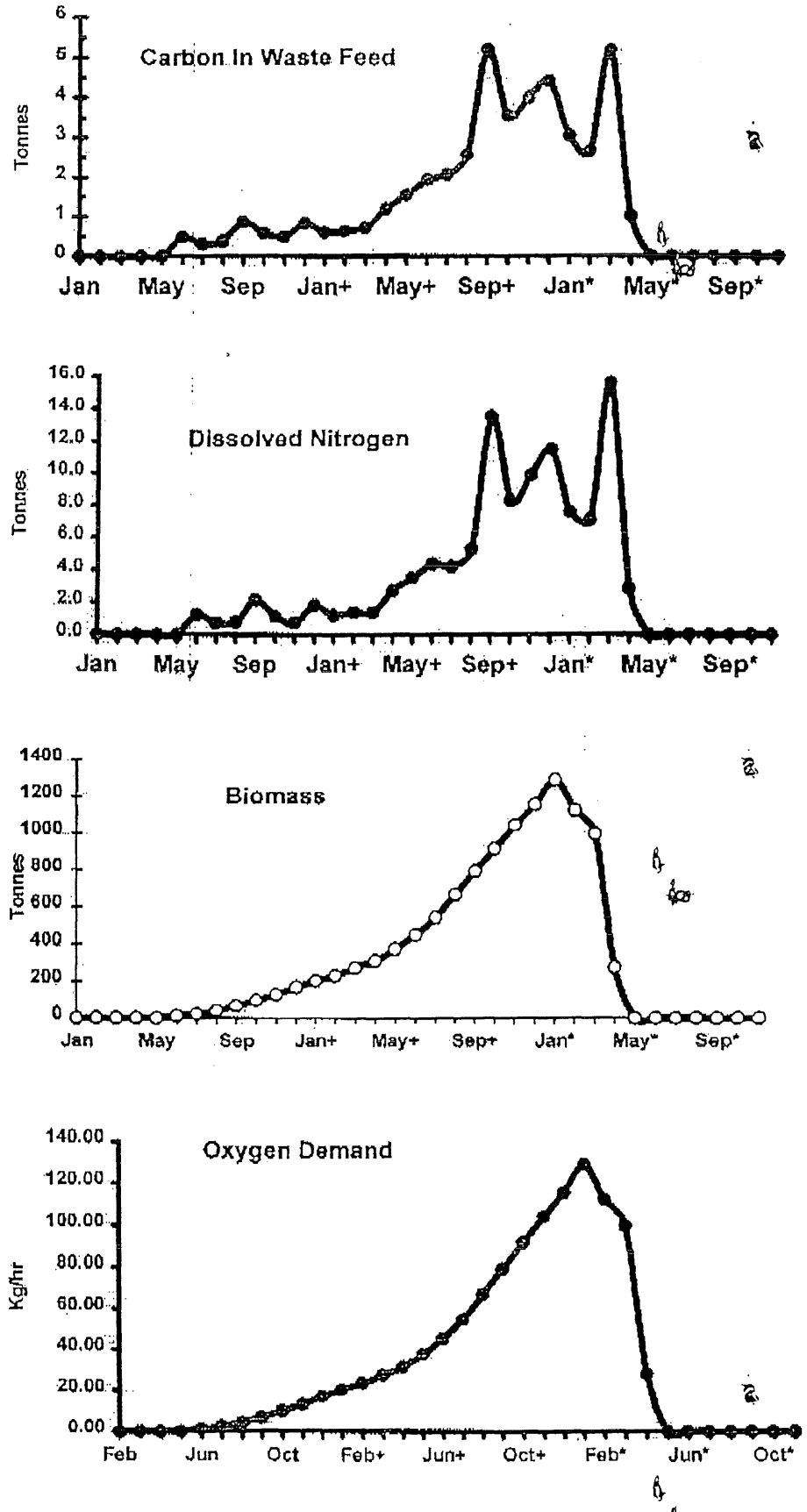

Figure 3. Time series of selected output from fish gowth sub-module

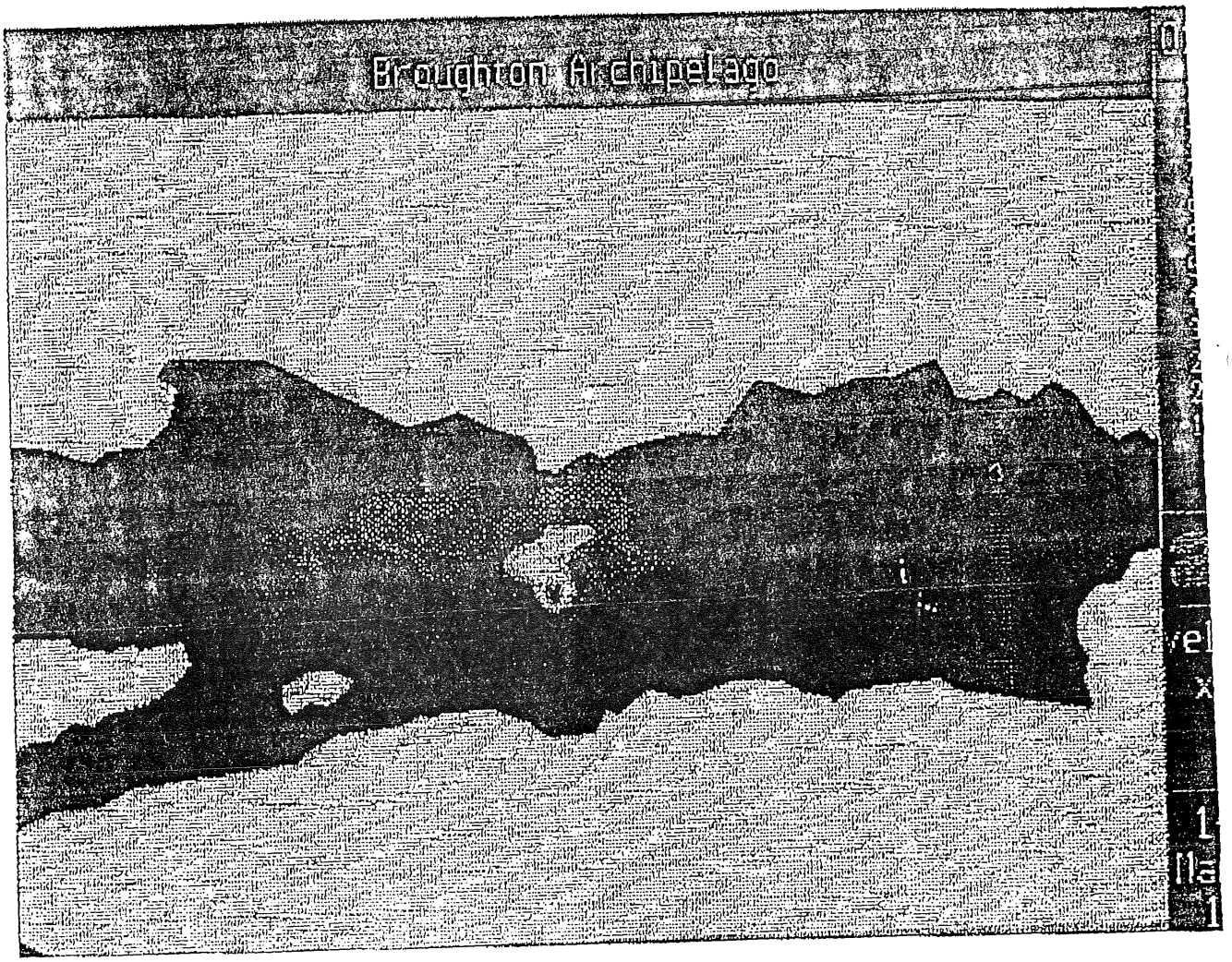

Figure 5 Contours of oxygen depletion due to fish respiration determined using fish growth, hydrodynamic and water quality sub-modules.

AN OVERVIEW OF MARICULTURE IN SOUTH AFRICA

prepared by the Mariculture Advisory Group of the
Sea Fisheries Research Institute, Cape Town, 1996

Submitted by Pedro Monteiro (Cape Town, South Africa)

CONTENTS:

MARICULTURE IN SOUTH AFRICA

1. BACKGROUND

South Africa, with its extensive yet relatively unbroken coastline of some 3000 km, has a limited number of sheltered bays and estuaries suitable for mariculture. Nevertheless, coastal waters are generally unpolluted and on the west coast, are highly productive, owing to upwelling. The potential for open-coast mariculture is large, provided that problems related to a high degree of exposure to storm-generated winds and waves can be overcome. The use of capital-intensive on-land tank farming holds immediate promise, as in the abalone culture systems which are currently under development in South Africa.

Although research activities at Sea Fisheries have been dominated until now by studies aimed at providing information for the sustainable utilisation of important marine resources such as hake and other finfish, pelagic fish species and coastal invertebrates such as abalone, rock lobster and squid, recent years have seen an upsurge of interest in mariculture. In view of the growing needs and rising demands of prospective mariculture operators, increasing attention is being given to mariculture affairs from statutory bodies such as the Departments of Environmental Affairs and Tourism and the Department of Agriculture.

2. GOVERNMENT POLICY

Mariculture is a relatively new development in the South African fisheries sector, but has seen considerable growth both in the number of species utilised and the number of active producers since 1985. Nevertheless, there is, to date, no formal government policy on mariculture. In fact, although Section 2 of the Sea Fishery Act 12 of 1988 (as amended), allows the Minister to "..determine the general policy with regard to the conservation and optimal utilisation of the South African living marine resources..", up until recently, no effort was made to elaborate fisheries policy at all. Fisheries management decisions have, instead, been made in accordance with the objective of the Sea Fishery Act 12 of 1988, namely:

"To provide for the conservation of the marine ecology[1] and the orderly exploitation, utilisation and protection of certain marine resources; for that purpose to provide for the exercise of control over sea fishery; and to provide for matters connected therewith."

In late 1994, in the wake of political changes in South Africa, a Fisheries Policy Development Commission was set up by the Minister of Environmental Affairs and Tourism - with whom responsibility for fisheries lies - to elaborate, through a consultative process, a fisheries policy for the country. This Commission is only expected to complete its work at the end of 1995, but a draft mission statement states that:

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[1] read "marine ecosystems)

"..the allocation of resources" will be "..on an equitable basis, resulting in optimal social and economic benefits for all the people. Use of the resources will be within the bounds of the continued sustainable healthiness of all our marine resources".

The draft policy document suggests that the future will see a greater emphasis on state assistance in the development of marioulture, particularly of small-scale, community-based enterprises. There is also reference to the need for controls on the introduction of foreign species, as well as the negative environmental effects of mariculture operations, and the need to address pollution problems impacting on mariculture. It is suggested that full impact studies be undertaken prior to the establishment of commercial operations.

3. LEGISLATION

There is no legislation dealing specifically with mariculture, nor does the Sea Fishery Act 12 of 1988 make specific reference to it. Control of the activity is effected by the Sea Fisheries Research Institute of the Department of Environmental Affairs and Tourism, which acts as the "lead agency" for the coordination of applications for and management of mariculture activities. Various aspects of mariculture are instead regulated by provisions from a variety of sources. These have been set out in a "Protocol for the Establishment of Mariculture Activities", and include:

Site Selection

In terms of the Sea Shore Act 21 of 1935, any person wishing to establish a mariculture operation on the sea shore between the high and low water marks of the sea, in the water or on the bed of the sea below the low water mark and within the 12 nm territorial waters of the Republic, including the water and the bed of the tidal portion of a river or tidal lagoon, must enter into a Lease Agreement with the relevant authority (the Cape Provincial Administration or, in Kwa-Zulu Natal, the local authority) for the use of that area. Private waters contained in artificially created marinas are excluded from this provision.

If a mariculture operation is proposed within an area 200 feet above the high water mark and in an area designated as an Admiralty zone/crown land, permission needs to be obtained from the Department of Public Works.

Importation of Foreign Species

In terms of Section 47 (j) of the Sea Fisheries Act 12 of 1988 anyone wishing to import or export any living marine organism must obtain a permit from the Chief Directorate: Sea Fisheries.

In terms of the Import and Export Control Act 45 of 1963 anyone wishing to import live fish eggs, live molluscs or live crustacea needs to apply for an import permit. Live fish

do not require an import permit in terms of this Act.

In terms of the Agricultural Pests Act 36 of 1983 anyone wishing to introduce foreign species for mariculture purposes needs to consult the Department of Agriculture's Directorate of Plant and Quality Control in order to determine whether a permit is required. Each case is dealt with individually depending on the particular circumstances.

Product Processing and Marketing

In terms of the Standards Act (No. 35 of 1962) a permit, issued by the South African Bureau of Standards, is required if the product is to be frozen or canned. Fresh products do not require such a permit. In order to obtain a permit, compulsory specifications for the processing of the product need to be complied with.

In terms of the Foodstuffs, Cosmetics and Disinfectants Act (No. 54 of 1972) any person marketing seafood for human consumption needs to ensure that the product complies with pathogenic and chemical standards, eg. for bacteria, heavy metals, etc.

In terms of the Health Act (No. 63 of 1977) any person processing or transporting products for human consumption needs to comply with specifications concerning the hygiene of the products.

Permits for effluent discharge

In terms of Section 21 of the Water Act 54 of 1956, any person wishing to discharge an effluent arising from an industrial process into a water body, must obtain an exemption permit from the Department of Water Affairs and Forestry. In the past, this applied to mariculture, but a recent amendment to the Act altered the definition of industrial processes to exclude mariculture, which is now, instead, recognised as an agricultural activity. This provision, therefore, no longer applies.

4. MARICULTURE ACTIVITIES

The South African mariculture industry is small relative to capture fisheries, but is continuing to develop since its beginning in about 1948 with the establishment of the first oyster farming operation (see review by Hecht and Britz, 1992). Growth has been most significant since about 1985, when there were only four active producers: by 1994 a total of 41 permits were issued to, or renewed by, 26 different concerns. Of these, 16 were for farming of oysters, 13 for abalone, 7 for black mussels, two for red bait, one for prawns, one for clams, and one for turbot on an experimental basis. Several applications to farm the red seaweed Gracilaria are pending.

Oysters

Oysters are cultivated mainly in Knysna Estuary, Port Elizabeth, Saldanha Bay, St Francis Bay, Port Nolloth, Port Alfred, St Helena Bay, and Alexander Bay. Almost all of this production is of the Pacific Oyster, Crassostrea gigas, and 4.5 million (i.e. about 380 tonnes) were sold in 1994, all for fresh consumption on the local market. The bulk of farming is on intertidal racks in estuaries, using spat obtained locally or from Chile. Local spat production was initiated in St. Helena Bay in 1993, and 15 million seed oysters were made available to local producers during 1994.

Mussels

Mussels make up the bulk of South African mariculture production. Permits for the cultivation of the Mediterranean or black mussel Mytilus galloprovincialis were issued to concerns operating at Saldanha Bay, Stompneus Bay and St Francis Bay in 1994. In Saldanha Bay, where cultivation is by two concerns, mainly using the Spanish raft system, 2 982 tons were produced, compared to 1 891 tons in 1993. Approximately 90% of production is frozen, 9% sold fresh, and 1% smoked or canned.

Abalone

Onshore abalone farming operations are being developed by ten concerns, operating between Port Nolloth and the Eastern Cape. All are culturing the local species Haliotis midae, and the industry is still considered to be in the advanced developmental stage, with current operational farm sizes of less than 1 ha. However, the first test shipment of "cocktail" sized abalone took place in September 1994, and commercial exports are likely in the near future.

Prawns

The farming of the prawns Penaeus monodon, P. japonicus and P. indicus has taken place at Amatikulu in Natal, since 1992. During 1994, 21 tons were produced in the 6 ha farm. Brood stock is collected from the wild.

Red Bait

The ascidian Pyura stolonifera ("Red bait") is harvested at Saldanha Bay as a by product of the mussel farming and sold to fishermen. A total of 11 950 kg was harvested during 1994.

Seaweed

Experimental cultivation of G. gracilis (formerly G. verrucosa) has been carried out by the Seaweed Unit of SFRI since 1992 in a project that now also involves collaboration with the industry and students funded by the Foundation for Research Development. A permit for experimental farming (suspended cultivation) of Gracilaria gracilis in Saldanha Bay has been issued to one concern, and applications were received from three others, one in Saldanha Bay and two in St Helena Bay.

5. INSTITUTIONAL CAPACITIES

Although mariculture in South Africa is still in the early stages of development, its present research needs are well catered for by extensive and well developed academic and government research infrastructure. The capacity building which will be necessary to accompany the long term growth of the industry will require additional funding of existing research bodies from either external or industry sources. The present status of institutional capacity is summarized as follows:

Government Research:

Department of Environmental Affairs and Tourism:

The *Sea Fisheries Research Institute* which has the brief of providing advice on managing marine resources in a sustainable manner carries out research predominantly on the environmental impacts of mariculture. This work which is interdisciplinary (Physics, Chemistry and Ecology) addresses issues such as the carrying capacity of bay systems for shell fish mariculture, toxic phytoplankton dynamics, modelling of environmental processes which impact water quality, the environmental requirements of mariculture species and the suitability of potential sites. It also carries out research in sea weed mariculture techniques. A proportion of this work is carried out in collaboration through contracts with universities. Most of the mariculture research at the SFRI is coordinated by the *Working Group: Interactions between Mariculture and the Environment* which brings together SFRI and University expertise as well as having representation from industry to maintain focus and relevance (Monteiro et al., 1995)

The Seaweed Unit of SFRI carries out research on mariculture of seaweeds, particularly of Gracilaria. Currently this also involves collaboration with the industry and post graduates funded by the Foundation for Research Development (FRD).

Department of Agriculture

The Department of Agriculture provides research support on production technology, marketing strategies, and production economics.

UNIVERSITY RESEARCH

Rhodes University

The *Department of Ichthyology and Fisheries Science* carries out research on the reproductive biology, spawning techniques, growth dynamics and feeding (natural and artificial feeds) of candidate species for mariculture which include abalone, spotted grunter and ornamental fish.

reality in the coming year. It is envisaged that the allocation of water leases will become a high priority issue in the near future and much effort has to be focussed in pre-empting the administrative problems that will arise when demand scales rapidly out of the realm of the existing management structure plan.

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APPENDIX - NAMES AND AFFILIATIONS OF MARICULTURE RESEARCHERS

Names	Institution	Activity
Anderson, RJ Dr	SFRI	Seaweed Research
Bolton, JJ Prof.	UCT	Seaweed Research
Boyd, A Dr	SFRI	Hydrodynamics
Cook, PA Dr	UCT/MASA	Abalone Research:
Hecht, T Prof.	Rhodes/DIFS	Fish Biology
Jackson, LF, Dr	SFRI	Pollution Control
Keats, D Prof	UWC	Seaweed Research
Monteiro, PMS Mr	SFRI	Environmental Impacts of Mariculture
Payne AIL Dr	SFRI	Director
Pitcher, G Dr	SFRI	Toxic Phytoplankton
Pollock, DE Dr	SFRI	Deputy Director: Environment
Tarr, R Mr	SFRI	Abalone Research
Carter, R Dr	CSIR	Technology

SFRI: Sea Fisheries Research Institute
UCT: University of Cape Town
MASA: Mariculture Association of South Africa
UWC: University of the Western Cape
Rhodes: Rhodes University
DIFS: Department of Ichthyology and Fisheries Science
CSIR: Council for Scientific and Industrial Research

Appendix 1: List of Participants

ICES WG, Nantes March 25-29th

NAME	AFFILIATION	Fax - Phone - E-mail
Harald ROSENTHAL	Dept of Fish Biol. Inst. Marine Sci. Univ. Kiel Dünsternbrooker Weg 20 24105 KIEL - FRG	[49]431-597.3916 phone [49]431-597.3917 fax
Edward BLACK	British Columbia Ministry of Aquaculture Fisheries and Food 808 Cogulas Street, VICTORIA B.C. Canada	[604]387.96.86 phone [604]356.72.80 fax eblack@galaxy.gov.bc.ca
Bob COOK	Dept of Fisheries and Oceans Maritimes Region, P.O. Box 550, Station M, HALIFAX, Nova Scotia Canada, B3J 2S7	[902]426-9068 phone [902]426-2706 fax Bob.Cook@Maritimes.dfo.ca
Bill SILVERT	Habitat Ecology - BIO Box 2006, DARTMOUTH, NS Canada B2Y 4A2	[1]902-426-1577 phone [1]902-426-2256 fax silvert@scotia.dfo.ca
Eva ROTH	Danish Institute of Fisheries Economics Research (DIFER) Niels Bohrsvej 9 DK-6700 ESBJERG - Denmark	[45]79.14.11.86 phone [45]79.14 11 99 fax er@suc.suc.dk
Maurice HERAL	CREMA (CNRS - IFREMER) BP 5 - Place du Séminaire 17137 L'HOUMEAU - France	[33]46.50.92.17 phone [33]46.50.91.60 mheral@ifremer.fr
Jean PROU	CREMA (CNRS - IFREMER) B.P. 5 - Place du Séminaire 17137 L'HOUMEAU - France	[33]46.50.94.40 phone [33]46.50.91.60 fax jprou@ifremer.fr
Antoine DOSDAT	IFREMER Fish Physiology Laboratory Centre de Brest 29280 PLOUZANE - France	[33]98.22.43.96 phone [33]98.22.45.47 fax adosdat@ifremer.fr
Alain FEBVRE	IFREMER Lab. Méditerranéen de Recherche Aquacole Station Expérimentale d'Aquaculture 34250 PALAVAS-les-Flots - France	[33]67.50.41.00 phone [33]67.68.28.85 fax afebvre@ifremer.fr

NAME	AFFILIATION	Fax - Phone - E-mail
Marc KEMPF	IFREMER Dept "Environnement Littoral" BP 70 29280 PLOUZANE - France	[33]98.22.43.22 phone [33]98.22.45.48 fax egiordma@ifremer.fr
Michel MERCERON	IFREMER Dept "Environnement Littoral" BP 70 29280 PLOUZANE - France	[33]98.22.43.47 phone [33]98.22.45.48 fax merceron@ifremer.fr
Guillaume BLANC* Hervé LE BRIS*	Ecole Nationale Vétérinaire de Nantes Laboratoire de Pathologie Aquacole C.P. 3013 44087 NANTES Cedex 03 - France	[33]40.68.76.76 phone [33]40.68.77.62 fax
Jean-Pierre CORLAY*	Institut de Géographie Université de Nantes B.P. 1205 44036 NANTES Cedex 01 - France	[33]40.14.11.53 phone [33]40.14.10.10 phone [33]40.14.10.05 fax
Régis PAJOT*	SMIDAP (Syndicat Mixte pour le Dévelopt Aquacole en Pays de Loire) 3 rue Célestin Freinet 44200 NANTES - France	[33]40.89.61.37 phone [33]40.89.61.47 fax
Jacqueline DOYLE	Marine Institute Fisheries Research Centre Abbostown Castleknock DUBLIN 15 Ireland	[353]1821 01 11 phone [353]1820.50.78 fax
Jan AURE	Institute of Marine Research Box 1870 - Nordnes N-5024 BERGEN -Norway	[47]55 23 53 00 phone [47]55 23 85 84 fax jan.aure@imr.no
Arne ERVIK	Institute of Marine Research Box 1870 - Nordnes N - 5024 BERGEN -Norway	[47]55 23 83 00 phone [47]55 23 83 33 fax arnee@imr.no
Håkon KRYVI	County Gov. of Hordaland Walckendorfsgt.6 5001 BERGEN -Norway	[47]55 23 77 75 phone [47]55 23 77 82 fax
Gunnar ANEER	County Administrative Board of Stockholm Dept Environmental Protection Box 22067 S-104 22 STOCKHOLM - Sweden	[46]8 785 51 18 phone [46]8 651 57 50 fax gunnara@ab.lst.se

* part time attendance

NAME	AFFILIATION	Fax - Phone - E-mail
Bernhard GLAESER	Göteborg University Dept of "Human Ecology" Brogatan 4 S-41301 GÖTEBORG - Sweden	[46]31-773 13 12 phone [46]31-773 49 33 fax bernhard.glaeser@ctv.gu.se
Jim SANDKVIST	SSPA MARITIME CONSULTING AB P.O. Box 24001 40022 GÖTEBORG - Sweden	[46]31 63 95 00 phone [46]31 63 96 24 fax
Peter BURBRIDGE	Dept Mar. Sci. and Coastal Management Ridley Building University of Newcastle NEWCASTLE UPON TYNE NEI 7RU U.K.	[44]191 222 5676 phone [44]191 222 7891 fax p.r.burbridge@newcastle.ac.uk
Ian DAVIES	SOAEFD Marine Laboratory P.O. Box 101 Victoria Road ABERDEEN AB9 8DB - U.K.	[44]1224 876 544 phone [44]1224 295511 fax daviesim@marlab.ac.uk
Sue UTTING	Fisheries Laboratory Benarth Road CONWY Gwynedd LL 32 8UB - U.K.	[44]1492 593883 phone [44]1492 592123 fax s.d.utting@dfr.maff.gov.uk

Field trip "Baie de Bourgneuf", March 29th

Introduction : see J-P. CORLAY, R. PAJOT (list of participants)

IFREMER, Station de Bouin
Zone ostréicole des Champs
85230 BOUIN - France
tél. [33]51.68.77.80
fax [33]51.49.34.12

Jean-Pierre BAUD, Joël HAURE

Oyster farms, BOUIN :

SODABO, Jean-Yves LE GOFF
Yannick BEGAUD

Fish farms, NOIRMOUTIER :
France Turbot and NATA
tél. [33]51.39.54.39
fax [33]51.39.56.28

Didier LECLERC, Elizabeth LEBÈGUE

Robert FOUASSON
tél. & fax [33]51.39.63.99

Appendix 2

Working Group on "Environmental Impact of Mariculture"

List of WG Membership, and participation of invited experts and observers in 1994

Professor Dr. H. Ackefors
Dept. of Zoology
Stockholm University
10691 Stockholm, Sweden
Tel: ++46 8 164020
Fax: ++46 8 167715

Dr. David Alderman
Ministry of Agricult., Fishery & Food
Fish Diseases Lab.
14 Albany Rd
Weymouth, Dorset DT 4 9TH
United Kingdom
Tel: ++44 305 772137
Fax: ++44 305 770955

Mr. Jan. Aure
Institute of Marine Research
PO Box 1870
5024 Bergen - Nordnes, Norway

Dr. E. A. Black
Aquaculture and Commercial
Fisheries Branch
808 Douglas Street
Victoria B.C. V8W 2Z7 Canada
Tel: ++?? 604 387 9686
Fax: ++?? 604 356 7280
E-Mail: EBLACK@GALAXY.GOV.BC.CA

Prof. B. v. Bodungen
Institute for Baltic Research
Seestrasse 15
18119 Warnemünde, Germany
Phone: ++49 3 81 5197 200

Mr. P.B. Brito
IPIMAR
Avenida de Brasilia
1400 Lisbon, Portugal

Dr. T. Cross
Dept. of Zoology
University College Cork
Cork, Ireland

Dr. Ian M. Davies
Marine Laboratory
PO Box 101
Victoria Road
Aberdeen AB9 8DB
United Kingdom
Tel: ++44 224 876 544
Fax: ++44 224 295511

Mr. R. Dijkema
Netherlands Institute of
Fisheries Research
PO Box 77
4400 AB Yerseke, The Netherlands
Tel: ++ 31 1131 2791
Fax: ++31 1131 3477

Mr. Antoine Dosdat
IFREMER
Brest Center
Living Resources Dept.
BP 70
Aquaculture Laboratory
29280 Plouzane, France
Tel: ++33 98 224396
Fax: ++33 98 224547

Ms J. Doyle
Dept. of the Marine
Fisheries Res. Centre
Abbotstown
Dublin 15, Ireland
Tel: ++353 01 8210111
Fax: ++353 01 8205078

Dr. L. A. Dushkina
VNIRO
Russian Federal Res. Inst. of
Fisheries & Oceanography
17, Verkhne Krasnoselskaya
Moscow B-107140
B.C. MAFF, Russia

Ms. M. Engelstad
EWOS Aqua A/S
PO Box 424
1471 Skårer, Norway

Mr. Arne Ervik
Institute of Marine Research
Division of Aquaculture
PO Box 1870
5024 Bergen - Nordnes
Norway
Tel: ++47 55 238300
Fax: ++47 55 238333

Dr. Richard FitzGerald*
Aquaculture Development Centre
University College Cork
Cork, Ireland
Tel.: ++353 21 276871 Ext.4936
Fax: ++353 21 274034

Appendix 2

Working Group on "Environmental Impact of Mariculture"

List of WG Membership, and participation of invited experts and observers in 1994

Mr. E. Gaard
Fiskirannsoknarstovan
PO Box 3051, Noatun
FR-110 Torshavn
Faroe Islands
Denmark

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

Ms. M. da Graça Cabeçadas
IPIMAR
Avenida de Brasilia
1400 Lisbon, Portugal

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

Dr. M. Héral
IFREMER
B.P. 133
17390 La Tremblade, France
Fax: ++33 46 361847

Mr. Marc Kempf*
IFREMER
Brest Center
Div. Environment Littoral
BP 70
29280 Plouzané, France
Tel.: ++33 98 224322
Fax: ++33 98 224548

Mr. H. Kryvi
Ministry of the Environment
PO Box 8013, Dep.
0030 Oslo, Norway
Tel.: ++47 22 345891
(or: ++47 55 237787)
Fax: ++47 22 349560

Dr. Reinhard Lauterbach
Landesforschungsanstalt für Landwirtschaft & Fischerei, Mecklenburg-Vorpommern, Inst. für Fischerei
An der Jägerbäk 2
18069 Rostock-Marienehe
Germany
Fax.: xx49 381 82 091

Dr. Tony Lewis*
Dept. of Civil Engineering
Hydraulics & Maritime Res. Centre
Munster Institute
Cork
Ireland

Dr. Timo Mäkinen
Finnish Game &Fisheries Res. Inst.
Fisheries Division
PO Box 202
SF-00151 Helsinki
Tel: ++358 0 624211
Fax: ++358 0 631513

Mr. P. Margonski
Sea Fisheries Institute
Gdynia, Poland

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

Mr. M. Merceron
IFREMER
Brest Center
Environment Dept.
BP 70
29280 Plouzané
France
Tel: ++33 98 224347
Fax: ++33 98 224548
E-Mail: merceron@ifremer.fr

Mr. Pedro Monteiro
Sea Fisheries Res. Institute
Private Bag X2
Cape Town 8012
South Africa
Tel.: ++27 21 4396160
Fax: ++27 21 4399345
E-Mail:
MONTEIRO@SFRI_2.SFRI.AC.ZA

Mr. Carter Newell
Great Eastern Mussel Farms
PO Box 141
Long Cove Road
Tenants Harbor ME 04860, USA
Tel: ++1 201 312 6317
Fax: ++1 201 312 8256

Appendix 2

Working Group on "Environmental Impact of Mariculture"

List of WG Membership, and participation of invited experts and observers in 1994

Dr. Brandon O'Connor*
Aquafact International Services Ltd.
12 Kilkeerin Park
Liosbaun, Galway
Ireland

Mr. W. Pelczarski
Sea Fisheries Institute
ul. Kollataja 1
81-372 Gdynia, Poland

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

Prof. Dr. Dr. H. Rosenthal (Chairman)
Institut für Meereskunde an der 81-322
Universität Kiel
Düsternbrooker Weg 20
24105 Kiel , F.R.Germany
Tel.: ++49 431 5973916
Fax.: ++49 431 565876

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

Dr. Heye Rumohr*
Institute of Marine Science
University of Kiel
Düsternbrooker Weg 20
24105 Kiel, Germany
Fax.: ++49 431 565876

Dr. William.S. Silvert *
Dept. of Fisheries & Oceans
BIO-HED
PO Box 1006
Dartmonth NS B2Y 4A2
Canada
Tel.: ++1 902 426 1577
Fax: ++1 902 426 2256

Mr. Pete Smith
Fish Diseae Group
Dept. of Microbiology
University College Galway
Galway, Ireland
Tel.: ++353 91 24411 Ext. 2370
Fax: ++353 91 750541

Mr. B.E. Spencer
MAFF Fisheries Lab.
Benarth Road
Conway Gwynedd LL32 8UB
United Kingdom
Tel: ++44 492 593883
Fax: ++44 492 592123

Mr. J. Stellwagen
DIFTA
NorsØcentret
9850 Hirtshals
Denmark

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

Appendix 3: Studies related to environmental aspects of Mariculture

Listing of completed, on-going and new projects

During the intersessional period new projects have been initiated on which brief information is provided. As far as possible, the earlier listings have been updated. Projects which have been listed as completed in 1992 are only given by title without any further notes unless late publications have appeared in the literature. Unfortunately, information on progress and completion of listed projects has not been obtained for all those reported in the 1992 Working Group Report. The numbering system has been maintained in order to permit project identification with the former listing and to allow also updating at a later date. Projects which have not yet been reported in any previous Working Group report have been assigned continuing numbers, appear at the end of the table.

No	Project Description	Completion Date	Country and Reference, if any
(1)	Investigation into the effects of fish cage culture on: benthos, hypernutrification, eutrophication, wild fish populations, and bacteria.	Dec. 1990	Denmark **results not reported to WG**
(2)	Algarve: Environmental studies at Faro-Olhao sea agoon "Ria Formosa". Regular monitoring of phyto-plankton; bacterial population in the lagoon, in bivalves; sediment - water column exchange of oxygen and nutrients	mid 1991	Portugal **results not reported to WG**
(3)	Mondego estuary: Regular monitoring of phyto-, zoo-and ichthyoplankton, and of physical conditions; studies on water exchange rates and fish pathology.	mid 1991	Portugal **results not reported to WG**
(4)	Calibration and validation of two ecosystem simulation models with which the carrying capacity for mollusc shellfish culture can be assessed in the Waddenzee and the Oosterschelde estuary.	1991-1994	Netherlands

Research into modelling of the ecosystems of the Wadden Sea, carried out by the Institute for Forestry and nature Research (IBN-DLO), the Netherlands Institute for Sea Research (NIOZ) and the National Institute for Coastal and Marine Management (RIKZ) is continuing. Special attention is also paid to modelling of the role of bivalves: mussels and cockles as well as non-commercial species, as a food resource for birds. Contact: B. Ebbinge (IBN), H. Lindeboom, NIOZ and J. Coosen (RIKZ). Completion date: n.a. Status: on-going

(5)	Research to assess the influence of two types of mollusc dredges, used for for musseland oyster cultivation, on the substrate of natural intertidal mussel beds and cultivation plots.	1992	Netherlands

Status: concluded: Contact person M. van Stralen, RIVO-DLO

(6)	Measurement of in situ production of nutrients and consumption of particulate food by mussels and the communities on cultivation plots.	1996	Netherlands

Status: on-oing , Contact: A., Smaal (RIKZ)

(7)	Research into suitable sites for mussel	completion date: 1996	Netherlands

cultivation in the Oosterschelde in relation with current velocity and food availability.
Status: on-going, reports not yet available. contact: R. Dijkema, see member list

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

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

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(10) Antibiotics in farmed fish, wild fauna and sediment, and degradation rates of chemicals — completed 1988 — Finland
Status: terminated; no info on reports

(11-13) No information available, *completed during 1990* — United States

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(14) Status reported in Country report 1992 — Eastern Canada

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(15) Letang Inlet aquaculture project — continuing anticipated completion date 1996 — Eastern Canada
A summary of the findings to date include: (a)predictions from the hydrodynamic model of regions, (b) nitrogen input by salmon farms; (c) benthic oxygen uptake under fish farms; (d) repsiration of the caged salmon. Details see country report in App. 4.of the 1992 WG-Report. A Technical Report on "Modelling Benthic impacts of Organic Enrichment from Marine Aquaculture" was published in 1994 (Can. Tech. Rep. Fish. Aquat. Sci. 1949, see Literature list)
Contact person: B.T. Hargrave, P.D. Keizer, D.C. Gordon, W. Silvert, all in Habitat Ecology Division, Bedford Inst. Oceanogr., PO Box 1006, Dartmouth, NS Can B2Y 4AZ

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(16) The effect of blue mussel culture on the benthic environment in Nova Scotia and Prince Edward Island — begun 1991 completed 1993 — Eastern Canada
Status: No information available to WG in 1994

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(17) The cause of summer kill in cultured blue mussel — begun in1989 completed in 1990 — Eastern Canada
Status: Reports are available from Dep Fish. , PEI, Canada

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(18) Phytoplankton profiles ..... — completed1992 — Eastern Canada
Status: no references on reports and no contact address presently available to WG

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(19) Cross contamination of oysters..... — commenced in 1989 — Western Canada
Status: terminated in 1992, Report see ICES/CM1991: F.23.

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(20) Plankton watch for marine aquaculture..... — Western Canada
Status: terminated 1993; Internal reports available, contact E.A. Black (address see membership list)

(21- 22) Completed, no longer listed,. *see 1989 WG report* — Western Canada

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(23)A winter disease profile, survey of a quarter of existing fish farms — Western Canada
completed1990, internal reports available, contact E.A. Black, see membership list

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(24) Antibiotic resistance of pathogens in the vicinity of fish farming — completed in 1992 — Western Canada
contact E.A. Black: see 1992 report and membership list

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

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

Work ongoing

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

Finished and reported in 1990 working group report.

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

Finished and reported in 1990 working group report.

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

Finished and reported in 1990 working group report.

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

Finished and reported in 1990 working group report.

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(31) Phytoplankton identification video — Western Canada

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

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

Status: finnished. Contact E.A. Black, see WG Membership Isting in Annex

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

Status: Finnished and published: Black et al., 1991. J. Appllied Ichthy.

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

Finnished and reported in 1990 working group report

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

Work continued

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

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

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

Finished and reported in 1990 Working Group report

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

Contact E.A. Black

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

Thesis expected 1992. Contact E.A. Balck

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

Contact Mr. B. Kay - as above

(41) Mandatory monitoring of waste loading at fish farm sites and trends in water quality — ongoing — Western Canada
Finished and reported in the 1990 Working Group report

(42) Review of the impacts of freshwater aquaculture on the environment — terminated — Western Canada
Finnished and reported in 1990 Working Group report

(43) An investigation of the impact of fish farming on the nearshore environment — terminated — Western Canada
Finnished and reported in 1990 Working Group report

(44) An experiment on the contamination of the environment by aquaculture (anti-fouling preparations — Western Canada
Finnished and reported in 1990 Working Group report

(45) Culture of oysters in salmon farm effluent — 1991 — Western Canada
as per project No. 19

(46)An assessment on the impacts of fish farming on herring spawning — 1991 — Western Canada
Results were presented at the AAC Annual meeting in June 1992, see publication

(47) Predation by cultured salmon on wild organisms — terminated — Western Canada
Finnished and reported in 1990 Working Group report

(48) Survey of salmon farm waste handling practices — terminated — Western Canada
Finnished. For further information contact Mr. J. Willow (same address as E.A. Black)

(49) Biophysical capability studies of the BC coast for marine salmon aquaculture — completed — Western Canada
A total of 4 reports have been completed recently. Contact: Mr. J. Truscott (same address as E.A. Black, Victoria, BC).

(50)

-53)project have been completed, *no further information available*Sweden

(54) Investigation of the impact of marine fish farms on the receiving water body. Keywords: nutrition, salts, sedimentation, benthic fauna — completed, no longer listed — Norway
Results have been published, see literature list of 1992 WG Rep: Aure et al. 1988

(55) Fate of organic waste from marine fish farms. — completed — 1990 — Norway
Report available: see literature list under Hansen et al, 1991 Nord (22), p.105-120.

(56) Development of a data base — completed in 1989 — Norway
No status information has been made available

(57) Development of methods for treatment of fish farm wastes — completed — Norway
Report available from: Jordforsk, Norges Landbrukshøgskole Ås

(58) Isolation and investigation of potentially toxic flagellates (especially *Chrysochromolina)* — completed — Norway
For information contact: Prof. E. Paasche, Universitetet i Oslo, Postboks 1066, Blindern 0316 Oslo 3

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

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(60-62) projects have been completed, — completed — Norway
(60) Environmental factors influencing growth of salmon
(61) Effect of crude oil exposure on fish farms,
(62) Development of low density fish feed
Information available from ROGALANDSFORSKNING, Postboks 2503, Ullandshaug , N-4004 Stavenger

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(63) Development of an efficient tool of coastal zone planning (LENKA) — completed 1990/91 — Norway
Several reports have been prepared. Final versions are available from the Ministry of Environment of Norway, Postboks 8013, Dep 0030 Oslo 1

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(64) Investigations of the effects and fate of antibiotics — 1991 — Norway
The study includes aspects of the ecological impacts of antimicrobials. At present no additional info on the status of the project is available other than publications listed under references in 1992 WG Report

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(65) Quantitative estimates of eutrophication effects of fish farming in fjords — 1986-92 — Norway
Description: Dealing with the effects of fish farming on eutrophication of the upper layer and the increased oxygen consumption in the basin water of fjords.
Contact person: Jan Aure, Inst Mar. Res., Norway
The project has resulted in a publication (see Literature list: Aure and Stigebrandt, 1990)

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(66) Level of drugs in farmed fish, wild fauna and sediment.... — completed — Norway
Information on results available from NIVA, Postboks 69, Korsvoll, 0808 Oslo 82

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(67) Investigation into resistant microflora in the sediments beneath fish farms — completed, — Norway
Information on project results available from V. Torsvik, IPM, Univerista of Bergen, Allegt 70, N-5000 Bergen

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(68) Investigation on feeding behaviour and control by hydro-acustic detection of feewaste and vertical rfish distribution — 1988-92 — Norway
Several publications have appeared during the intersessional period. See literature list

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

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(71) Alternative traetment of salmon lice. — 1989-92 — Norway
The project deals with alternative chemicals in lice control.
Contact person: Jens Chr. Holm, Inst.Mar. Res., Norway; a publication has appeared, see literature list of 1992 WG Report

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

(72-78) deleted from the listing, because no reports on progress have become available since 1990

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(79) Biological control of sea lice — project dates:1988-1992 — Norway
Contact person (new address): Äsmund Bjordal, Inst.Mar. Res., Norway.
Besides the report presented at the 1988 Statutory Meeting, no further reports have yet become availalbe

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

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

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

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

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

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

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

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(115) The role of benthic fauna in decomposition of organic waste from aquaculture — completion date 1992 — Norway

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

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(116) Project is deleted from this list because no further information on their progress could be traced since its early listing — Norway

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

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

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

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

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(119) Escaped farmed fish - influence on populations of wild Atlantic salmon — completion date 1992 — Norway

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

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

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

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

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

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(122) The parasitic biology of Caligus elongatus and Lepeophtherius salmonis on farmed salmon untreated for infestation. — completed1990 — Ireland

The objective of this study is to find a method to control sea lice populations without resorting to environmentally damaging pesticides. Information is being collected on the natural rhythm of infestations and parasitic intensity, and population turnover time at different temperatures. A thorough understanding of these processes will, it is hoped, enable more effective physical or biological control of epizootics of these parasites.

Results published: Tully, O. 1989. The succession of generations and growth of the calligid copepod Calligus elongatus and Lepeophtheirus salmonis, parasiting salmon smolts (Salmo salar). J. mar. biol. Assoc. 69: 279-287.

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(123) The detection of Dichlorvos in the marine environment, its effects on marine ecosystems and lethal and sublethal effects on fish, crustaceans and bivalves. completed1990 Ireland

Results have been reported at conferences, 3 publications appeared: Tully, O. 1999. Detection of dichlorvos in the marine environment and its toxicity to bivalves, crustaceans and fish. Shellfish Res. Lab. Carna, lab Rep. Series B, No. 0062: 11-22.

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(124) The impact of tributyltin (TBT) residues on mollusc spawning and survival completed 1989 Ireland

(No report has become available)

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(125) Uptake of antibiotics from salmon farms by edible molluscs completion date 1990 Ireland

(Project has been posponed)

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

There is no information on status and interim results of the project available

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*(128) Recovery of environments exposed to TBT: as part of an on-going monitoring of the impact of TBT on marine life. was active in 1992 Scotland

There is no information on status and interim results of the project available

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

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

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

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Projects listed as NEW in the 1992 WG report

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

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

Study completed in1993. First internal report available, publication planned in 1994

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*133 Kiel cage performance The project aimed at optimizing feeding strategy under widely fluctuating temperatures and oxygen levels (farm situated in the waste heat plume of a coastal power station. 1990-1991 F.R. Germany
completed in 1992

Projects reports (in german) are available from the Dep. of Fishery Biology, Univ. Kiel. Interim results were presented as Doc. ICES. C.M. F:1990. For further details see country report.in WG Rep 1992

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*134 Sedimentation under cages in a non-tidal inlet 1991, completed F.R.Germany
Changes in sediment geochemistry and in benthos composition have been demonstrated. A publication is presently under preparation. contact: H. Rosenthal, Dep. Fishery Biology, Univ. Kiel., Manuscript submitted to J. appl. Ichthyology 1994

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*135 Effects of intermittant (tidal) oxygen depletion on Pacific salmon 1991-1993 F.R.Germany Western Canada
Aim: establishing an ethnogram that permits to identify early warning sings in stressed fish
contacts: Dr. U. Waller, Dep. Fishery Biology, Univ. Kiel. For further details see country report for Germany ; Publication in preparation, expected to appear in 1995

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*136 Oyster culture site selection and monitoring program for New Brunswick Eastern Canada
begun in 1988
anticipated completion 1995
A collaborative program involving the New Brunswick Dep. of Fisheries &Aquaculture, Canada Dep. of Fisheries and Oceans, &the Environmental Res.Unit of the Université de Moncton with the oyster growers. For details see Canadian Country Rep. Contact Person: Dr. A.Boghen, Dep.Biology, Université de Moncton, Moncton, New Brunswick.

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*137 Determination of metabolites produced by three marine, non-salmonid fish species ongoing France
Investigation on nitrogen end products by marine fish contact Mr Dosdat IFREMER

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*138 Modelling of nutrient effluents in marine fish farms ongoing France
contact: Mr. Dosdat, IFREMER
Study conciders turbot and sea bass; conditions followed are: Fish farm management, nutritional requirements and resulting environmental parameters

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*139 Reduction of fish farm effluents through improved nutrition ongoing France
contact: Mr. Dosdat, IFREMER
Study on nitrogen digestibility of feeds and their energy content; estimation of marine fish phosphorus metabolism, excretion and requirements.

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*140 Potential interaction between shellfish and finfish culture ongoing in 1994 France
contact: Mr. Merceron, IFREMER
Study on accumulation of antimicrobials in farmed shellfish, Analysis for pathogenic bacteria, Study on transfer of faeces &organic matter from various origin (eg shellfish, finfish, phytoplankton, sewage) in relation to suspended solid output from finfish culture

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*141 Characterisation of organic matter derived from fish faeces under culture conditions ongoing in 1994 France
contact: Mr. Dosdat, IFREMER
The studies considers sedimentation rates from turbot and sea bass farms as well as leaching of material (laboratory study).

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* 142 Impact of nutrient release on the environment (Channel, Mediterranean) ongoing in 1994 France
contact: Mr. Merceron, IFREMER
The study employs hydrodynamic and primary production models for macro-tidal Atlantic environments as well as Mediterranean situations

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*143 Causes of summer mortality in Atlantic salmon smolts completed France
contact:M. Merceron, IFREMER, Brest
The study is concerned with the "fade disease" , a condition in which fish show mortality and very low appetite

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*144 Preliminary research on indsutrial offshore fish farming in the Mediterranean coastal zone completed France
contact: A.Febvre, IFREMER, Chemin de Maguelone, 34250 Palavas les Plots

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*145 Estimation of nutritional needs and quantification of wastes for cultured shellfish species ongoing France
contact: Mr. Heral, IFREMER

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

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*146 Nutrient flux in coastal areas (Northern Brittany) completed France
contact: Mr. Piriou, IFREMER Brest, DEL, BP 70, 29280PLOUZANE
Modelling of nutrient flux between open ocean and inshore areas, including estuaries. Models aimed at describing the evolution of impacts in order to improve ecosystem management approaches in relation to human resource uses

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*147 Evaluation of the return of escaped salmon to the River Polla 1989-1990 Scotland
contact: Dr. Youngson, Aberdeen
The project has been extended to include the second year following their escape. Evaluation of the genetic consequences of the spawning of escaped salmon in the Polla in 1989 and 1990. publications have appeared in 1993-1994

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*148 Distribution of the progeny of female salmon which have escaped from aquaculture ongoing Scotland
contact: Dr. Youngson, Aberdeen
Fry bearing canthaxanthin were detected in 14 of 16 western and northern Scottish rivers. Overall, 5% carried canthaxanthin. publications see literature listing 1994

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*149 Studies of structuring among wild salmon populations ongoing Scotland
contact Dr. Youngson, AberdeenSOAFD Marine Laboratory

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*150 Investigation of the factors affecting the rate of recovery of the benthic environment at abandoned fish farm sites **new project** four years from1992 onward Scotland
*Contact: Dr. A. Bullock , Dunstaffnage Marine Lab Oban
Interim reports not expected prior to fall 1993 /spring 1994*

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*151 Development of analytical methods for the determination of antibiotic residues in sediment and biota at Scottish fish farms, including field studies at 3 farms in Shetland **completed** Scotland
Report available from: J.C. McKie, SOAFD Marine Laboratory, Aberdeen

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*152 Development of mathematical models of water circulation and dispersion in Scottish sea lochs, to assist in the assessment of the carrying capacity of lochs for farmed fish ongoing Scotland
Contact address: Dr. I.M. Davies, SOAFD Marine Laboratory, Aberdeen

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*153 Development of mathematical models of the interaction between sea bed sediments and water quality in Scottish sea lochs new project start 1992 Scotland
Contact address: Dr. I.M. Davies, SOAFD Marine Laboratory, Aberdeen

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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*176 Antibacterial agents in the marine environment. completion Dec 1993 Norway

Description: Investigation on: 1) the stability of several antibacterial agents in sea water and marine sediments, 2) metabolism of oxylinic acid and flumequin in salmon, 3) investigation of residues in wild fish sampled in farms with feed-collector/detector. Contact person: Arne Ervik Inst.of Mar. Research, Norway

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

Investigate the decomposition of different antibacterial agents in use. Develop toxicological environmental tests to predict the effects of new agents. contac person H. Hektoen, NIVA, Postboks 69, Korsvoll, 0808 Oslo 822

*178 Genetic adaptations among strains of salmon. — 1992-93 — Norway

Modelling different impact of the genetic properties. Contact person: H.B. Bentsen, AKVAFORSK, N-6600 Sundalsøra

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

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

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

Investigation of the correlation between pH, Eh and pS in the sediment and remineralization of organic materials.
Contact- M. Frog, Nordlandsforskning, Postboks 6003, N-8016 Mørkved

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Ongoing, contact person S. Høie

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

Ongoing, Contact person. Dr. Renger Dijkema (see Country Rep in WG Rep 1992)

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

Starting in 1992, contact Dr. Renger Dijkema (see Country Rep in WG Rep 1992)

NEW Projects (1994): not in previous WG Reports

191 Modelling carrying capacity of Marennes-Oleron Basin. ongoing France
Natural environment processes (advection, primary production, competitors) and molluscs physiological parameters (filtration rates, faeces and pseudo-faeces formation) are investigated.
Contact: Mr. Heral, IFREMER/CNRS, CREMA, 17137 L'HOUMEAU

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192 Environmental quality monitoring network (RNO) of the french coast. ongoing France
Seawater quality parameters through 130 stations in France, metallic and organic contaminants in living animals, sediment quality.
Contact: Mr. Claisse, IFREMER, Nantes Center, BP 1049 , 44037 NANTES

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193 Microbiological monitoring network (REMI) of shellfish farming zones. France
Aimed at keeping the sanitary level of products on 300 sites.
Contact: Mrs. Miossec, IFREMER Nantes Center, BP 1049 , 44037 NANTES

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194 Phytoplancton monitoring network (REPHY) of coastal zone. France
System aimed at alerting in case of toxical risk for human and marine health on 30 sites in researching toxic species.
Contact: Mrs. Belin, Nantes Center, BP 1049 , 44037 NANTES

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195 Shellfish health and growth monitoring network (REMORA). France
Test oysters are placed in 15 ongrowing sites and observed once a year. Give an integrated value of the environmental quality.
Contact: Mr. Mazurie, IFREMER, BP 26, 56470 LA TRINITE SUR MER

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196 Carbon, nitrogen and phosphorus mass balance in a shellfish semi closed basin (Thau lagoon). France
Environmental modelling of shellfish interactions, modelling oxygen cycles, evolution of suspended micro organisms.
Contact: Mr. Deslous-Paoli, IFREMER, 34200 SETE

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197 Recycling systems as a tool to reduce fish farm effluents. France
Improvement of biofilters, selection of nitrification bacterial strains, development of denitrification reactors, secondary treatments in order to reduce fish farm loadings and permit farming activity onshore in land-based facilities.
Contact: Mr. Blancheton, IFREMER, GIE RA, 34250 PALAVAS LES FLOTS

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198 Self pollution assesment concerning ammonia and oxygen. France
Effects of ammonia and oxygen levels on physiological status of marine fish.
Contact: Mrs. Person, IFREMER Brest DRV , BP 70, 29280 PLOUZANE

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199 Fish farming chemotherapy France
Behaviour of antibiotics & other vetproducts in marine &freswater environments.
Contact: Mr. Le Bris, Ecole Veterinaire de Nantes, BP 3013 44087 NANTES

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200 The status of salmon and trout stocks in the Baltic and on the west-coast of Sweden. Sweden
Objective: Annual assessment of salmon- and trout stocks. Continuing, no time limit.
Project leader: Lars Karlsson Salmon Research Institue, S-810 70 Älvkarleby, Sweden

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201. Population genetic investigations of salmon and trout. Ongoing Sweden
Objective: By studying the genetic variation of natural and hatchery raised smolts to get knowledge for managing and conserve the genetic diversity. No time limit.
Project leader: Håkan Jansson,Salmon Research Institute S-810 70 Älvkarleby Sweden

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202 The migration pattern of salmon at delayed release. Time frame:1990-1996 Sweden
Objective: To determine if delayed release of smolts is profitable to promote fisheries.
Project leader: Curt Eriksson, Salmon Research Institute, S-810 70 Älvkarleby,Sweden

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203. Strategies to prevent disease dispersal when stocking white fish in areas close to salmon and trout rearing. Time frame: 1992-1995 Sweden

Objective: To minimize the risks for spreading diseases to salmonin in connection with cultivation of white fish for stocking purposes.
Project leader: Nils Johansson,Salmon Research InstituteS-810 70 Älvkarleby,Sweden

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204 Reproduction problems in conncetion with M 74, an unidentified disease - 6 different projects. started 1993 termination?? Sweden

Objectives: 1)To elucidate the cuauses and mechanisms behind M 74-mortality. 2) To get knowledge for prognoses and selection of females which will produce offsprings with M-74 mortality. 3) To elucidate causes and develop methods and culture technique to decrease juvenile mortality among individuals with partial M74 mortality. T
Project leader Hans Börjesson, Salmon Research Institute, S-810 70 Älvkarleby, Sweden

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205. Many projects in tropical areas dealing with fishculture, integrated shrimp farming, farming in mangrove areas, environmental impacts of aquaculture. 1992 plus Sweden

Project leader : Nils Kautsky , Stockholm University, S-10691 Stockholm, Sweden

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206. Toxic environmental pollutants- collection, extraction, separation, toxicity testing and chemical characterisation of liphopjhilic extracts from abiotic and biotic samples from the Baltic. started 1994 continuing Sweden

Project leader: Dag Broman, Stockholm University, S-10691 Stockholm, Sweden

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207 Altered bleaching process- Changes in the water recipient. started 1993 continuing Sweden

Project leader: Dag Broman.
Stockholm University, S-10691 Stockholm, Sweden

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208. Biological effects of fractionated extracts from sediment including identified and unidentified organic compounds and chemical characterisation of potent fractions. started 1993, ongoing Sweden

Project leader: Dag Broman, Stockholm University, S-10691 Stockholm, Sweden

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209. Stocking a coastal Baltic Sea area with pikeperch- a possibly economically profitable way to improve water quality. Proposed project, not yet implemented Sweden

Project leader Sture Hanson, Stockholm University, S-10691 Stockholm, Sweden

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210. Restoration of coastal waters and fiords by the application of mussel farming. Sweden

Project leaders: Haamer, Edebo,Molander,Oskarsson.
Proposed project, soon to be implemented
Gothenburgh University, Department of Oceanography, Box 4038, S-400 40 Göteborg, Sweden.

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211. The distribution of *Angillicola* in Sweden and its association with thermal discharge areas. Sweden

Project leaders: Inge Boethius, Jan Höglund and K. Holmgren. The national Vetrinary Institute, Swedish National Environmental Protection Agency, Coastal Laboratory, Institute of Freshwater Research. Time frame 1989- until present; Published papers; see reference list.

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212 A study on the relation between eutrophication of the Wadden Sea and growth and condition of mussels. completion Dec1994 The Netherlands

Exact landing statistis of mussels make good time-series possible of mussel condition in a number of production areas since the 1950's, which time-span covers the period of increase and supposed decrease of eutrophication.
Contact: M. van Stralen (RIVO-DLO) Status: new, Completion date: 1994

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

Contact: R. Dijkema (RIVO-DLO) Completion date: perpetuous ,Status: on-going

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214 National monitoring programmes for bacterial water quality, toxic phytoplankton and biotoxins, which are financed by both the government and the shellfish industry. Completion date: perpetuous The Netherlands

Contact: R. Dijkema (RIVO-DLO) Status: on-going

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215 Research into effluent characteristics of intensive fish farms Completion date: 1997 The Netherlands

(mainly recirculating eel farms) at the RIVO-DLO in IJmuiden is being continued.

Contact: A. Kamstra (RIVO-DLO)

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216 Development research into the culture of turbot (*Scophthalmus maximus*) is carried out at the RIVO-DLO in IJmuiden 1994- 1997 The Netherlands

A pilot plant for commercial production of turbot, using power plant cooling water, was built and will be started in 1994. Contact: A. Kamstra (RIVO-DLO), Ijmuiden

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217 Research into suitability of sites for mussel culture in the Wadden Sea Completion date: 1994 The Netherlands

Contact (M. van Stralen (RIVO-DLO) , IJmuiden

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218 Study on the status of Marine TBT antifouling contamination in Aquaculture areas. 1993 Ireland

Status: paper in press Minchin and Duggan.

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219 Introductions of exotic species associated with Pacific Oyster transfers from France to Ireland. Ongoing Ireland

Status: Preliminary report to ICES 1993 Statutory Meeting.

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220 STRIDE Pollution control of freshwater fish, farm effluents 1994 Ireland

Status: Report in preparations (Dr. M. Costello TCD).

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221 Cleaner fish technology as an alternative to pesticides 1993 Ireland

Status: Completed (Dr. M. Costello TCD).

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222 The developing of a vaccine for *furunculosis* caused by *A. salmonicida* in Salmonid fish. 1995 Ireland

Scientist in charge Prof. T.J. Foster TCD.

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223 Fate and sinks of malachite green in the natural environment natural environment. 1994 Ireland

Scientist in charge Dr. James Wilson TCD.

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224 Study of the rates of recovery in shallow embayments following intensive Aquaculture activities over a 10 year period. 1994 Ireland

Salmon Research Agency Dr. Ken Whelan (projects 7-11)

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225 Research into the fate of antibiotic residues in the Marine Environment 1994 Ireland

Salmon Research Agency Dr. Ken Whelan (projects 7-11)

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226 Research into the residency time of certain pathogens under hypoxic and oxic sediment conditions in marine fish farms. report in press Ireland

Salmon Research Agency Dr. Ken Whelan (projects 7-11)

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227 The role of bioturbaling animals in the fate of antibiotic residues in the marine environment. Ongoing Ireland

Salmon Research Agency Dr. Ken Whelan (projects 7-11)

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228 A study of temporal changes in the genetic Ongoing Ireland

composition of juvenile salmon populations from selected rivers adjacent to fish farms.

Salmon Research Agency Dr. Ken Whelan (projects 7-11)

228	Vaccination trials	no info presently available		Ireland
229	Phytoplankton species associated with imports of the Pacific Oyster*Crassostrea gigas*, from France to Ireland.		Ongoing	Ireland
	Preliminary Report to ICES 1993			
230	Studies on Sea Trout and interactions with Salmon farms		Report tabled	Ireland
	Publications available, Coyne et al., 1994; Kerry et al., 1994			
231	Fate and impact of antimicrobial agents in marine fish farms Studies on the concentration of the agents and the frequencies of resistance in sediments with respect to area, depth and finess. Influence of sedimentation quality on these factors.		Ongoing	Ireland
	Coyne et al., 1994; Kerry et al., 1994			
232	Reduction in the biological activity of antimicrobial agents in the aquatic environments. Impact of chemical and physical parameters.		Ongoing	Ireland
	Contact: Dr. Peter Smith UCG			
233	Studies of antimicrobial agent resistance in marine micro-flora. Methods of quantitation; factors leading to elevated frequencies. Genotypic and phenotypic characterisation of the resistances selected.		Ongoing	Ireland
	Contact: Dr. Peter Smith UCG			
234	Studies on the development of new techniques of measuring concentrations of biologically active antimicrobial agents in the marine environment.		Ongoing	Ireland
	Contact: Dr. Peter Smith UCG			
235	The influence of benthic fauna on remineralization of organic material from aquaculture.		April 1993	Norway
	Investigation of the quantification of organic material and on the connection between load and effect.			
236	Genetic influence of escaped salmon on strains of wild salmon.		1994	Norway
	Investigation of the spawning success of escaped farmed salmons to evaluate potential genetic interactions with wild salmons.			
237	The fatty acid profile in brain tissue is used as an identification parameter.		1994	Norway
238	Transfer of resistance against antibacterial agents in *Aeromonas salmonicida*.		1995	Norway
	Characterization of two transferable resistance plasmids identified in the furunculosis bacteria.			
239	Transfer of disease between salmon and different marine fish species.		1995	Norway
	Surveillance of escaped farmed salmons.			
240	Investigation of the relative abundance of escapees caught in the sea and in the rivers.		1995	Norway
241	Surveillance, migration and survival of escaped farmed salmon.		1995	Norway
242	Reproductive threat of cultured salmon to wild populations.		1996	N orway

243	Reproductive isolation mechanisms between wild and farmed salmon.	1996	
244	Investigation of the negative effect of escaped farmed salmon on the redds of wild salmon.	1994	Norway
245	Development and transfer of antibiotic resistance.	1993	Norway
246	Pharmacokinetics of different antibacterial agents.	1995	Norway
247	Ecological impact of antibacterial agents and antiparasittic agents used in fish farming industry	1993	Norway
248	Ecological & physiological consequences of sea lice on salmonids in fjords.	1994	Norway
	Alternative treatment of salmon lice.		
249	Studies on environmental suitable methods to reduce the sea lice problem	1993	Norway
	Both chemical and biological methods are investigated.		
250	Biological delousing of salmons. Use of wrasse as cleaner fish.	1993	Norway
251	Preventive and integrated treatment of sea lice.	1995	Norway
	Quantifying the effect of syncroniced treatment.		
252	Impact and performance of Atlantic salmon cage farming in Chile	1993-1994	Germany
	Contact: H. Rosenthal, Institute for Marine Research, Kiel University		
253	Geochemistry of sediments under a cage farm in Kiel Fjord	1993-1994	Germany
	Contact: H. Rosenthal, Institute for Marine Research, Kiel University		
254	Bacteriology of caged fish and sediments under farms along the Baltic coast of Schleswig-Holstein and Mecklenburg-Vorpommern	1994-1996	Germany
	Contact: H. Rosenthal, Institute for Marine Research, Kiel University		

Appendix 4:

An overwiew of Norwegian and French environmentally oriented research in aquaculture

DEL/AA/95.060 - MK
Mars 1996

ICES WG "Environmental interactions of mariculture"
Nantes, March 25-29th 1996

LIST OF THE FRENCH ONGOING PROGRAMMES

Project description	Degree of achievement*
Quantification of wastes from clam and oyster intensive farms which use underground salt water. The animals are fed cultivated phytoplankton and housed in controlled tanks.	NC
Associated farming assays of marine fish and mollusks, in order to improve the utilization of external inputs.	IP
Model of the carrying capacity of a mollusc farming zone (Marennes-Oleron). This very complete work includes natural environmental processes (advection, primary production and its nutritive value, suspended matter, competitors, etc.) as well as the physiology of farmed molluscs (filtration rate, ingestion rate, threshold of pseudofaeces and faeces formation, and their variation along with physico-chemical conditions, etc.).	NC
The basic model is completed. Further applications integrate other coastal zone uses (e.g. agriculture runoff...) and develop new tools such as linkage with GIS	IP
Environment quality monitoring network on the French coasts, for temporal trend studies of seawater (ordinary quality parameters are investigated about 6 times a year in 130 stations grouped in 12 main sites) and living animals (metallic and organic contaminants are analysed 4 times a year in about 100 stations). Sediments are investigated each ten years. Data collected for 20 years are registered in a bank.	IP
Phytoplankton monitoring network of French coastal zones aiming at providing warning of toxic hazard to human or marine animal health (REPHY). About 30 sites are investigated two times per month (counts of dominant genus of phytoplankters and research of toxic species).	IP
Monitoring network of health and growth of molluscs in farming zones (oysters and mussels) : REMORA (growth and quality), REPAMO (pathology and diseases belonging to the E.U. list).Test molluscs are placed in 15 sites along the French coasts, and observed once a year. Till now, it involves only Japanese oysters. Moreover, environmental factors and shell opening/closure behaviour are recorded from outbreaks of disease or unexpected mortalities.	IP

* St = Starting ; IP = In Progress ; NC = Nearly Completed

Genetic improvements of molluscs are undertaken in a specially designed programme (REGEMO) :

. triploidy of Japanese oysters NC
. physiological characteristics improvement of Japanese oysters (low metabolism, high assimilation rate ... : selection) IP
. flat oyster disease resistant strains (selection) IP

In a Mediterranean lagoon (Thau), relations between mollusc farming and environment through modelling carbon, nitrogen, phosphorus and oxygen cycles. In the same lagoon, evolution of suspended micro-organisms, and impact of suspended-feeders on them. NC

Quantification of wastes from four marine species of farmed fish (turbot, seabass, seabream, brown trout), and variation of discharges with farming conditions : food, feeding rate, temperature, stock density, etc.). Improvement of fish food quality, in terms of both the balance between N, P and C and the feed behaviour in water. IP

Impact of marine fish farms on the environment : water column, sedimentation, oxygen depletion, benthic macrofauna, farmed molluscs, marine plants, solid wastes tracing by metals, video sea-bed monitoring, etc. IP

Research on closed circuit development concerns differents apects IP

. self-pollution risks of fish farming, concerning ammonia and oxygen concentrations in water IP
  food-waste relations and effluent treatment
. zootechniques and technology
. fish behaviour in closed intensive environments (stress, locomotion, feeding ...)
. sanitary and parasite prophylaxy.

Behaviour of antibiotics and other veterinary products in marine and freshwater environments (oxolinic acid, oxytetracycline, dichlorvos, levamisole), and their impacts. IP

An overview of Norwegian environmentally oriented research in aquaculture

1. Salmon Lice

No.	Project title	Institution	Project manager
1.1	Registration of salmon, sea trout and char all along the Norwegian coast	Norwegian Institute for Nature Research (NINA)	B. Finstad
1.2	Registration, primarily of sea trout, in selected river systems	NINA; County Governor of Nordland	B. Finstad
1.3	Registrations in Talvik and Ims	NINA	B. Finstad
1.4	Population consequences of salmon lice infections of salmon and sea trout; registrations in two rivers in each county from Rogaland to Troms, plus 37 rivers in Hordaland	University of Bergen	Per Jacobsen and Are Nylund
1.5	Physiological consequences of salmon lice infections on salmon and sea trout	University of Bergen/NINA	Per Jacobsen
1.6	Genetic mapping of salmon lice	University of Bergen	Are Nylund
1.7	Combatting salmon lice by oral administration of an active substance	Nutreco/Skretting	Kjell Arne Hoff and Gordon Ritchie
1.8	Combatting salmon lice by oral administration of an active substance	EWOS	Ole K. Kaurstad and Jon Ingen Erdal
1.9	Lice infections, localization and biology of salmon lice	EWOS	Kristian Wallace

1.10	Oral delousing	ALPHARMA	Bernt Martinsen and S. Aleksandersen
1.11	Oral delousing	Norwegian Fishery College, University of Tromsø, Nutreco	Grøntvedt, Falk-Petersen, Ritchie, Jørgensen
1.12	Development of a practical method for delousing using pyrethrum	MOWI/Melbu Verft	Pelle Kvenseth
1.13	Delousing using pyrethrum	Norsk Pyrethrum	Morten Haugberg
1.14	Cypermetrin - a new water-based pyrethrum preparation	Grampian/Univ. of Bergen/Akvavet. Sunnmøre	Are Nylund and Leiv Aarflot
1.15	Effects of Salmosan at various temperatures	University of Bergen; Fish Health	??
1.16	Development of salmon lice at low temperatures	Marine Research Institute, Austevoll Research Station	Jens C. Holm
1.17	Winter infections of salmon lice	Marine Research Institute, Austevoll Research Station	K. Boxaspen, A. Kårdal and T. Næss
1.18	Treatment regimes, overwintering of wrasse	Aquaculture consultant in Flatanger, Fosnes and Namsos	Per Andersen
1.19	Registration methods adapted to user groups, cost analyses	MOWI; Aquaculture consultant in Flatanger, Fosnes and Namsos	Pelle Kvenset and Per Andersen

1.20	- Wrasse as louse foragers on small and large salmon - reinfection of lice after delousing - Winter storage of wrasse	MOWI	Pelle Kvenseth
1.21	Seasonal variations in occurrences of fish pathogene microorganisms in a population of wrasse	Univ. of Bergen	A. M. Kvenseth
1.22	Parasites on wrasse from Hordaland	Univ. of Bergen	Aina Solberg
1.23	Virulence and vaccine trials on wrasse	Univ. of Bergen	A. M. Kvenseth
1.24	Host localization in salmon lice	Univ. of Oslo, Dept. of Biology	P. A. Heuch
1.25	Host preferences in salmon lice; freshwater tolerance, life cycle speed	NINA	B. Finstad, Grimnes
1.26	Operational and financial consequences of salmon lice for aquaculture	Akva Institutt	K. Steinshylla, O. Løfsnæs and K. Maroni
1.27	Copeodite success as a consequence of temperature, light and age	Univ. of Bergen	P. Jacobsen, Augestad
1.28	Hatching and start feeding of wrasse	Sogndal Regional College	
1.29	(Producing a training/information video on salmon lice and environmentally friendly methods of treatment)	FFK + SFT	Rune Vindenes, Per Jacobsen, etc.
1.30	Salmon lice and the use of light in fish farms	Iniv. of Bergen, Fish Health	Ernst Morten Hevrøy

1.31	Delousing with perethrum during sorting	WINGAN Brothers	
1.32	Delousing using pyrethrum during sorting	Frøya	Solveig Gåså
1.33	Delousing technology with the help of tarpaulins	SINTEF	Kåre Tvinnereim

2. Projects financed by the Research Council of Norway's Fish and Animal Health Programme, 1995

2.1	Antibioticv preparations for fish; Pharmacology and effectiveness of treatment	Marine Research Institute	Ole Bent Samuelsen
2.2	Studies of the genetic mechanisms underlying resistance to antibiotics in fish pethogenic bacteria	Dept. of Pharmacology, Microbiology and Food Hygiene, Agricultural University of Norway	Henning Sørum
2.3	The establishment and spread of resistance to antibiotics in fish farms	Univ. of Bergen, Dept. of Microbiology	Øivind Enger
2.4	Diseases of wrasse. Transfer of disease between salmon and marine species	Marine Research Institute	Brit Hjeltnes
2.5	Preventive and integrated treatment of salmon lice	Marine Research Institute	Karin Boxaspen
2.6	Population genetic structure of salmon lice in the North Atlantic 1995 - 97	Univ. of Bergen, Dept. of Fisheries and Marine Biology	Are Nylund
2.7	Effects of variations in host quality on receptivity and consequences of salmon louse infections in salmonids	NINA	Bengt Finstad
2.8	Development of salmon lice at low temperatures	Marine Research Institute	Jens Chr. Holm

3. Projects funded by the Research Programme "Environmental Effects of Aquaculture", 1990 - 1994

3.1	Antibiotics in the marine environment	Marine Research Institute	Arne Ervik
3.2	Effects of chenical therapeutics on the environment around fisah farms	Norwegian Institute of Water Research (NIVA)	Halvor Hektoen
3.3	Relationships among antibiotic-resistant genes	Norwegian College of Veterinary Science	Henning Sørum
3.4	Development and transfer of resistance to antibiotics	Norwegian College of Veterinary Science	Henning Sørum
3.5	Evaluation of the properties of antibiotics in treating salmon	Norwegian College of Veterinary Science	Tor Einar Horsberg
3.6	Ecological effects of antibiotics	Marine Research Institute	Arne Ervik
3.7	Ecological effects of medicines used in aquaculture	NIVA	Halvor Hektoen
3.8	Evaluation of the risk of genetic effects on wild populations	Marine Research Institute	Øystein Skaala
3.9	Genetic influence of escaped cultivated salmon on wild populations	Univ. of Bergen, Dept. of Zoology	Petter Larsson
3.10	Genetic adaptation in salmon populations	Akvaforsk	Hans B. Bentsen
3.11	Genetic effects of escaped cultivated salmon; DNA studies	NINA	Kjetil Hindar
3.12	Identification of escaped cultivated salmon	Univ. of Bergen, Dept. of Chemistry	Otto Grahl-Nielsen
3.13	Monitoring escaped cultivated salmon	NINA	Bror Jonsson

3.14	Monitoring, migration and survival of escaped cultivated salmon	NINA	Lars P. Hansen
3.15	Reproductive threat of cultured salmon to wild populations	NINA	Bror Jonsson
3.16	Reproductive isolation mechanisms between wild and cultivated salmon in nature	NINA	Tor G. Heggberget
3.17	Escaped cultivated salmon	Norwegian Institute of Fisheries Technology	Dag Furevik
3.18	Escaped cultivated fish - effects on wild salmon populations	NINA	Bror Jonsson
3.19	Macroparasites in cod	University of Tromsø	Arne Skorping
3.20	Transfer of disease between salmon and cod	Marine Research Institute	Brit Hjeltnes
3.21	Effects of salmon louse infections from fish farms on wild salmonid populations	Univ. of Bergen, Zoological Museum	Per J. Jakobsen
3.22	Ecological and physiological consequences of lice on salmonids in fjord systems	NINA	Bengt Finstad
3.23	The importance of benthos for the turnover of organic material from aquaculture	Marine Research Institute	Arne Ervik
3.24	Sediment chemistry rehabilitation study of aquaculture sites	Nordland Research Centre	Morten Frogh

4. The State Pollution Control Authority's Programme for Cleaner Aquaculture Technology
Contact person: Kjell Maroni, SPCA/Akva Instituttet, Box 2065, Trondhjem, Norway
Te.: 73514460 Fax: 73514535

	Project no.	Title	Status	SFT Funding (NOK)
4.1	95561	Utilization of organic material and nutrient salts in integrated production of salmon and mussels	Started Dec. 1995	150,000
4.2	95560	Environmentally friendly cleaning of nets in fish farms - continuation of SFT project # 95404	Started	70,000
4.3	95559	Demonstration seacage for closed bag technology with collection of particulate material	Started (continuation of previous project)	232,000
4.4	95558	Cleaning station for organic waste in wastewater from net-washing systems	Started Dec. 1995	550,000
4.5	95556	Nutrition-related disease prevention in fish	Started December 1995	450,000
4.6	95549	Testing and optimization of equipment concepts for treatment of sludge-water from hatcheries	Started December 1995	210,000
4.7	95512	Delousing cultivated salmon with pyrethrum during sorting, withe recirculation of chemicals and collection	Started December 1995	389,000
4.8	95469	Cleaning system for aquaculture nets	Started November 1995	667,150
4.9	95468	Further development of collecting unit for feed and dead fish for Lift-Up Combi	Started November 1995	379,000
4.10	95437	Demonstration and verification of model for production and emission prognoses for salmon farming	Under way	407,500
4.11	95434	Development of sampling instrument for seabed samples	Under way	164,000
4.12	95404	Environmentally friendly cleaning of nets in fish farms	Under way	35,000
4.13	95330	Environmental handbook for fish-farming; additional funding	Under way	30,000
4.14	95326	Demonstration of new concept for handling and washing fish-farm nets	Under way	300,000

4.12	95404	Environmentally friendly cleaning of nets in fish farms	Under way	35,000
4.13	95330	Environmental handbook for fish-farming; additional funding	Under way	30,000
4.14	95326	Demonstration of new concept for handling and washing fish-farm nets	Under way	300,000
4.15	95269	Mussel farming as a method of improving recipients	Under way	343,000
4.16	95250	Information film on salmon lice and environmentally friendly methods of combatting infections	Under way	100,000
4.17	95215	Efficient feeding - demonstration of methods for optimal feeding without waste	Under way	40,000
4.18	94702	Small land-based fish-farms	Under evaluation	1,020,000
4.19	94672	Environmental handbook	Under way	60,000
4.20	94662	Delousing during sorting using pyrethrum	Completed	125,000
4.21	94661	Protein quality in feeds	Final report in preparation	250,000
4.22	94597	Trials of OKADORA process for utilization of fish-processing waste	Final report in preparation	700,000
4.23	94565	Trials and optimization of an equipment concept for treatment of sludge-water from hatcheries	Under way	350,000
4.24	94417	New antifouling agent	Completed	100,000
4.25	94416	Demonstration system for mechanical dewatering of hatchery sludge	Completed	260,000
4.26	94370	Pellet collection system for floating closed system	Under way	652,000
4.27	94249	Demonstration of the importance of temperature for the effect of different types of vaccine on cold-water vibriosis.	Completed	200,000
4.28	94182	Development of an efficient delousing bag for cultivated salmon	Completed	144,000

4.29	94121	The use of sea urchins to reduce fouling of nets; part 2	Final report in preparation	40,000
4.30	94029	Particle trap for hatcheries	Completed	400,000
4.31	93703	Keeping Costia spp. parasites under control	Final report in preparation	98,000
4.32	93639	Breakdown of antibiotics in silage	Completed	710,000
4.33	93620	Pellet collection system for floating closed system; pilot study	Completed	100,000
4.34	93545	Transport of wrasse: II	Completed	25,000
4.35	93537	The use of sea urchins to reduce fouling of nets; part 1	Completed	25,000
4.36	93504	New models of feeding	Completed	2,100,000
4.37	93390	Environmental analysis and operational experience of closed aquaculture plants in open sea	Completed	499,700
4.38	93389	Demonstration system for land-based operation	Completed	750,000
4.39	93386	Transport of wrasse I	Completed	100,000
4.40	93361	Sludge removal from land-based fish farms; introductory tests	Completed	80,000
4.41	93334	Filtration efficiency of Sobye EMiljøfilter in conjunction with Lift-Up Combi collector for feed and dead fish	Completed	90,000
4.42	93258	Healthy feeeds for smolt	Completed	224,246
4.43	93255	Biofish - final phase	Completed	50,000
4.44	93253	Prolonged production of fry	Incomplete	100000
4.45	93252	Feeding station	Completed	400,000
4.46	93164	Hydroacoustic control of feeding medicine dosing	Under way	1,000,000
4.47	93157	Demonstration effect of internal control	Completed	39,000

4.48	93030	Wrasse II	Under way	61,000
4.49	93014	Wrasse I	Completed	140,000
4.50	93013	High-energy feeds - final feeding	Completed	250,000
4.51	93010	Salmon cultivation in closed sea-cagte (Giga-cage); demonstration system	Completed	600,000
4.52	92488	Environmental feeds; phase 2	Completed	685,000
4.53	92328	Lift-Up Combi collecting unit for feed and dead fish	Completed	600,000
4.54	92232	Washing nets as an alternative to impregnation	Completed	25,000
4.55	92057	Toxicity testing of antibiotics	Completed	76,000
4.56	91136	Environmental feed, phase 1	Completed	1,400,000
4.57	91112	Lift-up, phase 2	Completed	650,000
4.58	90481	Cleaning emissions from hatcheries	Completed	1,615,000
4.59	90450	Behaviour-based feeding	Completed	100,000
4.60	90449	Lift-up, phase 1	Completed	75,000
4.61	90252	Biofish	Completed	300,000
4.62	90251	Cleaning systems for land-based fish farms	Completed	900,000

SFT's Programme for Cleaner Aquaculture Technology: Summary financial table

Area	SFT MNOK	SFT %	Industry MNOK	Industry %
Antibiotics	3.377	12.6	6.969	15.6
Feeds and feeding	9.120	34.11	18.074	40.4
Chemicals	2.502	9.36	4.057	9.07
Closed systems and cleaning	8.931	33.4	13.140	29.3
Information	0.194	0.73	0.570	1.14
Miscellaneous	2.614	9.78	1.983	4.43

Appendix 5

Chemical usage
Coastal zone issues
Diseases
Environmental impact issues (except chemicals and exotics)
Exotic species, escapees, GMOs, ballast water and ship hull issues
Integrated aquaculture systems
Modelling
Species interactions
Toxic algae, algal blooms
Waste water treatment

SELECTED BIBLIOGRAPHY OF PUBLICATIONS AND REPORTS RELATED TO THE IMPACTS OF FISH FARM THERAPEUTANTS ON SEDIMENTS

The Working Group has over the years collected the relevant literature related to environmental issues of mariculture. The data base has grown substantially. Often partial abstracting had been undertaken to facilitate the background information available to the working group for indepth discussion. It is intended to continue the data collection with the aim to produce in the near future (1-2years) a comprehensive search profile for relevant environmental and management mariculture issues, including integrated coastal zone management aspects. This should facilitate easy access to the relevant literature and its content, in particular for those groups who try to analyse trends in aquaculture development and environmental management, as recently has been done through EU contracts.

Chemical usage

Alderman, D.J., 1991. Malachite green and alternatives as therapeutic agents. pp. 235 -244. In: De Pauw, N., Joyce, J. (Eds.). "Aquaculture and the Environment. European Aquacult. Soc. Spec. Publication 16.

Alderman, D.J., Clifton-Hadley, R.S., 1993. Malachite green: a pharmacokinetic study in rainbow trout, Oncorhynchus mykiss (Walbaum). J. Fish Dis. 16: 297-311.

Anonymous. 1994: Antibiotiques en elevage intensif. European Symposium on antibiotics and intensive farming, Oct. 25-27, 1994. Published by ISPAIA (Institut Superieur des Productrons Animales Agro-alimentaires). Ploufragan, France

Bailey S.K., and I.M. Davies, 1991. Continuing impact of TBT, previously used in mariculture, on dogwhelk (Nucella lapillus L.) populations in a Scottish sea loch. Mar. Env. Res., 32, 187-200.

Bailey, S.K., I.M. Davies, M.J.C. Harding, and A.M. Shanks, 1992. Effects of tributyltin oxide on the dogwhelk Nucella lapillus (L.). Proc 10th World Meeting of ORTEP Association, Berlin, Sept 26/27 1991, pp 1-66.

Barnes, A.C., Hastings, T.S., Myes, S.G.B. 1994. Amoxycillin resistance in Scottish isolates of Aeromonas salmonicida. J. Fish Dis. 17: 357-363.

Carr, W.H., Brock, J.A., Swingle, J.S. 1995. An experimental trial of oxytetracycline as a therapy for black spermatophore disease in Penaeus vannamei. J. Aquat. Animal Health 7: 331-336. The efficancy of oxytetracycline was assessed as a potential therapy for male reproductive tract syndrome in a population of 160 previously affected, pond-reared adult Peneaus vannamei. All animals were individually tagged and the severity of disease was assessed grosly 2 weeks before, during, and 4 weeks after feed medicated with oxytetracycline hydrochloride was administered. Bacterial cultures indicated that more Vibrio p. were isolated from animals with melanied spermatophores thatn from animals with normal spermtophores at the same site. Vibrio alginolyticus was the most common bacterial isolate and the bacterial isolates were sensitive to oxytetracycline. A t-test analysis of the mean lesion severity scores showed no significanct difference between the control animals and animals that received the medicated feed. A significant difference in severity scores among designated severity groups (low, medium, high: $p < 0.01$) was maintained throughout the experiment. Overall, the trend in all severity groups was a gradual increase in severity over time. These results suggest that this case of male reproductive tract syndrome was not responsive to oxytetracycline therapy. In addition, these results provide further evidence of a noninfectious primary etiology.

Coyne, R. and Smith, P. (1996). Quantitation of sediment loading by oxytetracycline under a marine salmon farm. Proceedings of Euroresidue 111, Utrecht (Submitted). The distribution of oxytetracycline in the sediment under a marine salmon farm was established by HPLC analysis of diver collected cores. The sampling grid employed in the survey allowed the extent of both the vertical and horizontal distribution to be established. The oxytetracycline was confined to the top 8 cm of the sediment and to an area approximately twice the area of the cage block. After an allowance was made for the current speed a clear relationship was evident between the amount of oxytetracycline used in individual cages and the concentrations detected in the sediments under these cages. These data have been used to provide an estimate of the total amount of oxytetracycline that was present in the sediment after 10 days of therapy. After 146 kg of oxytetracycline had been administered to the fish the total amount of oxytetracycline in the sediment was 1.4 kg or

approximately 1% of the total input. The data obtained in this survey on the ratio of peak sediment concentration to the average input per cage is similar to the data produced in 12 of 13 studies of the fate of oxytetracycline in marine salmonid farms. It is argued that these data strongly suggest that the majority of oxytetracycline administered at these farms is not deposited on the sediment.

Coyne, R., Hiney, M. and Smith, P. (1994). Evidence associating overfeeding on a salmon farm with a prolonged half-life of oxytetracycline in under-cage sediments. Bulletin of the European Association of Fish Pathologists 14, 207- 210.

A survey of the persistence of oxytetracycline was performed at a fish farm that had been studied on two previous occasions On this third occasion a very significant increase in the persistence of oxytetracycline was recorded A set of limited anecdotal. and non-quantitative data is presented that is consistent with the hypothesis that sediment oxygen concentrations may be significant in determining persistence. The hypothetical chain of events that led to an increase in the half-life of oxytetracycline involved an outbreak of pancreas disease which resulted in over presentation of feed This in turn resulted in reduced sediment oxygen concentrations and a consequent reduction in the extent of bioturbation mediated by polychaete worms The data also suggests that current speed and farm hydrography may not be dominant factors in determining persistence

Coyne, R., Hiney, M. P., O'Connor, B., Kerry, J., Cazabon, D. and Smith, P. (1994). Concentration and persistence of oxytetracycline in sediments under a marine salmon farm. Aquaculture 123, 31-42. The concentration of oxytetracycline in the sediment under two adjacent cage blocks in a marine salmon farm was determined following the therapeutic use of the drug. The sediment cores were grey, indicating some build up of organic material. Infaunal polychaetes were present as were mobile fauna including crabs, starfish and flat fish. There were no significant accumulations of undigested feed pellets under the cages. At one block where 186 kg oxytetracycline was used over 10 days the oxytetracycline concentrations were determined under a single cage that received 8.65 kg oxytetracycline during the treatment. Peak concentrations in the top 2 cm of the sediment were 9.9 2.9 g g-1. This declined at an exponential rate (r2= 0.99) with a half life of 16 days. At the second block the oxytetracycline concentration was measured with a sampling programme designed to determine the horizontal and vertical distribution of oxytetracycline under the whole cage block during, and after a treatment where 175 kg of oxytetracycline were used over 12 days. Peak concentrations, in the top 2 cm of the sediments under the cage block, were 10.9 -6.5 g g-1 and this declined at an exponential rate (r2= 0.99) with a half life of 13 days. Nineteen days after the end of the therapy oxytetracycline was detected at depths of up to 8 cm in the sediment but the concentration of the antibacterial agent had decreased at all levels in the sediment 14 days later. At the end of the treatment oxytetracycline was detected in an area of the sediment less than twice the area of the cages themselves. Data on current flow and sedimentation rate were used to generate a predictive model of the area of sediment that would be subject to the deposition of both pelleted fish feed and fish faeces. Oxytetracycline was confined to the area of sediment predicted to be subject to feed deposition that was directly under and slightly to the west of the cage block. Oxytetracycline was not detected in the area predicted to be subject to faecal deposition only.

Davies I M, 1995. Pesticide usage in marine fish farming - the role of the chemist. Proc. Roy. Soc Chem, in press.

Fowler, L.G., Banks, J.L., 1990. Iodophor Toxicity to Eggs and Fry of Fall Chinook Salmon. Prog. Fish-Cult. 52(3): 176-178. Eggs of fall chinook salmon (Oncorhynchus tshawytscha) were treated for 30 min during the water-hardening stage with an iodophor containing 75 mg active iodine/L. The treatment significantly increased total mortality of eggs and fry. Water hardening of eggs in water for 30 min and then in the iodophor for 30 min also increased mortality.

Gerundo, N., Alderman, D.J., Clifton-Hadley, r.S., Feist, S.W. 1991. Pathological effects of repeated doses of malachite green: a preliminary study. J. Fish Diseases 14: 521-532. This stuy reports the histopathological observations made upon the livers and gills of rainbow trout exposed to a continuing series of exposures to 1.6 ppm 40 min baths of malachite green at weekly intervals. Afteer the third week of exposure, sinusoidal congestion and focal necroses were evident on the livers. At the ultrastructural level, consistent mitochondrial damage was evident with swelling and disruption of the cristae, together with dilation of the rough endoplasmic reticulum. Nuclear alterations increased in severity in the later periods of exposure. However, these hepatic changes were not severe enough to be reflected in serum protein changes. In the gills of treated fish, separation of the epithelial lining from both lamellar and interlamellar regions was noted and lamellar cell necrosis and leuccyte infiltration became more frequent with increased exposure.

Gilderhus, P.A., Lemm, C.A., Woods III, L.C., 1991. Benzocaine as and Anesthetic for Striped Bass. Prog. Fish-Cult. 53(2): 105-107. Benzocaine was tested as an anesthetic on juvenile and mature adult striped bass *(Morone saxatilis).* Concentrations of 55 mg/L at 22°C to 80 mg/L at 11°C effectively anesthetized fish in about 3 min. Recoverey was more rapid as temperature increased. Fish survived concentrations of twice the effective concentration and exposure times up to 60 min at the effective concentration. Striped bass required higher concentrations for

anesthetization than had been previously demonstrated for salmonid fishes, but safety margins for both concentration and exposure time were wider than for the salmonids.

Granops,-M.; Kolman,-R. 1989. Preliminary studies on the effect of the disinfectants used in fish culture upon the effectiveness of the diatomic water filters. ROCZ.-NAUK-NOLN.-SER.-H-RYBACTWO. 1989. vol. 102, no. 2, pp. 7-13. Results are presented on the effect of malachite green, formalin and salt solutions upon the diatomic biological water filters. The disinfectants used in fish culture did not disturb the efficiency of the water filter. On the other hand, 1% salt solution increased sorptive abilities of the diatomite substrate with respect to ammonia.

Henderson-Arzapalo, A., Lemm, C., Hawkinson, J., Keyes, P., 1992. Tricaine used to separate phase-I striped bass with uninflated gas bladders from normal fish. Prog. Fish-Cult. 54(2): 133-135. Tricaine (MS-222) was used to separate striped bass (Morone saxatilis) with uninflated gas bladders from normal fish. Pond-reared, phase-I striped bass (19-71 mm total length) were anaesthetized in a 12.5% saltwater solution containing 110-123 mg MS-222/L. Fish with inflated gas bladders were neutrally buoyant or floated, whereas fish with uninflated gas bladders remained on the bottom. Dissection of buoyant and nonbuoyant fish indicated the procedure was 90-100% accurate. Eliminating fish with uninflated gas bladders will improve efficiency and quality of phase-II production.

Hiney, M. P., Coyne, R., Kerry, J., Pursell, L., Samuelsen, O. B. and Smith, P. (1995). Failure of Flumisol bath treatments during commercial transport of salmon smolts to prevent the activation of stress inducible furunculosis. Aquaculture 136, 31-42. This paper reports the development of protocols for the bath administration of flumequine to Atlantic salmon (Salmo salar L.) smolts during their transfer from a fresh water hatchery to a marine farm in buckets suspended under a helicopter. The fish were treated at a density of 365 kg m 3 in water of pH 6.3 and hardness 13.2 mg/l CaCO3. Serum flumequine concentrations showed a linear increase with respect to time of the bath and were dose dependent. The addition of benzocaine to the baths had little effect on uptake during the first 20 min of the bath. 720 000 smolts with covert stress inducible furunculosis were transported to 20 sea cages during 180 helicopter trips in buckets containing 100 g/ml flumequine and 5.7 g/ml benzocaine. Furunculosis was detected in fish in all sea cages shortly after transfer and the treatment was considered to have failed to control the activation of the covert infections. The pharmacokinetics of flumequine were determined in fish that were introduced to sea water at the termination of a bath treatment in fresh water. This data was compared to that obtained from fish that remained in fresh water following a similar treatment. The introduction of the fish into sea water resulted in a very rapid excretion of flumequine via the intestine. It is argued that this rapid elimination of the antimicrobial agent may have been an important factor in the failure of the bath treatment under commercial conditions.

Hiney, M., Samuelsen, O. B.., and Smith, P. R. (1994). Association of mortalities in a salmon hatchery with the oral administration of flumequine. Bulletin of the European Association of Fish Pathologists 14, 204-206.

Jobling, S., Reynolds, T., White, R., Parker, M.G., Sumpter, J.P. 1995. A Variety of Environmentally Persistent Chemicals, Including some Phthalate Plasticizers, are Weakly Estrogenic. Environmental Health Perspective, vol. 103, no.6 (1995)

Kane, A.S., Johnson, D.L., 1989. Use of TFM (3-Trifluoromehtyl-4.Nitrophenol) to Selectively Control Frog Larvae in Fish Production Ponds. Progr. Fish-Cult. 51(4): 207-213. The efficacy of TFM (3-trifluoromehtyl-4-nitrophenol) for the selective control of frog larvae in fish culture ponds was examined. Mortalities of frog larvae and fathead minnows (pimephales promelas) in exposure cages as well as end-of-season standing crops were used to quantify the selective effects of TFM in three treatment ponds, A, B, and C. The chemical was completely effective in controlling frog larvae in treated ponds A and B; no tadpoles were recovered after treatment. These ponds were filled just before the study. The standing crop of tadpoles in the untreated control pond, which was also filled just before the study, was 219,7 kg/hectare. Treatment of pond C, which was filled throughout the year and had an established population of older, larger tadpoles before TFM application, was not effective, leaving 243,3 kg frog larvae per hectare). Exposure-cage mortalities of frog larvae ranged from 22.0 to 95.0%. Failure to kill all frog larvae was most likely due to insufficient TFM concentration for the life stage of the tadpoles treated. The half-life of TFM was 10.3 d in ponds A and B, and 20.1 d in the more sediment-laden pond C. No stratification of the toxicant was observed in any of the ponds. Results indicate that TFM effectively controls infestations of frog larvae if applied to ponds when the tadpoles are relatively young or newly hatched. Application of TFM will probably not selectively control tadpoles at older life stages.

Kapetanaki, M., Kerry, J., Hiney, M., O'Brien, C., Coyne, R. and Smith, P. (1995). Emergence, in oxytetracycline-free marine mesocosms, of microorganisms capable of colony formation on oxytetracycline-containing media. Aquaculture 134, 227-236.

Tanks (39 cm x 30 cm x 27 cm) containing marine sediment overlaid with various amounts of

sterilised commercial fish food pellets and sea water were used to study the emergence of microorganisms capable of forming colonies on TSCA media in both the presence and absence of 25 g/ml oxytetracycline. All experimental systems were free of oxytetracycline. Initial levels of culturable organisms in the sediments used in these experiments were 7.1 x 104 cfu/g of which 0.2% were capable of growth on the oxytetracycline-containing agar. In tanks containing no feed, the number of resistant cfu/g increased slightly, from 1.8 x104 to 5.1 x 104 cfu/g, over 70 days incubation at 8.5 - 12 oC. In the tank containing low levels (1-2 cm depth) of feed, the increase in resistant organisms was from 4.9 x 103 to 2.3 x 104 cfu/g. There was no significant increase in the relative size of the resistant sub-population in either tank. In the tank containing high levels (16-17 cm depth) of fish feed, the levels of oxytetracycline-resistant cfu's/g rose from below the limit of detection (<5 x 101) to 1.9 x 108 and their relative abundance rose to 34% by the end of the experiment (t = 70 days). The resistant flora isolated from the tanks with high levels of feed were characteristically slow-growing and resistant to high levels (>512 g/ml) of oxytetracycline. Over 50% of these strains were insensitive to oxolinic acid, cotrimoxazole and furazolidone, but the frequency of sensitivity to ampicillin and chloramphenicol was high. In contrast, the flora isolated from the sediment used in all tanks exhibited more rapid growth and lower levels of resistance to oxytetracycline. These strains were more frequently sensitive to the other antimicrobial agents.

Kerry, J., Coyne, R., Gilroy, D. and Smith, P. Spatial distribution of oxytetracycline and elevated frequencies of oxytetracycline resistance in sediments beneath a marine salmon farm following oxytetracycline therapy. Aquaculture (Submitted).

The concentrations of oxytetracycline and the frequencies of oxytetracycline resistant microorganisms were determined in 11 samples taken from the sediments in the vicinity of a block of fish cages at a marine salmon farm. The cage block contained 10 tonnes of Atlantic salmon smolts and a total of 20 kg of oxytetracycline were administered during the 12 day treatment. Samples cores were collected by divers five days after the end of the period of therapy and the top 2 cm of each core was analysed. HPLC analysis was able to quantify the oxytetracycline concentrations in 3 of the 6 samples taken directly under the cage block. The mean concentration under the cage was between 0.65 and 1.2 g/g (n=6) depending on the values attributed to samples where the concentrations were below the level of quantitation (1.2 g/g). In the 5 samples taken from locations not directly under the cage block oxytetracycline was only detected in the sample taken adjacent to, and down current from, the cage block. This sample was collected 10 m to the west of the cage block and contained 4.2 g/g oxytetracycline. These data indicate that oxytetracycline was confined to an area of the sediment which was smaller in extent than the area of the cage block itself. The frequencies of resistance to oxytetracycline in the microflora cultured from the samples were determined by differential plating on 2216V media, containing 25 and 100 g/ml oxytetracycline. Analysis of eighty three samples from sites free of overt human influence demonstrated that the background levels of resistance at these two selection concentrations were 1.0 1.3 % and 0.4 0.6 %, respectively. Elevated frequencies of resistance were detected in samples from a wider area than the cage block. The median frequency of resistance in the samples (n=6) taken from directly under the cage block was 1.4 % at 100 g/ml and 5.3 % at 25 g/ml. In the samples (n=5) taken from outside the cage block the frequencies were 5.3 % at 100 g/ml and 8.5 % at 25 g/ml. There was no correlation between the concentration of oxytetracycline in a sample and the frequency of resistance that was determined in the culturable microflora in that sample.

Kerry, J., Gilroy, D., Hiney, M., Coyne, R. and Smith, P. (1995). The effects of harrowing on oxytetracycline resistance in marine sediment microorganisms beneath a salmon farm. Bulletin of the European Association of Fish Pathologists 15, 172-175.

An investigation was conducted into the effects which the process of harrowing sediments, beneath marine fish cages, had on the oxytetracycline resistance frequencies in microorganisms in those sediments. The results obtained demonstrates that a significantly elevated frequency of oxytetracycline resistance occurred 4 days after harrowing. The resistance frequency determined 11 days post-harrowing was not significantly different from the oxytetracycline resistance frequency determined prior to the start of harrowing. The oxytetracycline residues in the sediments at the site investigated were below the limit of quantitation of the HPLC method used (1.2 g/g). The very limited data obtained pertaining to the area of sediment affected suggests that harrowing may have an impact on the microflora over an area significantly larger than that actually harrowed.

Kerry, J., Hiney, M., Coyne, R., Cazabon, D., NicGabhainn, S., and Smith, P. (1994). Frequency and distribution of resistance to oxytetracycline in microorganisms isolated from marine fish farm sediments following therapeutic use of oxytetracycline. Aquaculture 123, 43-54.

The background level of resistance to oxytetracycline in sediments free of anthropogenic influences was determined on 2216 V agar with 25 g/g oxytetracycline. The mean frequency of resistance in 153 samples taken in Galway Bay was 1.2 + 1.8%. The impact of oxytetracycline therapy on the frequency of resistance in the sediments under a marine fish farm was investigated on two occasions. In the first investigation. oxytetracycline was detected at a concentration of 9, 9 ± 2,9 g/g in the sediments under a cage that received 865 g oxytetracycline per day for 10 days, but no significant rise in resistance frequency was detected. In the second investigation. oxytetracycline was detected at a concentration of 10.9 ± 6.5 , g/g in the sediments under a cage block that received 175

kg oxytetracycline over 12 days. The frequency of resistance reached 16.0 ±8.9% after the treatment. The frequency declined at an exponential rate(r-=0.89)with a half-life of 26 days. At 73 days after the end of therapy the frequency, in under-cage samples, was not significantly higher than the background level. At the end of the therapy elevated frequencies of resistance were detected up to 75 m from the edge of the cage block and in samples where the levels of oxytetracycline were below the limit of detection (1.2 g/g) . Thirty-three days after the end of the therapy the frequency of resistance in all samples not directly under the cages was not significantly higher than in samples taken from sediments tree of anthropogenic influence.

Kerry, J., Hiney, M., Coyne, R., NicGabhainn, S., Gilroy, D., Cazabon, D. and Smith, P. (1995). Fish feed as a source of oxytetracycline resistant bacteria in the sediments under fish farms. Aquaculture 131, 101-113. Concentrations of oxytetracycline and the frequency of oxytetracycline resistance in the environmental microflora were monitored following the therapeutic use of this agent at a marine fish farm. 529 kg of oxytetracycline were administered over a 24 day period at an average of 1.4 kg per cage per day. Three days after the end of the therapy 4.6 ±3.7 g/g oxytetracycline were detected in the sediments and the frequency of resistance in the sediment microflora was 9.0 ±5.3 %. A rise in the frequency of resistance in this flora to 26± 8.7 % occurred twenty four days after the therapy. This rise was not associated with any increase in the concentrations of oxytetracycline in the sediment. At this time the frequency of resistance in the flora isolated from mussels suspended above the sediments (36 8.5 %) was significantly (P= 0.005) higher than that present in the sediment flora. The feed used on the farm twenty four days after the end of therapy was shown to contain 4.6 x 104 oxytetracycline resistant cfu/g. The distribution of phenotypic groups in the oxytetracycline resistant flora in this feed and in the sediments during the peak in resistance were compared with those from other marine environments. These data demonstrated that resistant flora in feed can, under certain circumstances, significantly contribute to the resistant flora detected in sediments under fish cages.

Kerry, J., Slattery, M., Vaughan, V. and Smith, P. 1996. The importance of growth rate in the performance of laboratory simulations of oxytetracycline-HCl impact on marine sediment processes. Aquaculture (Accepted for publication). Small scale microcosms were used to investigate the impact of oxytetracycline-HCl on both the metabolic activity and the emergence of elevated frequencies of resistance in marine sediment microflora. The microcosms were designed to simulate the environment of sediments found under fish farms and included marine mud, fish feed and sea water. In these microcosms the sediment was the most significant source of metabolically active bacteria and the feed provided the major substrate. Metabolic activity was monitored via measurements of increased gas pressure in the sealed microcosms. The frequency of resistance was monitored by differential plate counts on 2216 V media with and without 25 g/ml oxytetracycline-HCl. After a 2 - 3 day adaption phase all microcosms entered a steady-state phase during which the increase in gas pressure was linear with respect to time. The addition of oxytetracycline-HCl (0.1 - 600 g/g) resulted in an increase in the length of the adaption phase but had no effect on the rate of gas pressure increase in the steady-state phase. The frequency of oxytetracycline resistant colony forming units was determined after 194 hours incubation of the microcosms. The frequency in microcosms containing over 25 g/g was >90 %, in those containing 6.25 g/g or less the frequency was < 7 %. Investigations revealed that there was a rapid increase in cell numbers only during the first 2 -3 days of the incubation and that the majority of the increase in resistance frequency occurred during this time. If the addition of oxytetracycline-HCl was delayed until after 3 days incubation little selection for increased resistance frequency occurred. These data are compared with the data from other microcosm studies of the impact of oxytetracycline on marine sediment processes. It is suggested that the rate of cell division achieved in such systems is a critical parameter determining the results that they generate.

Klaver A L, and R A Matthews, 1994. Effects of oxytetracycline on nitrification in a model aquatic system. Aquaculture 123, 237 - 247. Experiments were conducted in 9 litre aquaria containing synthetic freshwater, sand substrate and active cultures of the nitrifying bacteria Nitrosomonas and Nitrobacter. The water contained initially 5 mg/l NH3-N. Nitrification was inhibited at all levels of OTC tested (12.5 - 75 mg/l). At 50 - 75 mg/l, there was nearly complete inhibition of nitrification within 7 days. 95% confidence limits for a 7 day EC50 were estimated at 8.6 - 27.0 mg/l OTC. The potential for doisrupting nitrification, which could lead to a build-up of toxic ammonia and nitrite, should be considered by aquaculturists treating diseased fish.

MAFF (Veterinary Medicines Directorate) 1996: Ecotoxicity testing of medicines intended for use in fish farming. AMELIA 11(Guidance Note): 1-31.

Marking,-L.L. 1991. Development of carbon filtration systems for removal of malachite green. FISHERIES-BIOENGINEERING-SYMPOSIUM. Colt,-J.;White,-R.J.-eds. American-Fisheries-Soc.,-Bethesda,-MD-USA.-Bioengineering-Sect. BETHESDA,-MD-USA AFS 1991. no. 10 p. 427. ISBN 0-913235-72-5. The U.S. Fish and Wildlife Service was granted an Investigational New Animal Drug permit (INAD number 2573) by the U.S. FDA to allow the use of malachite green at selected state and federal fish hatcheries.

However, the INAD permit requires that the fungicide be removed from all treated water after March 1989. A study was designed to (1) determine the type of filter and kind of carbon that was most efficient and (2) demonstrate that carbon filters can be used to remove malachite green from water used for egg incubation or to hold adult salmon before spawning. Minicolumn simulation studies showed that 8 x 30-mesh granular carbon was effective for continuously removing malachite green from water for 230 d at a flow rate of 500 gal/min and for only 62 d at a flow rate of 1,000 gal/min. The removal capacity at the slower flow rate was 69 mg of malachite green per gram of carbon. A filter system that contained 20,000 lb of activated carbon in each of two chambers was effective for removal of malachite green from treated water in adult salmon holding ponds at flows of 500 gal/min (6.4 gal/min per ft super(2)) and greater.

McHenery J G, C Francis and I M Davies, 1995. Threshold toxicity and repeated exposure studies of dichlorvos to larvaè of the common lobster (Homarus gammarus L.). Aquatic Toxicology, in press.

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

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

Mitchell, A.J. 1995. Importance of treatment duration for Praziquantel used against larval digenetic trematodes in sunshine bass. J. Aquat. Animal Health 7: 327-330.

The effectiveness of praziquantel (Droncit) against yellow grubs Clinostomum complanatum and unidentified, encysted larval nematodes was tested in infected sunshine bass Morone chrysops female x M. sacatilis male. Praziquantel treatment significantly reduced the total numbeer of live grubs in the fish in most treatment regimes tested. Treatment at 0.25 mg/L for 24 h was as effective as one at 8 mg/L for 8 h. Mature dead and dying metacercaria may have released toxins that killed host fish in some treatments.

Nevenka, M., Brancia, M., Wang, Y., Harrison, R.M., 1996: Organolead compounds in mussels (Mytilus Galloprovincalis) from the eastern adriatic coast. Environ. Sci. Technol., 30: 499-508.

P G Provost, K D Black, I M Davies and P A Read, 1996, in press. Antibiotics in Scottish fish farm sediments. Proceedings of 3rd International Conference on Environmental Pollution, (ICEP'95), St Petersburg, Russia.

Pursell, L. and Smith, P. (1994). In vitro experiments on the bioactivity of flumequine in the matrix of the intestinal contents of Atlantic salmon. Bulletin of the European Association of Fish Pathologists 14, 141-143. This paper presents an in vitro investigation of the biological activity of flumequine in the environment of the intestinal contents of Atlantic salmon reared in marine fish farms. The data demonstrates that the activity of flumequine against the A. salmonicida strains used in these experiments was significantly lower than that detected in standard laboratory media. MBCs determined in vitro in intestinal contents were well in excess of maximal intestinal concentrations expected from a standard oral therapeutic dose of 12 mg flumequine/kg body weight. After l4 hours incubation in intestinal contents the percentage bioactivity of flumequine was determined to be 0.3% when MBC data were considered and 3.1% when MIC data were used. It is argued that the use of MIC and MBC data derived under standard laboratory conditions cannot be used to determine the significance of inteslinal concentrations of flumequine during therapy especially when these concentrations have been determined by methods of analysis such as HPLC

Pursell, L., Dineen, T., Kerry, J., Vaughan, S. and Smith, P. 1996. The biological significance of breakpoint concentrations of oxytetracycline in media for the examination of marine sediment microflora. Aquaculture (Submitted).

Comparative methods were employed to investigate the relative biological activity of oxytetracycline in two media that have been used in studies of the frequency of oxytetracycline resistance in marine sediments associated with fish farms. Tryptone Soya Citrate Agar (TSCA) which has been used in Norwegian studies and 2216V agar which has been used in Irish studies were chosen for investigation. Using a nominal breakpoint concentration of 25 g/ml oxytetracycline and identical incubation conditions higher total numbers and significantly lower frequencies of resistance were detected in ten samples of a non-fish farm marine sediment when 2216V media were used. 57 of 60 colony forming units, originally isolated on 2216V agar containing 25 g/ml oxytetracycline were capable of forming colonies on TSCA. Of these all could also form colonies on TSCA containing 25 g/ml oxytetracycline. In contrast only 37 of 60 colonies originally isolated on TSCA containing 25 g/ml oxytetracycline were capable of colony formation on 2216V agar and of these only 70% were capable of colony formation on this media containing 25 g/ml oxytetracycline. The minimum inhibitory concentrations (MIC) of oxytetracycline against ten bacteria were established in Mueller Hinton Agar, TSCA and 2216V agar. MIC values were consistently higher when determined on both TSCA and 2216V

agar but the extent of the increase showed significant strain to strain variation. These data indicate that it is not possible to arrive at a universally applicable value for the biological activity of oxytetracycline in these agar media. The significance of the inhibition of oxytetracycline activity in media that have been used to investigate the environmental impact of the use of this agent in marine fish farms is discussed.

Pursell, L., Samuelsen, O. B. and Smith, P. (1995). Reduction in the in-vitro activity of flumequine against Aeromonas salmonicida in the presence of the concentrations of Mg++ and Ca++ ions found in sea water. Aquaculture 135, 245-255. The effect of an ionic representation of sea water on the kinetics of inhibition and killing of Aeromonas salmonicida isolates by flumequine was investigated. The minimum inhibitory concentration (MIC), the minimum bactericidal concentration (MBC) and the percent bioactivity all varied with respect to time. The concentration of flumequine required to inhibit growth over 24 hours was 4 g/ml in Tryptone Soya Broth (TSB) and 128 g/ml in the same medium supplemented with sea water ions. The concentrations required to inhibit growth over 72 hours were higher; 16 g/ml and 256 g/ml respectively. This increase in the MIC over time was shown to be due to the emergence, during the assay, of cells with elevated resistance to flumequine. These strains also showed reduced sensitivity to a number of unrelated antimicrobial agents. The MBC of flumequine at 24 hours was 16 g/ml in Tryptone Soya Broth (TSB) and 2048 g/ml in the same medium supplemented with sea water ions. At 72 hours the MBC determined in TSB increased to 32 g/ml, and in media supplemented with sea water ions the MBC decreased to 256 g/ml. Thus the percentage reduction in the bioactivity of flumequine resulting from the presence of sea water ions varied not only with time but also with respect to whether MIC or MBC data was considered. There was no effect by sea water or sea water ions on the HPLC assay of flumequine over the range 1 - 4,096 g/ml. It is argued that HPLC analysis will necessarily overestimate the concentrations of biologically active flumequine in the marine environment. The data presented in this paper indicates some of the factors that must be considered in the design of a valid and relevant biological assay of flumequine in this environment.

Ringle, J.P., Nickum, J.G., More A., 1992. Chemical separation of Channel catfish egg masses. Prog. Fish-Cult. 54(2): 73-80. Chemical methods were developed and evaluated for dissolving the matrix surrounding eggs of channel catfish (Ictalurus punctatus), which permits eggs to be incubated in cylindrical jars. Screening tests identified several dissolving agents, and four solutions appeared most suitable: (1) 1.5% Na2SO3; (2) 1.5% Na2SO3 plus 0.2% papain; (3) 1.5% L-cysteine-HCl plus 0.2% papain; and (4) 1.0% Na2SO3, 0.5% L-cysteine-HCl plus 0.2% papain. Production-level testing on whole egg masses demonstrated that hatching success of channel catfish eggs chemically separated and incubated in jars averaged 20.5% higher than with traditional trough-and-paddle incubation methods. No significant differences in fry deformities or survival were found amoung the nine treatments and controls. A trend toward higher percent hatch and higher fry viability was detected when eggs were separated from medium-sized egg masses (601-900 g) more than 24 h after the eggs were spawned. Chemical separation of eggs reduced fungal disease problems and labor associated with egg incubation. This process has been used for several years in a variety of cultural situations. Other fish species with adhesive eggs have been successfully incubated with variations of this technique.

Roth,-M.; Richards,-R.H.; Sommerville,-C. 1992. Preliminary studies on the efficacity of two pyrethoid compounds, resmethrin and lambdacyhalothrin, for the treatment of sea lice (Lepeophtheirus salmonis) infestations of Atlantic salmon (Salmo salar) FIRST-EUROPEAN-CRUSTACEAN-CONFERENCE,-PARIS,-AUGUST-31-SEPTEMBER-5,-1992,-ABSTRACTS.#PREMIERE-CONFERENCE-EUROPEENNE-SUR-LES-CRUSTACES,-PARIS,-31-AOUT-5-SEPTEMBRE-1992,-RESUMES. Museum-Natl.-d'-Histoire-Naturelle,-Paris-France PARIS-FRANCE MNHN 1992 p.129.

Two pyrethroid pesticides, resmethrin and lambdacyhalothrin, were tested in the laboratory for their efficacy (% reduction in numbers of lice/fish) in the treatment of sea lice, Lepeophtheirus salmonis, infestations of lice infected Atlantic salmon, Salmo salar. In one hour bath trials, lambdacyhalothrin was found to be 100% efficacious at a dose rate of 0.05 mg/l. However, the compound was also found to have a low therapeutic margin, producing 100% mortality in the treated salmon at 0.005 mg/l. Resmethrin was found to be less toxic to lice with efficacy ranging from 80 to 100% at doses ranging from 0.01 to 0.1 mg/l depending on the experimental conditions. Optimum efficacy (90% reduction) was achieved 8 hours post treatment. Resmethrin was also found to have a wider therapeutic margin. Fish tolerated single exposures at doses of 0.05 and 0.1 mg/l without signs of stress. Fish also tolerated a single exposure of 1.0 mg/l but displayed severe signs of stress following treatment. It is suggested that pyrethroids may be a suitable alternative for the treatment of sea lice infestations of farmed salmon warranting further testing under field conditions.

Samuelsen, O. B., Pursell, L., Smith, P. and Ervik, A. 1996. Multiple-dose pharmacokinetic study of Romet 30 in Atlantic salmon (Salmo salar) and in vitro antibacterial activity against Aeromonas salmonicida. Aquaculture (Submitted).

Samuelsen, O.B., Lunestad, B.T., Husevaf, B., Hølleland, T., Ervik, A. 1992. Residues of oxolinic acid in wild fauna following medication in fish farms. Dis. aquat. Organisms 12: 111-119.

Samuelson O B, V Torsvik and A Ervik, 1992. Long range changes in oxytetracycline concentration and bacterial resistance towards oxytetracycline in a fish farm sediment after medication. Science of the Total Environment, 114, 25-36.

Following 10 days medication with oxytetracycline, marine sediment was sampled beneath three selected cages at a fish farm over a period of 18 months, in order to detect any change in the sediment oxytetracycline concentration, bacterial numbers, and bacterial resistance towards the drug. The bulk of the OTC disappeared during the first few weeks, but it persisted in the sediment at lower concentrations for quite some time after the medication. Half-lives were estimated at 87 - 144 days. At the end of the medication, all three sediments had >100% OTC-resistant bacteria. This value dropped to 20% after 72 days, and stabilised at levels between 10 and 50%. The changes in bacterial numbers, described as total and plate counts, was due to seasonal variations rather than to the medication.

Sandaa R and O Enger, 1994. Transfer in marine sediments of the naturally occurring plasmid pRAS1 encoding multiple antibiotic resistance. American Society for Microbiology. Microcosm experiments performed with the fish-pathogenic bacterium Aeromonas salmonicida acting as a donor showed that promiscuous plasmid pRAS1, which encodes tetracycline resistance, is transferred at high frequency in marine systems, even in the absence of a selection factor.

Smith, P. and Samuelsen, O. B.. Estimates of the rates of resolution of oxytetracycline from sediments under fish farms. Aquaculture (Submitted).

A portion of the oxytetracycline administered to fish in marine fish farms is deposited on the sediments under the fish cages. Oxytetracycline is believed to leave these sediment via resolution into the water column. A simple modelling approach has been developed to quantify the kinetics of the resolution process. The model was applied to data generated in two previously published field studies of the fate of oxytetracycline following its therapeutic use on fish farms. In applying the model a number of assumptions were made as to the value to be ascribed to parameters for which empirical data were not available. In each case the values set for these parameters were such as to maximise the predicted water column concentrations resulting from resolution. At a farm where the maximum concentration of oxytetracycline detected in the sediments was 285 g / g the maximum water concentration predicted to occur as a result of resolution was 0.1 g /g. At a second farm where the maximum sediment concentrations were 10.9 g / g the maximum predicted water concentrations was 0.02 g / g. In the presence of the divalent cations, Mg++ and Ca++, present in sea water it is unlikely that these concentrations are of any biological significance.

Smith, P. R. (1995). The meaning of changes in the frequency of resistance to oxytetracycline in the sediments under marine fish farms. Bull Aquaculture Assoc. of Canada 95-4, 17-21. What does field data mean? A number of investigations have reported an increase in the frequency of oxytetracycline resistance in the microflora under fish cages in marine fish farms 9, 10, 17, 18, 22, 23 and Weston 23 has provided a summary of these data. This short paper presents a commentary on the probable meaning of these data. Meaning is not an objective property of data, it is context dependent. The meaning and validity of data can only be assessed by reference to the uses to which they may be applied. Three areas of the meaning will be considered. The first is the extent to which the available data provide an adequate picture of the changes that occur in the microbial populations of the sediments. The second is the extent that it is reasonable to infer that the changes in frequencies of resistance which have been observed, are a result of the therapeutic use of oxytetracycline by the farms studied. The third is the extent to which the available data allow an estimation of the potential risks, associated with the use of oxytetracycline in fish farms, for its continued value as a therapeutant in human and animal medicine. An attempt to address these issues has been made in a previous review by the author 20. Although some degree of repetition is inevitable this paper will concentrate on more recent developments in this field.

Smith, P., Donlon, J., Coyne, R. and Cazabon, D. J. (1994). Fate of oxytetracycline in a fresh water fish farm: influence of effluent treatment systems. Aquaculture 120, 319-325. The fate of orally administered oxytetracycline in a fresh water hatchery was investigated using High Performance Liquid Chromatography. A filter of nominal porosity 50 M in the farm effluent was capable of at least a 500-650 fold concentration of the oxytetracycline into the filter retentate flow. No oxytetracycline was detected in the filtered farm effluent (limit of detection 0.02 ppm). Analysis of hourly samples of the retentate taken over a twenty four hour period allowed an estimate of the daily amount of oxytetracycline retained by the filter. This estimate (1250 g) was of the same order as the amount of oxytetracycline used on the farm (904 g on the day of sampling and 1104 g on the preceding day). Thus, the quasi-totality of the input oxytetracycline was removed from the farm effluent by the filter. A sedimentation trap on the filter retentate flow removed oxytetracycline from this flow at a

variable and lower (12-92%) efficiency. It is argued that correct design of effluent treatment systems could significantly reduce the environmental impact of antibiotics in land based fish farms.

Smith, P., Hiney, M. P. and Samuelsen, O. B. (1994). Bacterial resistance to antimicrobial agents used in fish farming: a Critical evaluation of method and meaning. Annual Review of Fish Diseases 4, 273-313. The use of antimicrobial agents in aquaculture has resulted in the increase in the frequency of strains resistant to these agents. Potentially these resistant strains can have an impact on the therapy of fish diseases, the therapy of human diseases, or the environment of the fish farms. Analysis of the extent of these impacts is hindered by the limited information available and the variation in methods that have been used. There is, for example, considerable variation in the methods used to measure the sensitivity of strains and in the criteria used to determine the clinical significance of these laboratory data. It is important that some standardisation of sensitivity testing methods is attempted. The available data on the frequency of resistance in fish pathogens suggest that the use of antimicrobial agents in aquaculture has significantly reduced the therapeutic options for treating fish diseases. The data available to assess the impact of the use of these agents in aquaculture on the therapeutic options for the treatment of human infections are incomplete. At present, no quantitative assessment of this risk can be attempted. Considerations of the data on the impact of the veterinary use of these agents on the therapy of human diseases would suggest that the extent of the risk represented by their use in aquaculture is small. The epidemiology of the human pathogens that have been associated with fish would tend to confirm this assessment There is little data pertaining to the ecology of R plasmids in the natural environment. The significance of these plasmids in transferring resistance determinants from the aquatic compartment to the human compartment can, at present, only be assessed at a theoretical level. However, such a theoretical analysis suggests that the contribution of R plasmids, selected in the aquatic environment, to the frequency of resistance in human pathogens is probably very small. Fish farmers will have to develop methods of husbandry that limit the rate at which resistant strains emerge. Without these changes in husbandry, fish farming will rapidly enter the pre antibiotic era. It is probable that these changes will also have the effect of reducing any impact of antimicrobial agents used in aquaculture on the environment outside the fish farm.

Smith, P., Keane, M., Dempsey, S., Concannon, M., McDonagh, M. O'Kennedy, R. Patching, J. Callanan, K. and Pursell, L. (1996). Theoretical and practical implications of minimum effect concentration measurements of antimicrobial agents. Proceedings of Euroresidue 111, Utrecht (Submitted). Two methods are described for the determination of the minimum concentration of oxytetracycline-hydrochloride (OHC) that exerted a detectable effect on bacteria (MEC). One, based on growth rate assessment determined the MEC values against Listonella anguillarum and Aeromonas salmonicida as 0.01 g/ml and 0.08 g/ml respectively. Determination of the minimum inhibitory concentrations (MIC) by standard agar dilution methods gave values of 6.45 g/ml and 3.22 g/ml, respectively. Measurement of carbon dioxide production rates allowed the determination of an MEC of 0.06 g OHC/ml against Yersinia ruckeri compared to an MIC of 4.5 g/ml as determined by standard methods. A model for the significance of the presence in the environment of bioactivities of OHC equivalent to the MEC values for the selection of increased frequencies of resistant bacteria is Presented. It is argued that the development of bioassays have the potential to present lower limits of detection and greater environmental relevance.

Smith, P., Niland, N., O'Domhnaill, F., O'Tuathaig, G. and Hiney, M. (1996) Influence of marine sediment and divalent cations on the activity of oxytetracycline against Listonella anguillarum.. Bulletin of the European Association of Fish Pathologists (In press). Tube dilution MIC and MBC assays were used to estimate the influence of Mg++ (54 mM) Ca++ (10 mM) and 25% (w/v) marine sediment of the biological activity of oxytetracycline hydrochloride against Listonella anguillarum. Assays were performed at 22 oC in phosphate-free tryptone media. MIC data indicated that, in the presence of Mg++ and Ca++, the bioactivity was 12.5 %, in the presence of sediment it was 1. 5 % and when both were present it was < 0.4%. Equivalent figures derived from MBC data were 6 %, < 0.4 % and < 0.4 % respectively. Concentrations in excess of 800 g / ml oxytetracycline were required to kill the test bacteria in the presence of sediment compared to the 3 g / ml required to have the same effect in the basic medium

Smith, P., Pursell, L., McCormick, F., O'Reilly, A. and Hiney, M. 1995. On the significance of bacterial resistance to oxytetracycline in sediments under Norwegian fish farms. Bulletin of the European Association of Fish Pathologists 15, 105-106.

Smith, P...1996. Is sediment deposition the dominant fate of oxytetracycline used in marine fish farms; a review of available evidence. Aquaculture (Submitted.

The data presented in previously published reports of 17 separate therapeutic administrations of oxytetracycline in marine fish farms have been analysed. The sediment concentrations detected were expressed as a function of the amount of oxytetracycline administered per cage per treatment. In four of the studies there was insufficient information to perform this calculation but the data, from all but one of other 13 studies, were remarkably similar. In 12 of the studies the mean sediment concentration, expressed as oxytetracycline concentration in the sediment (g/g) per kg oxytetracycline administered, to

a single cage, during the treatment studied, was 0.76 0.67 g/g/kg/cage. In the remaining study, the figure was 475 g/g/kg/cage or 600 fold higher. It is argued that the differences in sampling protocols used in this work cannot explain this difference in concentration. In 15 of the 16 studies which detected similar concentrations the data collected was insufficient to provide an estimate of the percentage of the administered oxytetracycline that was detected in the sediments. In 12 of the 16 studies these deficiencies in the empirical data were overcome by formulating a set of assumptions as to the probable vertical and horizontal distribution of the agent. Each of the assumptions was formulated in such a way as to overestimate the amount of oxytetracycline in the sediments. Application of these assumptions to the field data allowed the prediction of the percentage of the administered oxytetracycline that was present in the sediments. The mean of the percentages generated from this analysis of the data reported in the 12 studies was 1.1 0.9 %. As these percentages represent maximum values it is argued that deposition on the sediment is neither the normal, or the necessary, fate of the majority of oxytetracycline administered to fish in marine fish farms. This, in turn, suggests that the fate, under normal farming conditions, of oxytetracycline administered to fish in marine farms, is unknown.

Steffenak,-I.; Hormazabal,-V.; Yndestad,-M. 1991. Rapid assay for the simultaneous determination of residues of oxolinic acid and flumequine in fish tissues by high-performance liquid chromatography. J.-LIQ.-CHROMATOGR. 1991. vol. 14, no. 1, pp. 61-70. A simple and rapid method for the simultaneous extraction and determination of residues of oxolinic acid (OX) and flumequine (FQ) in fish tissue, muscle and liver, is presented. The samples were extracted with acetonitrile and ammonia. The drugs were then extracted into a water phase, acidified, and extracted with CHCl sub(3). After evaporation, the sample was redissolved in mobile phase and filtered through a spin-X centrifuge filter. The filtrate was injected onto the HPLC. The calibration curves were linear, and the recovery of oxolinic acid was 101-104% while the recovery of flumequine was 88-94%. The detection limits were 5 ng/g for oxolinic acid and 10 ng/g for flumequine.

Turrell W.R. and I.M. Davies 1991. Preliminary assesment of the possible impact of the proposed EQS values for Dichlorvos on the salmon farming industry. Submission to the Veterinary Products Committee.

Vaughan, S. and Smith, P. (1996). Estimations of the influence of river sediment on the biological activity of oxytetracycline HCl. Aquaculture (In press). The biological activity of oxytetracycline hydrochloride (HCl) was shown to be very significantly reduced in the presence of fresh water sediment. The inhibition was a function of the interaction between the sediment and the agent and, over the range 2- 8% w/v, its extent was proportional to the concentration of sediment. The biological activity of the agent was measured using a plate diffusion bioassay in which Yersinia ruckeri was used as the indicator organism and in tube-dilution MIC and MBC assays using Y. ruckeri and Staphylococcus aureus. The extent of the inhibition of the biological activity detected was dependent on both the bioassay method and on the indicator organism used. In the presence of 8% w/v sediment a maximum percentage biological activity of 15% was detected in plate diffusion bioassay experiments and a minimum of 0.3% was detected when the MBC values against S. aureus were examined. The mechanisms underlying the inhibition were not identified but evidence is presented that it was not mediated via the concentrations of Mg2+ or Ca2+ in the sediment. It is argued that the reduction of the biological activity of oxytetracycline HCl in the presence of river sediments presents major problems for the interpretation of data on the chemical concentration of this agent in such environments.

Vaughan, S., Coyne, R. and Smith, P. (1996). The critical importance of sample site in the determination of the frequency of oxytetracycline resistance in the effluent microflora of a fresh water fish farm. Aquaculture (In Press). The frequency of oxytetracycline resistance in the microflora was studied in the effluent of a fresh water Atlantic salmon farm which had not used any oxytetracycline for three years. Resistance was defined as the ability to grow on casein peptone starch agar containing 25 g ml-1 oxytetracycline. The farm effluent passed through a rolling drum filter and the retentate flow then entered a sedimentation tank. The effluent was sampled from the filter retentate as it left the filter and from the settled solids in the sedimentation tank. 12 independent samples were taken on four sampling days from two sampling sites. The frequency of resistance was dramatically different in samples taken at the two different locations in the farm outflow. In samples from the retentate of the outflow filter the median frequency of resistance was 0.47% (range 0.25% - 1.2%). In contrast in samples taken from a sedimentation tank downstream from the filter the median frequency was 38% (range 10% - 48%). Studies in oxytetracycline-free laboratory mesocosms demonstrated that in the presence of anaerobically decomposing fish feed, river sediments and river water the frequency of oxytetracycline resistant strains increased rapidly during incubation at 18oC. After 14 days incubation the frequency had risen from 1.0% to 25%. In a similar mesocosm from which feed was omitted the frequency of resistance remained below 1%. It is suggested that elevated frequencies of oxytetracycline resistance may be encountered in environments where fish feed accumulates. These results have important implications for the design of surveys of the impact of antimicrobial agent use in fresh water fish farms.

Vermeer,-G.K.; Falls,-B. 1988. Evaluation of metomidate as an anesthetic for common snook, Centropomus undecimalis. RED-DRUM-AQUACULTURE.-

PROCEEDINGS-OF-A-SYMPOSIUM-ON-THE-CULTURE-OF-RED-DRUM-AND-OTHER-WARM-WATER-FISHES. Arnold,-C.R.;Holt,-G.J.;Thomas,-P.-eds. 1988. vol. 30, no. suppl p. 197 Symp. on the Culture of Red Drum and other Warm Water Fishes, Corpus Christi, TX (USA), 22-24 Jun 1987. Metomidate (an analog of etomidate) is a potent, hypnotic anesthetic. Induction and recovery times of juvenile and adult snook (Centropomus undecimalis) exposed to metomidate were recorded. Adult mean standard lengths were 63.3 cm and juveniles were 16.6 cm. Induction time was defined as the time from first contact with the anesthetic until equilibrium was lost and swimming motions ceased. Recovery time was the time interval to return of equilibrium after immersion in drug-free seawater. Adult induction and recovery times were more than twice as long as juveniles, however all times were well within accepted limits. Normal feeding behavior, after anesthesia, resumed within two days for juveniles and within four days for adults. Metomidate is a safe, effective and low-stress anesthetic for snook.

Wu, Q., Knowles, R. 1995. Effect of chloramphenicol on denitrification in *Flexibacter candensis* and *Pseudomonas denitrificans*. American Society for Microbiology,

Experiments on the effects of chloramphenicol on denitrification by the above bacteria showed that inhibition increased with increasing chloramphenicol concentration, and that the rates of production of nitrite from nittrate decreased. The authors concluded that chloramphenicol inhibits denitrification at the level of nitrate reduction and, in F canadensis, also at the level of NO reduction.

Wu, Q., Knowles, R. 1995. Effect of chloramphenicol on denitrification in Flexibacter candensis and Pseudomonas denitrificans. American Society for Microbiology,

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Coastal Zone Issues

Ackefors, H., Rosenthal, H. New Approaches of Integrating Sustainable Aquaculture and Fisheries in Coastal Planning and Management: Case Histories. (in press).

Aquaculture in coastal and estaurine waters is a fast growing sector of aquatic food production in many parts of the world. Because of its growth several problems have arisen, some of them are related to environmental issues while many others are concerned with the growing conflicts posed upon aquaculture development by other users of the coastal resource system. There have been numerous attempts to develop environmental management tools to safeguard the environment and the aquaculture industry and these are best exemplified by the Swedish approach, with LENKA and MOM programmes of Norway, the CRIS programmes of British Columbia, Canada and the ASEAN countries. All these approaches focus on site selection criteria, looking at carrying and holding capacities as well as resource allocation to minimise user conflicts through appropriate planning and monitoring. In Sweden the legal instrument has been used for planning the coastal zone and the municipalities have been responsible for the integration of various activities in the coastal zone. In the ASEAN countries special research sites have been used to focus on problems and environmental issues to be considered for integrated coastal zone planning. It is only recently, however, that scientists, planners, administrators and politicians realise that optimum use of valuable coastal resources will not be possible unless jointly managed by all interested in the coastal zone and by co-managing the resource system. One of the attempts to evaluate the potential that resources within coastal zone can play in multiple use is to study and quantify their functions within the system so that their dependence on each other and their utility under sustainable criteria can be identified and allocated to those who are interested in their use. This concept has been discussed by several organisations and most recently presented at the ICES Workshop "Principles and Practical Measures for the Interaction of Mariculture and Fisheries in Coastal Area Planning and Management" in Kiel, Germany. The concept is briefly outlined and visualised by graphics.

Alexander, C.E., Monaco, M.E. 1994. pp.814-826. NOAA's National Estuarine Inventory: A Tool for comparative Assessments. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 2. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. NOAA's National Estuarine Inventory (NEI) is a series of information development,synthesis, and analysis activities that represents the only ongoing, comprehensive assessment programfor the Nation s estuarine resource base. This information, compiled primarily from existing sources andorganized into a consistent spatial framework, provides a basis for national, regional, and, in somecases, local resource assessments. The consistent methodologies used to develop and compile the dataenables comparative assessments across the Nation's estuaries. Thecurrently includes national datasets describing the physical, hydrologic, and natural resource characteristics for 106 estuaries of the contiguous United States.This paper provides an

overview of t e, defining its importance, uses, and future vision.Although the knowledge available to effectively conserve and manage the Nation's estuarine resourcebase is limited, theand associated data bases provide an important tool for assessing, comparing,and contrasting the biological and physical characteristics of the Nation's estuaries.

ASEAN/US CRMP (Association of Southeast Asian Nations/United States Coastal Resources Management Project). 1991. The coastal environment profile of south Johore, Malaysia. ICLARM Technical Reports 24, 65 p. International Center for Living Aquatic Resources Management, Manila Philippines. Pontian, Johore Bahru and Kota Tinggi are the southernmost districts in the State of Johore at the southern tip of Peninsular Malaysia. They are also collectively referred to as South Johore. Chosen as the project site, South Johore has experienced rapid development over the past 20 years, fueled primarily by the exploitation of coastal resources and the utilization of coastal space. Its economic growth can continue on a long-term basis, but only if development of coastal areas is planned properly and coastal resources are managed effectively. The district of Johore Bahru is undergoing heavy industrialization and urbanization. Due to lack of proper industrial and domestic waste treatment facilities, pollution is becoming a serious problem in Johore Strait. If left unchecked and without proper contingency schemes, pollution could severely damage important industries such as capture fisheries and aquaculture. The district of Kota Tinggi is experiencing a boom in tourism. Consequently, inland forests, mangrove areas and beaches may be degraded further if well-devised management plans are not implemented. When the equilibrium of the ecosystem is disturbed, the natural attractiveness of the area deteriorates. Thus, without efforts to conserve the remaining forest cover, the tourism industry will suffer. Conflicts over resources use are also serious concerns. Capture fisheries and aquaculture interests may be at odds as the clearing of for destroys the breeding and nursery habitat of important marine species. Artisanal fishermen and their commercial counterparts are beginning to compete for the same resources as the fish production of South Johore's waters appears to be leveling off. Sand mining must be monitored and regulated. Mining in rivers and off the east and west coasts is occurring with limited regard for its negative impacts on marine life and the physiographic balance of the areas involved. One of the key reasons for the issues cited above is the lack of a strong and effective legal and institutional framework in regulating and managing coastal area activities. Thus, coastal area management (CAM) has a crucial role to play in providing concrete solutions to these problems. This profile provides baseline data on all aspects of South Johore's coastal environment as a tool for planners in designing an integrated CAM plan., The profile highlights major coastal resources and activities as well as critical issues that must be addressed before South Johore can benefit from sustainable development. It is hoped that with the successful implementation of an integrated CAM plan, South Johore will serve as a model site for future development efforts in all the coastal areas of Malaysia.

ASEAN/US CRMP, DGF (Association of Southeast Asian Nations/United States Coastal Resources Management Project, Directorate General of Fisheries, Indonesia). 1992. The integrated management plan for Segara Anakan-Cilacap, Cental Java, Indonesia. ICLARM Tech. Rep.34, 100 p. The Indonesian government chose, an estuary on the south coast of Central Java as the site to apply the concepts of integrated management planning (IMP). The goal of IMP is to allow sustainable development. Its philosophy is to examine development issues in the management area from a holistic perspective as opposed to a sectoral approach. Linkages between biophysical and socioeconomic systems are taken into consideration. The 51,700-ha Segara Anakan management area is located west of Cilacap. It includes three major ecosystems; marine, estuarine and upland, that are intimately linked with each other by biophysical processes. The estuary has 24,000 ha of mangrove forest, the largest single stand in Java. This estuary is protected from the sea by a rocky 10,300-ha barrier island (Nusa Kambangan) that runs parallel to the coast. A rich coastal marine ecosystem lies offshore. With only 7,840 inhabitants and a density of 129 people/km^2, Segara Anakan is thinly populated compared with other areas of Java. The population is decreasing by 0.9% annually due to migration. Aquaculture development is encouraged by the government. Over 50 ha of fishponds have been developed and the area between Klaces and Motean has been recommended for future aquaculture development. Due to problems of acid soils and high silt content of the water, only a few hardy species such as tilapia and mudcrab can thrive in Segara Anakan ponds.

Auer, M.R. 1994. Regional Cooperation to Protect the Coastal Zone of the Baltic Sea. pp.111-128. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 1. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. In 1974, six European nations in the Baltic Searegion signed the Helsinki Convention -- a multilateralagreement to protect the Baltic Sea. Each nation in the regionwas expected to adjust national legislation to meet the termsestablished under the Convention. Case studies are analyzed ofSwedish and Polish efforts to control nutrient loadings to thesea over the past twenty years. Environmental conditions incoastal waters are examined to gage the effectiveness ofpollution control policies. Swedish efforts to control pointsource nutrient loadings met with some success during

theperiod. However, diffuse sources of nitrogen from Swedencontinued to grow. During the same period, Polish environmentalpolicies failed to reduce both point and non-point sourcenutrient loadings. Recommendations are made for the next roundof cooperative environmental action in the region. The region'snew Joint Comprehensive Environmental Action Programmeidentifies Over 130 "hot Spots"' and almost 50 "priority hotSpots". Cooperative financing schemes and broader publicparticipation will prove important in regional efforts toremediate these hot spots.

Bajzak, D., Roberts, B.A. 1996. Development of Ecological Land Classification mapping in support of forest managemnt in northern Newfoundland, Canada. Environmental Monitoring and Assessment 39: 199- 214.

Banner, A., Meidinger, D.V., Lea, E.C., Maxwell, R.E., Von Scken, B.C. 1996. Ecosystem mapping methods for British Columbia. Environmental Monitoring and Assessment 39: 97-117.

Bellemare, P., Light, E., Ogilvie, M. 1994. Cooperation in the Management of Coastal Information - The Atlantic Canada Approachof. pp.769-783. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 2. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. A- Coastal Zone Management is an on-going process. hose responsible foreffectiverequire accurate and accessible information. Given current fiscal restraint,the best way to provide m agers with the infothey require is to cooperate, on a multi-agency basis, in the management of this information. Through the development and implementationof land and waterstandards, bi-lateral and multi-lateral projects to exchange data, andjoint review and andi g of infor ~tion-related projects, inform tionare better able toprovide coastal zone managers with the data they require.

Bewers, J.M., Vandermeulen, J.H. 1994. Integrated Coastal Zone Management: The Implications for Science. pp.3-17. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 1. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. Agenda 21, of the United Nations conference on theEnvironment and Development (UNCED, 1992) formalized the conceptof Integrated Coastal Zone Management (ICZM). The conceptinvolves the comprehensive management of both marine andadjacent land environments and of anthropogenic activitiestherein. We argue that, while ICZM might be seen as a newmanagement approach subsuming sectoral interests in the coastalzone, it is foremost a new perspective on the process ofexploiting and preserving coastal resources in the context ofsustainable development. Meaningful acceptance of ICZMnecessitates radical rethinking of the status quo regardingcoastal management in two dimensions: socio-economic andscientific. This reflects the inadequacy of current scientic/social/political interactions. In our analysis we take as basictenets the need to account for externalties and comprehensivecoverage of diverse anthropogenic practices as well as a prioriacceptance of the legitimacy of waste assimilation.In this paper we discuss: 1) appropriate levels for theestablishment of guidelines, urgingthe preservation of flexibility and enablement at local levelsso as to avoid unreasonable constraints on the options for thesustainable use of resources and amenities within individualcoastal areas; 2) the critical dependence of ICZM on theintegration of hitherto sectoral perspectives; 3) ICZM in thecontext of the recently-developed GESAMP Framework forEnvironmental Protection; and 4) major scientific elements ofICZM including the definition of coastal zone, scientificuncertainty, the application of conservatism, the acceptance ofchange as an inherent feature of the natural environment, andscientific elements of environmental planning and environmentalimpact assessment. Finally, we propose the use of model coastalenvironments as testing grounds for ICZM design andimplementation.

Bondesan, M., Castiglioni, G.B., Elmi&, C., Gabbianianelli&, G., Marocco, R., Pirazzoli, P.A., Tomasin, A., 1995: Coastal areas at risk from storm surges and sea-level rise in northeastern Italy. Journal of Coastal Research, 11: 1354-1379.

Boverket (Swedish National Board of housing, building and planning): 1995. (ed. by Ylva Rönning). Öp-Analys kust och Hav - en utvärdering av kustkommunernas översiktsplaner (Comprehensive plan analysis of the coast and Sea - an evaluation of the comprehensive plans of the coastal municipalities). Erfarenheter av översiktsplanearbetet . Boverket Publikationsservice, Box 534, S-371 23 Karlskrona, 76 pp, Annexes.

Chandler, P.C.P., Carswell, B.L. A Modular Aquaculture Modelling System (MAMS) and its application to the Broughton Archipelago, British Columbia. submitted.

British Columbia Ministry of Agriculture Fisheries and Food has undertaken the development of a numerical model to enhance its aquaculture management capabilities. The purpose of this computer based system is to provide a tool for Ministry staff that can support the decision making process

concerning the licensing of aquaculture sites by assessing the local and regional impacts of aquaculture operations. The modelling system has a modular structure and is coprised of three principal modules; the first is a pre-processor to establish the scenario to model; the second is a processor to coordinate the execution of the sub-modules that simulate a range of biophysical processes; and the third is a post-processor to display the results. These three modules are interconnected by a Windows based Graphical User Interface, a Geographic Information System, and an on-line support document. At present this aquaculture modelling system (MAMS) has sub-modules to simulate two-dimensional hydrodynamics, water quality, fish growth, and sedimentation. An assessment of the modelling system has been carried out for a region of important aquaculture activity in British Columbia, the Broughton Archipelago. MAMS can provide managers with a tool to examine and communicate the complex nteraction of chemical, physical and biological processes that are relevant to salmon aquaculture in the Broughton Archipelago.

Clark, J.R. 1992. Integrated management of coastal zones. FAO Fisheries Technical Paper. No. 327. Rome,. 1992. 167p. This report identifies governmental actions that can lead to effective management of coastal resources and strengthening the national capacity for effective coastal resources management through Integrated Coastal Zone Management (ICZM). This is a system for controlling development and other human activities that affect the condition of economic resources and the quality of environment in coastal zones. The overall objective of ICZM is to provide for sustainable use of coastal natural resources and for maintenance of biodiversity. Environmentally planned development is reputed to add to economic and social prosperity of a coastal community in the long term. The orientation of the report is toward developing countries, particularly those of the coastal tropics. Fisheries productivity, increased tourism revenues, sustained mangrove forestry, and security from natural hazard devastation are among the practical benefits of ICZM. ICZM incorporates modern principles of planning and resources management, information bases an interdisciplinary processes. A major objective is to facilitate the interactions of different coastal economic sectors (e.g., shipping, agriculture, fisheries) toward optimal socio-economic outcomes, including resolution of conflicts between sectors. ICZM may be initiated in response to a planning mandate but more often because of a crisis -a use conflict, a severe decline in a resource, or a devastating experience with natural hazards.

Chess, C., Hance, B.J., Sandman, P.M. 1988. Improving dialogue with communities. A short guide for Government Risk communication. New Jerjey Dep. Environm. Protection, Div. Sci. & Res., New Brunswick, NJ, USA.pp. 1-30.

Chia, L.S., Habibullah, K., Chou, L.M. 1988. The coastal environmental profile of Singapure. ICLARM Technical Reports 21, 92 p. International Center for Living Aquatic Resources Management, Manila Philippines. Singapore is situated between latitudes 1°09'N and 1°29'N and longitudes 103°38'E and 104°06'E. The Republic is located to the south of Peninsular Malaysia and is separated from its northern neighbor by Johor Strait. To the south are scattered the islands of the Indonesian Riau (also Rhiau, Rhio or Rio) archipelago (Fig. 1.1). The only clear view of the open sea is from Horsburgh Lighthouse at the eastern end of the Singapore Strait looking towards South China Sea. The main island of Singapore (henceforth referred to as Singapore Island) is 41.8 km long and 22.5 km wide. The total area of Singapore stands at 621 km^2, which includes about 60 islets (referred to as the "offshore islands") having a total area of 46 km^2. Land from foreshore reclamation has added some 40 km^2 as of 1985. The offshore islands are found mostly to the southwest of the main island although the largest two islands, Pulau (P. throughout this text, and which means island) Tekong Besar and P.Ubin, are respectively located to the east and northeast of the main island. As an island nation in a region dominated by water, Singapore is by its very nature highly maritime. The country is heavily dependent on its marine resources including its strategic location on a major international sealane for commercial shipping, which perhaps may be considered the country's most important marine resource. Dependence on marine resources arises also as a result of the small physical size of the country, requiring it to be outward-looking in terms of international relations and its laissez faire policies on trade, manufacturing and services. The economic and social foundation of Singapore lies in its being an entrepot center, providing the trading links between the surrounding region and the developed nations of the West and Japan. Singapore's strategy has been to build up its internal infrastructure such as a well-developed system of port and road network, planned industrial estates and other essential facilities and to create an administrative and legal system that will ensure efficient services to sustain the vital linkages with the rest of the world. This strategy has led to Singapore being called the "global city". The development momentum beginning from the 1960s together with increase in population has resulted in very great pressures on the marine or coastal resources with consequent impacts on the coastal environment of the country. Singapore's territorial waters are limited in area as they are circumscribed by the waters of its neighboring countries. For this reason, the country is referred to as a "Geographically Disadvantaged State" (GDS) in the language of the United Nations Conference on the Law of the Sea (UNCLOS). However, the limited coastal area has played an important role in Singapore's economic growth and prosperity. Singapore has taken advantage of its strategic location between the economically powerful European states and the rapidly growing countries of the Arabian Gulf to the west and the expanding East Asian markets. Singapore is also the transportation hub for the Southeast Asian region to develop its external trade; to produce manufactured goods and provide services for the international community; and to become what is popularly known as one of the "Newly

Industrializing Countries" (NICs). Its deepwater harbor and centrally located position have also made Singapore the second largest oil refining center in the world. The large flow of merchant ships including modern container vessels, oil tankers and other specialized bulk carriers further accentuated the growth of port facilities and led to the emergence of various supporting industries such as shipbuilding and shiprepairing and ancillary services such as banking and insurance.

Corlay, J.-P., 1993: Coastal wetlands: A geographical analysis and some projects for management. Ocean & Coastal Management, 19: 17-36.

Costello, M.J. 1995. Environmental impacts of aquaculture, and coastal zone management in Ireland.

Davis, B.W., Haward, M. 1994. Oceans Policy and Overlapping Regimes. pp.155-164. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 1. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994.

The various attempts to delineate ocean boundaries,manage marine resources and protect ocean environments havegenerated a number ofi international conventions - so many infact that they are beginning to interfere with one another. Analphabet soup of international conventions (UNCLOS, CCAMLR,MARPOL, IWC and many others) provide the basis for numerousoceanic regimes. These regimes provide a complex background ofconflicting interests and overlapping intentions. Currentinitiatives relating to the implementation Agenda 21, the MadridProtocol and the development of a regime on high seas fishingare complicated by the existence of existing oceanic regimes.The overlap between regimes may complicate the implementation ofthe post-UNCED agenda and raise important issues related to thenexus between international regimes and national policy making.In federal nations, such as Canada and Australia, the situationis further exacerbated by national-provincial jurisdictionissues and the overlays of authority and interest which plaguecoastal management. How is the nexusinternational-regional-domestic to be handled and morespecifically, what kind of institutional arrangements anddecision processes of a participatory nature can be devised tohandle this increasingly complex situation. Is good sciencefollowed by bad decision and how are the inevitable conflicts tobe resolved? The paper will explore some options, with specificemphasis on coastal management in federal nations.

Elliott A.J., Gillibrand P.A., and W.R. Turrell 1991 Tidal mixing near the sill of a Scottish sea loch, pp 35-56 In: Dynamics and exchanges in estuaries and the coastal zone. Ed: D Prandle, Publ: Springer-Verlag, New York, 647pp. (Coastal and Estuarine Studies 40).

Finkl, C.W., 1996: What might happen to America's shorelines if artificial beach replenishment is curtailed: A Prognosis for southeastern Florida and other sandy regions along regressive coasts. Journal of Coastal Research, 12: iii-ix.

Gomes, C. 1995. Predictions under uncertainty. Fish assemblages and food webs on the Grand Banks of Newfoundland. Social and Economic Studies 51: 190 pp. (ISER, Institute of Social and Economic Research, Memorial University of Newfoundland).

Harris, R.H. 1995. Perspective: Risk assessment - a coming of age. Human and Ecological Risk Assessment 1(2): 5-8.

Hawboldt, S. 1994. Community Conservation: A Model for Coastal Resource Conservation. pp.706-717. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 2. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994.

The Clean Annapolis River Project) is a charitable non-governmental organization created in March 1990 to actively promote, encourage, and assist with the wise use of the resources of the Annapolis River and its adjacent watershed and coastal zone. Since that time the group has over two dozen projects related to environmental quality assessment, community environmental action, public awareness, and ecosystem-wide planning. CARP was one of the first community groups invited to participate in the Atlantic Coastal Action Program, an initiative of Canada's Green Plan and has received broad local, regional, national and international exposure for its efforts to build community-conservation utilizing a broad multi-partnership approach to the issues. This presentation will outline the creation, development and organizational structure of the group. Building on this, the paper will briefly discuss the various projects in which CARP hase been involved. The Annapolis Basin Coastal Zone Project will serve as an illustration of the partnership building approach often used by CARP. While the CARP model may be uniquely suited to the environmental, cultural and political realities, the general principles upon which this community organization is built should be easily transferred to other regions.

House, J.D. 1994. From Canadian Periphery To Global Competitor: A New Paradigm for the Development of Coastal Communities in Atlantic Canada. pp.199-224. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal

Zone': Conference Proceedings. Volume 1. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994.
Economic developers in Atlantic Canada have been faced to look for a new wealth generation and employment creation to ensure the survival and development of their coastal. In the case of Newfoundland and Labrador ; the new approach involves transforming the economy from one characterized by heavy dependence on resource industries and government transfers. In contrast, the 'new economy' is diversified, knowledge-and characterized by high productivity and low unemployment. This transformation is well underway and involves two phases: laying a strong foundation and economic activity. After four years of emphasis on building the foundation and significant success in that regard, the Province is currently focusing on stimulating economic activity. This is occurring without a major dependence on markets or investment from central Canada and in the face of a negative image based on troubles in the old economy.

Johanson, L., 1995: Coastal area management in Sweden. Report on comprehensive coastal planning in the municipality of Lysekil. SWEDMAR Reports, 1/95: 1-56.

Johansson, L. 1995. Coastal Area Management in Sweden. Report on comprehensive coastal planning in the Municipality of Lysekil. Swedish Environmental Protection Agency. SWEDMAR, PO Box 423, S-401 26 Göteborg 56 pp. (ISSN 1400-7738).

Johansson, L. 1995. Coastal area management in Sweden. Report on comprehensive coastal planning in the Municipality of Lysekil, SWEDMAR, Swedish Environmental Protection Agency. This report has been prepared as a background document for the environmental cooperation around the Baltic Sea. The report focuses on coastal area planning as a process to include physical, biological and human components within a comprehensive management framework for the coastal zone. One of the purposes of the report has been to provide demonstration material for use in the Swedish bilateral cooperation with countries. in central and eastern Europe. It should be underlined that the management and planning strategies must be developed within the framework of the cultural, legal and administrative system of each country. In developing these strategies the comprehensive plan of the Municipality of Lysekil could be seen as an example of the Swedish approach to coastal and marine management at municipal level. The report has been prepared by Lars Johansson and Antonia Sanchez Hjortberg, Swedmar, the international consultancy group of the National Board of Fisheries. The report has been compiled with the help of the Municipality of Lysekil and the County Administrative Board of Gothenburg and Bohuslän, which have kindly put their planning material and knowledge at disposal. Also the EFEM Architects in Gothenburg, the municipality s planning consultant. has provided valuable assistance. This work was carried out at the request of the Swedish Environmental Protection Agency which also has funded the report.

Kantardgi, I., Mairanovsky, F., Sapova, N., 1995: Water exchange and water quality in the coastal zone in the presence of structures. Coastal Engineering, 26: 207-223.

Mah, S., Thomson, S., Demarchi, D. 1996. Ecosystem Mapping Methods for British Columbia. Environmental Monitoring and Assessment 39: 119-126.

Marine Law Inst., Univ Main School of Law 1992. Legal methods for promoting local salmon farming operations in Down East Maine. NRCI-W-92-010. (National Coastal Resources Research & Development Institute). 71 pp + Appendices.

Marshall, I.B., Smith, C.A.S:, Selby, C.J. 1996. A national ecosystems Framework for monitoring and reporting on environmental sustainability in Canada. Environmental Monitoring and Assessment 39: 25-38.

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OECD 1993. Coastal Zone Management. Selected Case studies. 2nd rue André-Pascal, 75775 Paris CEDEX 16, France, 128 pp.

Opadeyi, J., Fabres, B. 1994. Database Design and Requirements for Integrated Coastal Fisheries Management (ICFM) in the Gulf of Paria. pp.784-813. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 2. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. The Gulf of Paria is bounded east and west by the island of Trinidad and Venezuelarespectively. This Gulf is the site for approximately 2500 commercial and recreational fishermen. The estimated returns from the fishing activities was TT$ 70.5 million (ex-vessel) for the Year 1991. An estimated 16,000 eco-tourists visited the Caroni wetlands surrounding the eastern part of the Gulf annually. Two major threats to the fisheries

have been identified in respect to the Gulf: overfishing and habitat degradation and destruction. In order to reduce the impact of these problems. an integrated coastal fisheriesmanagement project was developed. The objective of the project is to improve the well-being of coastalcommunities and society at large, through improved management of marine and related land-based coastalresources and through the protection of the coastal -system. This paper shall focus on the firstcomponent of the project "Information Gathering and Research" by highlighting the data, databases andother requirements developed towards the meeting of the project objective.

Paw, J.N., Bunpapong, S., White, A.T. , Sadorra, M.S.M., editors. 1988. The coastal environmental profile of Ban Don Bay and Phangnga Bay, Thailand. ICLARM Technical Reports 20, 78 p. International Center for Living Aquatic Resources Management, Manila Philippines. A development planning study was carried out for the Upper South Region under JICA (JICA 1985) which has been designated by the Royal Thai Government (RTG) as one of the target regions for development. The government's initial Master Plan identified several potential areas for development, including coastal resources, but no consideration for was made. ONEB, recognizing the need for integrated development and management of coastal resources, prepared a proposal for a CRM plan for the Upper South. The proposal, which identified Ban Don Bay and Phangnga Bay as the two key planning areas, was approved for inclusion in the ASEAN-US CRMP. This book presents a profile of literature and a collation of available data for the preparation of plans for Ban Don Bay and Phangnga Bay. Contained are information on their physical setting, natural and human resources, economic conditions and institutional framework. Existing constraints (e.g., lack of institutional coordination, adequate plans and strategies) to effective management are also evaluated, and issues of special concern are identified. The preparation of these plans is the primary objective of the project. The plans are expected to serve as a practical guide in pursuing RTG activities related to the two areas' optimal "economic-cum-environmental" development. Recent trends of exploitation and importance of marine resources in Thailand show that the fisheries resources of the Gulf of Thailand have already passed maximum sustainable production. "Trash fish" now represent more than 40% of the total marine landings from Thai waters with up to 50% of the "trash fish" being juveniles of valuable fish and shrimp. In coastal areas, land use patterns are changing. In the Eastern Seaboard, emphasis is on heavy industries, whereas in the Upper South, tourism and tin mining are of economic importance to Phuket and Phangnga. Aquaculture, particularly for shrimp, is being expanded in Ban Don and is encroaching into the adjacent mangrove areas (TDRI 1987). The Thai fishing sector supplies about 23 kg of fish/person/year to a population of 52 million. Marine capture fisheries account for over 90% of total fish production but many problems threaten the of the industry and the catch. Poverty and overfishing of inshore fisheries resources have exacerbated the conflicts between small-scale fishermen and large trawlers. Further, the declaration of the Exclusive Economic Zones (EEZ) by neighboring countries has reduced Thai fishing grounds. Thus, there is a need in Thailand for management of all coastal resources such as estuaries, mangroves and coral reefs. It is important to formulate a CRM plan for Ban Don Bay before development goes too far. This area is rich in natural resources which have vast development potential. The coastal resources appear to be in good condition at present, but this is expected to change because of population pressures and land-based development. This bay receives runoff from one of the largest catchments in the Upper South so that water resource development may alter the bay's hydrological and water quality conditions in the future. Surat Thani, for instance, is one of the largest urban zones. Continued development here will increase change in land use patterns, pollution loads and coastal resources exploitation pressures. Although on the west of Phangnga Bay are ecological characteristics similar to most other areas in the Upper South, it harbors the largest intact mangrove forest in the country.

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

Robinson, C.L.K., Levings, C.D. 1995. An overview of habitat classification systems, ecological models, and geographic information systems applied to shallow forshore marine habitats. Can. Manuscript Rep. Fish. Aquat. Sci. 2322: 1-65.

Robitaille, A., Saucier, J.-P. 1996. Land District, Ecophysiographic Units and Areas: The Landscape Mapping of the Minstere des Ressources Naturelles du Quebec. Environmental Monitoring and Assessment 39: 127 - 148.

Sims, R.A., Corns, I.G.W., Klinka, K. 1996. Introduction - Global to local: Ecological land classification. Environmental Monitoring and Assessment 39: 1-10.

Southgate, H.N., 1995: The effects of wave chronology on medium and long term coastal morphology. Coastal Engineering, 26: 251-270.

This report is a background document for the environmental cooperation around the Baltic Sea. The report focuses on coastal area planning ass a process to include physical, biological and human components within a comprehensive management framework for the coastal zone. One of the purposes of the report has been to provide demonstration material for use in the Swedish bilateral cooperation with countries in central and eastern Europe.

Uhlig, P.W.C., Jordan, J.K. 1996. A spatial hierarchical framework for the co-management of ecosystems in Canada and the United States for the Upper Great Lakes Region. Environmental Monitoring and Assessment 39: 59- 74.

White, A.T., Martosubroto, P., Sadorra, M.S.M., editors. 1989. The coastal environmental profile of Segara Anakan-Cilacap, South Java, Indonesia. ICLARM Technical Reports 25, 82p. International Center for Living Aquatic Resources Management, Manila Philippines. Segara Anakan and its surrounding environments in the Cilacap coastal area are a unique ecological feature in Java (Fig. 1.1). The area, a continuation of the Depression Zone of Java (Rahardjo, 1982), has long been recognized as resource-rich. Numerous proposals have been made for resource development and management. Interest in the development of the area dates back prior to World War II when attempts were made to divert part of the downstream portion of Citanduy River into Segara Anakan. Blommenstein (Ludwig 1985) considered the possibility of converting Segara Anakan into a polder by diking Citanduy and diverting its discharge directly to the Indian Ocean. He intended to close off Segara Anakan from the sea by means of cutoff dikes at the outlets. It was further proposed that the resulting polder be drained by pumping and that entry of local rainfall flush the salt water so the area could be converted to productive agricultural land. The River Basin Development Project (DGWRD-DR, 1976) envisioned the conversion of the lagoon from a tidal estuary into a freshwater lake. This was to be accomplished by the construction of tidal and gates at the outlets to the sea; the diversion of the silt-laden Citanduy River directly to Indian Ocean; and the diversion of Donan River into the lagoon. The surrounding tidal-dependent mangrove, tidal swamp and marsh areas would be naturally desalinated by this procedure and reclaimed for agriculture (Ludwig 1985). It was noted in 1975 that the major fisheries value of the lagoon was as a source of shrimp and finfish captured by offshore fishing vessels. The value of fish captured within the lagoon was considered small in comparison. The possibility of using the shallow freshwater lake resulting from the proposed development for aquaculture appeared to be limited. Subsequent reports on the Segara Anakan Reclamation Project indicated that the sedimentation filling rate had accelerated rapidly and that the usefulness of the lagoon as envisioned before was seriously impaired (Ludwig, 1985). (Table 1.1 shows the change in land and water areas from 1900 to 1984.) These studies focused on the reclamation aspect and were oriented to augmenting available agricultural land. The ecological and fisheries studies were limited. Since these proposals were made, the Ecology Team has shown that Segara Anakan performs a significant biogeographical role for many aquatic organisms and, in particular, for migratory populations. Ecologically, the interrelated mangrove complex and the aquatic systems believed to have a significant role to the adjoining marine coastal ecosystem. On the other hand, this adjoining system and the water drainage systems flowing into the lagoon perform important functions. The resources which evolved from these dynamic interactions are exploited by the local inhabitants, and thus possess a socioeconomic role. The conceptual linkages of the lagoon and drainage basin; The roles performed by Segara Anakan; and management possibilities are shown in Fig. 1.2. At present, the Segara Anakan system constitutes and/or is affected by six linked components, each having a significant role (Fig. 1.2). The important components and processes in the area are: 1. Hydrological aspects; 2. Natural resource (mangrove, offshore and lagoon system); 3. Physiographical aspects, which include: hydrological changes, land subsidence and submergence and erosion in the upper river basin and the adjacent coastal lands; 4. Terrestrial vegetation; and 5. Socioeconomic aspects which include human activities affecting the area and how people are affected by the changing resource base. Siltation may adversely affect some fish species in the lagoon, but may benefit others., especially those with the ability to adjust to the resulting water system. This condition arises due to environmental changes, often drastic, which will further cause changes in the availability and/or accessibility of preferred habitat which may function as refuge, spawning, nursery, feeding or general living area: and natural food supply, both in quality and quantity. Segara Anakan and its adjacent areas as estuarine lagoons are important as sources of fisheries commodities for food and commerce by the local people. Maintenance of productive fisheries may require limitation of fishing effort and protection of habitat. The fisheries resources and estuarine-mangrove habitat are modified by: (1) increases in sedimentation; (2) reduction of by human encroachment; (3) potential influence of pollution from in the agricultural runoff water; (4) water pollution from human settlements and industrial sites; and (5) of the lagoon fisheries.

Wright, D.G. 1994. The Approach of the Department of Fisheries and Oceans to Land Use Planning in Canada's Arctic Coastal Zone. pp.31-45. in: Wells, P.G., Ricketts, P.J., Eds. Coastal Zone Canada '94, 'Cooperation in Coastal Zone': Conference Proceedings. Volume 1. Coastal Zone Association, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada. 1994. The Canadian Arctic encompasses approximately 40 percent of the nation's total land mass and approximatelytwo-thirds of Canada's marine coastline. This vast and variedarea raises y different visions and expectations. For

some itrepresents Canada's heritage and its future, to be preserved andprotected; others view it as a huge storehouse of hydrocarbonsand minerals to be developed for economic benefit; to thepeoples who have lived there for generations, its land, watersand renewable resources are integral to their culture andprovide food, clothing and other materials.The governments of Canada and the Northwest Territories, inpartnership with the aboriginal peoples of this vast area, arccommitted to developing a comprehensive framework for land use ,planning and conservation. This is true both for the terrestrialenvironment and far the marine environment. Although many ofthese initiatives are led by other federal, territorial oraboriginal government departments, they present the Departmentof Fisheries and Oceans (DFO) with opportunities forinteragency cooperation and program coordination. This paperpresents a review of the history and current involvement of theDepartment of Fisheries and Oceans with the land use planningprocess the Northwest Territories and Yukon North Slope. Landuse planning has and is occurring in four regions of theNorthwest Territories. DFO maintains that conservation and protection of the Arcticenvironment and its renewable resources for the benefit andenjoyment of present and future generations of Canadians shouldbe the primary goal of any land use plan. However, such anapproach must be balanced with the continued use of fish andmarine mammal resources by subsistence, commercial andrecreational fishers, as well as with compatible non-renewableresource development. DFO has classified areas in each planningregion into three or four categories reflecting the relativeimportance to fish, marine mammals and harvesting, the threatsfrom the environment, and the adequacy of the data -base. Aseries of maps showing distribution with spatial and temporalhabitat use by the major species of fish and marine mammals wasdeveloped for each planning region. From these, a master mapdepicting a land use classification and a companion set ofassociated protection m requirements was developed. The DFOposition was then integrated with the recommendations andpositions of other agencies and users to to develop a land useplan. This strategy allows for an informed, proactive approachto the sustained use of Arctic marine renewable resources.Application of DFO's strategy has been and will continue to be acritical step in ensuring sustained use of renewable resourcesand a careful balancing of industrial activities, communitydevelopment and traditional pursuits of hunting and fishing.

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Karasev, A.B., Kuzmin, O.G., Finstad, B., Nilsen, S.T., 1995: Salmon rivers of the Kola Peninsula. Salmon Lice (Lepeophtheirus salmonis Kroyer) on atlantic salmon (Salmo salar L.) from the Varzuga river. ICES, CM 1995/R:3: 1-14.

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against sea lice. The complexity of the total louse extract probably resulted in antigenic competition which prevented an effective immune response to potentially protective antigens. We have now selected, as putative antigens, protein components of the louse gut expressed by louse DNA libraries and are now testing the potential of such antigens in experimental vaccines. Immunohistochemistry on sectioned lice, using monoclonal antibodies to the proteins expressed from the library, was used to screen the many thousands of antigen clones. Selected clones were used to immunise salmon. The salmon immune response was monitored by ELISA and responding fish were selected for experimental challenge with sea lice copepodites. The development of lice was monitored as an indicator of protection induced by the selected antigens. The first few potentially protective antigens are currently being tested for their efficacy against sea lice.

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Virus infectivity of IHNV in nonirradiated river water was 0.56 TCID sub(50)/l and U.V. irradiated water was less than 0.32 TCID sub(50)/l. Infectivity of the IHNV in the pond water where there was an IHN outbreak was measured 5.60 TCID sub(50)/l. Two groups of 1,000 rainbow trout Oncorhynchus mykiss (body weight 0.11 g), were cultured in 45 l of aquarium water, to use the river water and U.V. irradiated river water. U.V. dosage was 6.0 to 10.0 x 10 super(3) mu W multiplied by sec/cm super(2). Cumulative mortality of these 2 groups of fish observed were 25 days as 99.7% in river water and 3.9% in U.V. irradiated river water.

Environmental impact issues (except chemicals and exotics)

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Ervick, A., Hansen, P.K., Kryvi, H. 1995. Regulation of Environmental Effects of Mariculture in Norway. ICES C.M.1995/R:7. The rapid development of the mariculture industry in Norway has caused pollution problems in the marine environment as well as conflicts with other users of the coastal zone. Research and practical experience have helped to identify the environmental problems caused by fish farming and have enabled the authorities to set up environmentai objectives for Norwegian mariculture regarding escapes of cultivated fish, diseases, medicines, chemicals and organic matter. Simultaneously, the authorities have promoted coastal zone management. and a planning tool for Norwegian aquaculture at the regional level called LENKA has been developed. As a continuation a new regulation system at site level called MOM is now under development. The two systems will facilitate coastal zone planning and site management.

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Fattal, B., Dotan, A., Parpari, L,m Tchorsh, Y., Cabelli, V.j. 1993. Microbialogical purification of fish grown in fecally contaminated commercial fish ponds. Wat. Sci. Tech. 27: 303-311. The digestive tract of tilapia reared in commercial fish ponds with animal manure and/or municipal wastewater generally were contaminated with the facal indictors E. coli and enterococci to levels greater than those in the environmental water. When the indicator densitiy in the water was sufficiently high, the liver and muscle tissue also became contaminated, albeit to much lower levels Thermotolerant Aeromonas were recovered from the environmental water and fish tissues at levels 2-4 logs higher than those of the fecal indicators. Accumulation of the indicators in the tissues of the naturally contaminated pond fish generally was greater than that in the arificially contaminated fish. The indicator levels in the tissues did not appreciably decrease when the pond-reared fish were maintained for 5-8 days under starvation conditions in tanks containing water which was not exchenaged. However, the coli and virus levels in the tissues of experimentally contaminated tilapia were appreciably and significantly reduced under the same conditions. The results point to the limited utility of conventional "purification" methods as applied to tilapia reared in fecally fertilized waters and of data obtained from studies in the lab. Since fish are cooked prior to consumption, the major public health

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Hargrave, B.T., Duplisea, D.E., Pfeiffer, E., Wildish, D.J. 1993. Marine Ecol. Progr. Ser. 96: 249-257. Benthic fluxes of dissolved oxygen and ammonium were measured at bi-weekly to monthly intervals during 1990-1991 proximate to and under an array of pens holding Atlantic salmon salmo salar L. in L'Etang Inlet, a macrotidal embayment in the Bay of Fundy, Canada. hierarchical clustering of data indicated that the 7 stations scould be divided into 3 groups (3 stations under the pen array. 2 at the perimeter of the array and 2 away from the cages. Average rates of oxygen uptake and ammonium release for the 3 stations under the pens were 4 and 27 times higher, respectively. than values at the 2 stations distant from the cages. Maximum average rates of ammonium release (38 mmol m-2d-1) in late July and oxygen uptake (99 mmol m-2 d-1) in early September for stations under the cages coincided with maximum water temperatures and sediment sulfide accumulation. respectively. Negative redoc (eh) potentials and reduced number f benthic polychaetes Capitella spp. also occurred in sediments under cages between mid-July and September. Values of >100 mVS in sediment pore water during September could have been toxic to benthic fauna as well as to heterotrophic bacteria that produce substrates utilized by sulfae-reducing bacteria.

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standard sieve series) showed the greatest capacity for benzocaine adsorption (76.12 mg benzocaine/g carbon); Filtrasorb 300 (8x30 mesh) ranked next (31.93 mg/g); and Filtrasorb 816 (8x16 mesh) adsorbed the least (1.0 mg/g). Increased adsorptive capacity was associated with smaller carbon particle size; however, smaller particle size also impeded column flow. Carbon filtration is a practical means for removing benzocaine from treated water.

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Leary, R.F., Peterson, J.E., 1990. Effects of water-hardening eggs in a Betadine or erythromycin solution on hatching success, development, and genetic characterstics of rainbow trout. Prog. Fish-Cult. 52(2): 83-87. We investigated genetic and developmental effects of using a Betadine (povidone-iodine) or erythromycin solution to water-harden eggs from rainbow trout (Oncorhynchus mykiss). Electrophoretic data indicated that no genetic differences existed between control fish and fish from erythromycin-treated eggs. In contrast, a small genetic difference existed between control fish and those from Betadine-treated eggs. The mean counts of five bilateral meristic characters were similar between fish from control and treatment groups, indirectly suggesting that the treatments did not influence development rate. Reduced hatching success was observed from eggs hardened in Betadine solution. Erythromycin appears to have disrupted the development of the fish, as indicated by the increased asymmetry (differences in left- and right-side counts) exhibited by meristic characters. These deleterious effects of the treatments, however, were not large, and in most situations the effects will be far outweighed by the value of the treatments as a mans of controlling disease transmission.

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Papoutsoglou, S., Costello, M.J., Stamou, E., Tziha, G. 1996. Environmental conditions at sea-cages, and ectoparasites on farmed European sea-bass, Dicentrarchus labrax (L.), and gilt-head sea-bream, Sparus aurata L., at two farms in Greece. Aquaculture Research 27: 25-34. Water quality in sea-cages, and metazoan ectoparasites on bass Dicentrarchus labrax (L.) and bream Sparus aurata L., were sampled at two fish farms in south-west Greece over 2 years. The seabed and marine life around the cages of one farm wa surveyed using scuba. The most frequent and abundant parasites were the monogeans paricotyle chryophrii and Furnestinia echenei on the gills of the bream, and Diplectanum aequans on the gills of bass. The copepod Caligus minimus occasionally occurred inn the buccal cavity of bass, but only in low numbers. Prevalence and abundance of parasites increased with bass size but F. echeneis levels decreased with bream size. Ammonia varied seasonally with sea temperature and with oxygen levels below 6 mg per L on many occasions. It is possible that fish suffered streff from a combination of high ammonia and low oxygen conditions. There was no accumulation of waste food or faeces below the cages at the one farm surveyed, but there were thousands of wild fish, including mullet (Mugilidae), Spicara sp and Diplodus spp present around the cages. Water quality may be improved by changes in farm management, such as reducing stocking densities below the present 16 kg per m3. Oxygen should be monitored at the cages on site daily. How comparable environmental conditions and impacts, and parasitization are at other bass and bream sea cage farms is unknown.

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Vandermeulen, H., Gordin, H. 1990. Ammonium uptake using Ulva (Chlorophyta) in intensive fishpond systems: mass culture and treatment of effluent. J. Appl. Phycology 2: 363-374.

Webb, J.H., McLaren, I.S., Donaghy, M.J. 1993. Spawning of farmed Atlantic salmon, Salmo salar L., in the second year after their escape. Aquaculture and Fisheries Management 24: 557-561. The frequency of escaped salmon in the River Polla, Scotland was estimated at spawning in 1990, the second year after the escape of 184 999 fish from a sea-cage site nearby. Fourteen of 73 spawners examined were of farmed origin. In only six of these fish were scale growth patterns consistent with their being part of the documented escape. All of these fish carried the pigment canthaxanthin. Fifty-nine redds were constructed at spawning. Five of 54 redds sampled contained embryos or alevins bearing canthaxanthin. The frequency of fry bearing canthaxanthin was determined in samples obtained from the neighbouring Rivers Hope and Dionard following spawning in both 1989 and 1990. There was no evidence of substantial returns of salmon from the documented escape to these rivers. These findings and those of a previous study suggest that more than 95% of those fish which returned to rivers near the site of the documented loss did so in the first year after escape and that fewer than 0.5% of those fish which escaped returned the 2 year of study.

Webb, J.H., Youngson, A.F., Thompson, C.E., Hay, D.W. Donaghy, M.J., McLaren, I.S. 1993. Spawning of escaped farmed Atlantic salmon, Salmo salar L., in western and northern Scottish rivers: egg deposition by females. Aquaculture and Fisheries Management 24: 663-670. In 1991, the progeny of female Atlantic salmon, Salmo salar L., were sampled at emergence from sites in 16 rivers in western and northern Scotland. The progeny of farmed females that had escaped from sea-cages were identified by detecting the presence of maternal canthaxanthin in the juveniles pigment load. Canthaxanthin was detected among fish sampled from 14 od the 16 rivers examined. Overall, 109 of the 2373 fry sampled carried canthaxanthin with an average frequency over all the rivers examined of 5.1%. This value will underestimate the real frequency of occurrence of the progeny of escaped farmed salmon: some escapees do not contain canthaxanthin and male fish do not contribute to the pigment load of their progeny.

Winfree, R.A., Allred, A., 1992. Bentonite reduces measurable Aftatoxin B1 in fish feed. Prog. Fish-Cult. 54(3): 157-162. Methods for extraction and quanitfication of aflatoxin B1 (AFB1) were tested and adapted for use with fish feed. We tested a wide range of minerals in vitro to find practical methods to reduce the bioavailability of AFB1. Several common feed additives previously reported to have a benificial effect in fish or in livestock were included. The amount of AFB1 recovered from methanol-water extracts declined by an average of 70% within 1 h of adding 10% bentonite to moistened trout feed. If bentonite has a similar in vivo effect, then the adsorption of undetected feed toxins might explain the reported benefinial effects of feeding bentonite to fish.

Xu, D., Rogers, W.A. 1994. Leaching loss from oxytetracycline medicated feeds. J. appl. Aquaculture 481: 29-38.

Youngson, A.F., Webb, J.H., Thompson, C.E., Knox, D. 1993. Spawning of escaped farmed Atlantic Salmon (Salmo salar): Hybridization of female with brown trout (Salmo trutta). Can. J. Fish Aquat. Sci. 50: 1986-1990. Atlantic salmon an F1 hybrids between Atlantic salmon and brown trout were distinguished among juvenile salmonids sampled at emergence from rivers in westeern and northern Scotland. Hybrids were present in samples obtained from seven of the 16 rivers examined. Salmon fry and hybrid fry that were demonstrably the progeny of female salmon that had escaped from fish farms were identified by detecting the presence of maternal canthaxanthin, a synthetic flesh colorant, in the juveniles pigment load. Canthaxanthin was

detected in 101 (4%) of the 2350 salmon and eight (35%) of the 23 hybrids examined. The difference in the frequencies of salmon and hybrids carrying canthaxanthin was significant. Escaped female salmon hybridized with trout more frequently than did wild females

Exotic species, escapees, GMOs, ballast water and ship hull issues

Chervinski, J., Klar, G.T., Parker, N., 1989. Predation by striped bass and striped bass x white bass hybrids on redbelly tilapia and common carp. Prog. Fish-Cult. 51(2): 101-104 In laboratory experiments conducted to evaluate the suitability of redbelly tilapia *(Tilapia zilli)* and common carp *(Cyprinus carpio)* as forage for striped bass *(Morone saxatilis)* and hybrids of stiped bass x white bass (M. chrysops), the hybrids ate larger redbelly tilapias than did striped bass, but striped bass ate the larger common carp. The mean vertical buccal gape of striped bass and hybrids did not differ significantly over the length range of predators tested. The maximum body depths of the prey consumed were about 30% smaller than the vertical gapes of the predators. Although girth of common carp was larger than girth of redbelly tilapias of the same length, striped bass ate larger common carp than redbelly tilapias. The selection of larger redbelly tilapias by hybrids than by striped bass suggested that hybrids were the more aggressive.

Gollasch, S., Riemann-Zürneck, K. 1996. Transoceanic dispersal of benthi macrofauna: Haliplanella luciae (Verrill, 1898) (Anthozoa, Actiniaria) found on a ship's hull in a shipyard dock in Hamburg Harbour, Germany. Helgoländer Meeresunters. 50: 253-256. In September 1993, 26 live specimens of the small, delicate sea anemone Haliplanella luciae were sampled from the hull of a ship docked in Hamburg Harbour. After a world-wide journey the ship had passed into the freshwater region of the river Elbe. Although the migratory potential of the species (supposed home region is Japan) is well known, its transport on ships' bottoms has never been documented. Behavioural traits enabling the anemone to settle on ships are discussed together with probable reasons why Haliplanella luciae did not establish itself in the fauna of the German Bight.

Hindar, K. 1993. Genetically engineered fish and their possibl environmental impact. NINA Oppdragsmelding 215: 1-48 (ISSN 0802-4103). The report provides an overview of the potential ecological and genetic effects of using genetically engineered fish in aquaculture. It reviewws the recent development in gene transfer to fish and considers how genetic engineering could be used in future aquaculture. When evaluating the environmental effects of transgenic fish, the report relies on experience from introductions of non-native species and populations of fish that have occurred for more than a century, and on the effects of the recent escapes of farmed fish in Norway. Throughout, the emphasis of the report is on salmonids and in particular on the culture of Atlantlc salmon. Three scenarios for the future use of genetically engineered Atlantic salmon in aquaculture are presented and discussed. The first scenario assumes that transgeic fish will be used in aquaculture in according to their profitability, and that no measures are taken to reduce the number of fish escaping from aquaculture. In this scenario, current negative trends for the genetic and ecological integrity of natural salmonid populations will be reinforced. In particular, the use of transgenic cold-tolerant Atlantic salmon would lead to a northwards expansion of aquaculture, so that a nnumber of populations that are now spared from the effects of escaped fish would be at risk. This could lead to loss of irreplaceable genetic resources in Atlantic salmon and could likewise affect a number of Artic charr (Salvelinus alpinus) populations which are currently the only fish spawning in the northernmost water courses. Transgenic growth-enhanced fish could also affect native populations negatively, but this would depend on how their larger appetite affects their survival in food-limited environments.

Laws, E.A., Weisburd, R.S.J., 1990. Use of Silver carp to control algal biomass in aquaculture ponds. Prog. Fish-Cult. 52(1): 1-8. The use of silber carp *(Hypophthalmichthys molitrix)* to control phytoplankton biomass in 0.4-hectare aquaculture ponds was studied ove a period of 2 years in Hawaii. The silver carp consistently decimated net-plankton (>10 µm) chlorophyll a, but nanoplankton (>10 µm) and total chlorophyll a always increased in ponds containing free-roaming silver carp. The stimulation of total chlorophyll a was statistically significant and amounted to almost 40% in ponds containing as few as 30 silver carp. The stimulation appeared to result from a combination of the following three factors: (1) a decline in herbivorous zooplankton due to predation by a competition with the silver carp, (2) an increase in resources available to the nanoplankton as a result of the decimation of the net-plankton population, and (3) bioturbation of the sediments caused by the swimming and feeding activities of the silver carp. Confining 1,500 silver carp to one-half of the pond with a net appeared to largely eliminate the first effect and probably reduced the impact of the third effect while still producing a 10-fold decline in net-plankton chlorophyll a. Nanoplankton chlorophyll-a concentrations in ponds with confined silver carp increased by only about 20% versus controls. The corresponding increase in ponds with free-roaming silver carp was 86%. Use of confined silver carp can therefore be recommended to reduce chlorophyll-a concentrations in bodies of water where a large

percentage of the phytoplankton is in the net-plankton fraction. However, the impact of silver carp on the nanoplankton will always be stimulatory, even if a zooplankton refuge is created by confining the silver carp. A preliminary examination of the size distribution of the plankton containing chlorophyll a is therefore recommended before considering use of silver carp to control phytoplankton biomass.

Pfeiffer, T.J., Lovell, R.T., 1990. Responses of grass carp, stocked intensively in earthen ponds, to various supplement feeding regimes. Progr. Fish-Cult. 52(4): 213-217. Fingerling grass carp *(Ctenopharyngodon idella),* averaging 4.8 g (SD, 0.21), were stocked in 16 earthen ponds (0.04 hectare) at a rate of 11,875 fish/hectare and were fed a commercial crumbled trout feed for 41 d, followed by a floating catfish starter feed for 23 d. Subsequently, the fish were assigned to four feeding regimes (each treatment replicated in four ponds)and fed for 108 d. The treatments were (1) a commercial-type catfish floating feed fed twice daily: (2) a grass carp floating feed fed twice daily; (3) the grass carp floating geed fed once daily; and (4) the gras carp feed in a sinking pellet fed twice daily. The grass carp feed contained 15% dehydrated alfalfa meal (Medicago sativa). The catfish and grass carp feeds were designed to be similar in crude protein (35%) and stimated digestible energy (3.1 kcal/kg). During the 64-d conditioning period, when all fish were treated similarly, mean fish weight increased rapidly, from 4.8 to 68.4 g (SD, 4.2). During the 108-d experimental period, growth was slower, with a final average weight of 174.9 g (SD, 18.3). There was no significand (P>0.05) treatment effect on fish size, but fish fed twice daily had a higher condition factor (K = 10 2 (weight, g)/length, cm)3) than those fed once daily. Feeding activity of the fish decreased when daytime water temperature exceeded 30°C in summer and again when the temperature dropped below 26°C in fall. These results indicate that grass carp will accept and utilize formulated feeds satisfactorily in growing from small fingerlings to a sizw capable of avoiding predation (175 g in weight and 24 cm in length).

Integrated Aquaculture Systems

Banerjee,-S.R.; Singh,-A.K. 1991. Integration of modulated circular carp hatchery with hill stream lift irrigation system. NATIONAL-SYMPOSIUM-ON-NEW-HORIZONS-IN-FRESHWATER-AQUACULTURE,-23-25-JANUARY,-1991.-PROCEEDINGS. 1991. pp. 208-210. A circular carp hatchery has been designed and its important features are the location of a rechargeable fissure under the bed of a proximate hill stream and creation of submerged well system; creation of a chain of high level ponds which collect rainwater and get replenished from the pumped water from the river bed fissure; water circulation of 5-6% at 30 l/sec; installation of a reverse biological filter alongside the pond; connection of the outlet pipe with two circular breeding tanks located 4 m below the filter outlet; location of breeding tanks and hatcheries half buried in the ground dispensing with all RCC work at the base; provision of turn-down pipes at the exit of the breeding tanks and hatcheries to facilitate water level and velocity manipulation; provision of well type vats at each bend of clay pipe line running into storage ponds from the vertex point to withstand the water pressure: and drainage of outlets from breeding tanks and hatcheries to agricultural fields. The carps (Catla catla, Labeo rohita, Cirrhinus mrigala. Labeo calbasu and Hypophthalmichthys molitrix) have been bred with screen in the hatchery.

Scarratt, D.J., Sephton, T.W., 1995: Proceedings of the 1995 oyster culture workship, Moncton, New Brunswick. Can. Ind. Rep. Fish. Aquat. Sci. 230: 26p.

The principal objective of the workshop was to bring together members of the oyster industry, academics, consultants and federal-provincial govemment officials to foster an effort at developing a cultured oyster industry capable of supplying high quality cultured oysters (primarily *Crassostrea* L *virginica)* on a year round sustainable basis. 102 participants from throughout the Maritimes Fattended the 2 day workshop held in Moncton at the Gulf Fisheries Centre on March 15-16, 1995. F The workshop introduction articulated the importance of pre-planning culture activities in light of known market demands and the drastic effects that diseases have on oyster production. Recent and ongoing aquaculture developments were reviewed for New Brunswick, Prince Edward Island F1 and Nova Scotia. An overview of the basic elements of developing a business plan was followed by a detailed review of the estimated costs and economic retums from a culture enterprise with a discussion on the merits of volume and unit sales into the marketplace. Basic marketing concepts I for a cultured product were reviewed. The 4 worlcshop sessions of day 2 were introduced with an overview of previously identified R&D priorities and on90ing NB aquaculture development programs. A summary of the workshop discussion sessions on Regulations and Inspection, Research Requirements, Technology Transfer and Training, and Marketing was presented and tabulated for future reference. At the conclusion, it was the desire of all participants to make the Oyster Culture Workshop an annual event.

Shpigel,-M.; Blaylock,-R.A. 1991. The Pacific oyster, Crassostrea gigas , as a biological filter for a marine fish aquaculture pond. AQUACULTURE. 1991. vol. 92, no. 2-3, pp. 187-197. An oyster (Crassostrea gigas) aquaculture system, designed to take advantage of excess phytoplankton production, was integrated with an intensive fish aquaculture system

on a pilot scale. The oyster culture system functioned as a biological filter to remove excessive and dangerous levels of phytoplankton from the fish pond water. Oyster growth was rapid at ambient temperatures greater than or equal to 27 degree C, producing a commercial product within 14 to 18 months; phytoplankton levels were sufficiently reduced to allow a 50% reduction in fresh sea water input to the fish ponds. The reduction of nutrient levels in the runoff water is ecologically advantageous in a system proximal to delicate coral reefs.

Souness,-R. 1990. Oyster depuration -- a case study. INDO-PACIFIC-FISHERY-COMMISSION.-PAPERS-PRESENTED-AT-THE-SEVENTH-SESSION-OF-THE-INDO-PACIFIC-FISHERY-COMMISSION-WORKING-PARTY-ON-FISH-TECHNOLOGY-AND-MARKETING.-BANGKOK,-THAILAND,-19-22-APRIL-1988., 1990. no. 401,supp pp. 287-294. By virtue of their filter feeding system shellfish accumulate human pathogenic bacteria and viruses when grown in sewage polluted waterways. On transfer to disinfected water, shellfish will eliminate the previously accumulate microorganisms with faeces as part of their feeding activity and become microbially cleansed. This process is termed depuration. The process by which an appropriate depuration system is developed from laboratory experiments through field trials to full-scale commercial application is described. Sydney rock oysters (Crassostrea commercialis) caused a significant food poisoning incident in 1978 involving 2,000 people. A depuration system developed to overcome the water pollution problems is presented as a case study; the principles developed for oysters can be applied to other shellfish.

Modelling

Castella, E., Speight, M.C.D., 1996: Knowledge representation using fuzzy coded variables: an example based on the use of Syrphidae (Insecta, Diptera) in the assessment of riverine wetlands. Ecological Modeling, Vol.81 No.1: 13-26.

Davies, I.M., W.R. Turrell, and D.E. Wells, 1991. The observation and simulation of the dispersion of DDVP in Loch Ailort - August 1990. Scottish Fisheries Working Paper, No. 15/91.

Foody, G.M., 1996: Fuzzy modeling of vegetation from remotely sensed imagery. Ecological Modeling, Vol.85 No.1: 3-12.

Gilibrand, P.A., Turrell, W.R. 1995. Modelling the Environmental Impact of new and existing Fish Farms in Scottish Sea Lochs. ICES, C.M.1995/R.4. In Scotland, the fish farming industry has developed over the past two decades to the point where farms are now in production in the majority of Scottish sea lochs. The regulation of the industry is coordinated between several bodies. As part of this process, simple box models have been developed to estimate the quantities of effluent released by fish farms and the residence times of such material within a loch. The models estimate the enhancement of nutrient and chemical levels within loch systems and also attempt to ascertain whether environmental quality standards are exceeded by the fish farms within a loch system. These box models make certain simplifying assumptions about the hydrodynamic characteristics of Scottish sea . A two- dimensional, laterally integrated n model has also been developed for Scottish sea . This model has been used to investigate the physical oceanography of various sea in detail and to test the underlying ass of the simple models. In this paper, the simple models are described and the use of the numerical model to validate them is also briefly explained.

Gillibrand, P.A., Turrell, W.R. (1995). Modelling the environmental impact of new and existing fish farms in Scottish sea lochs. ICES CM 1995/R:4.

Gillibrand, P.A., Turrell, W.R., 1995: Modelling the environmental impact of new and existing fish farms in scottish sea lochs. ICES, CM 1995/R:4: 1-7

Karasev, A.B., Kuzmin, O.G., Finstad, B., Nilsen, S.T., 1995: Salmon rivers of the Kola Peninsula. Salmon Lice (Lepeophtheirus salmonis Kroyer) on atlantic salmon (Salmo salar L.) from the Varzuga river. ICES, CM 1995/R:3: 1-14.

McGlade, J.M., Price, A.R.G. 1993. Multi-Disciplinary Modelling: aan Overview and Practical Implications for the Governance of the Gulf Region. Marine Pollution Bulletin, Vol.27, pp.361-377, 1993. We examine the broad effects of the 1990-91 Gulf conflict, and the constraints on future governance of the Gulf's resources. To date, the majority of studies have concentrated on the most immediate, short term environmental effects, leaving no clear regional picture. We therfore suggest a new approach to the problem by developing a theoretical framework for local, national and regional forms of environmental governance for a spatially extended biophysical system such as the Gulf. We argue that these new forms of governance are needed because: 1. the dynamics of the Gulf are influenced by a complex mixture of long- and short- term

phenomena operating over a variety of spatio- temporal scales and 2. the most important processes are only captured to varying degrees in the current environmental management policies and institutional structures. We conclude that without such an integrated approach, future progress in policy development and environmental governance in the Gulf will be limited.

McGlade, J.M., Price, A.R.G., 1993: Multi-disciplinary modeling: an overview and practical implications for the governance of the gulf region. Marine Pollution Bulletin, 27: 361-377.

Scarratt, D.J., Sephton, T.W., 1995: Proceedings of the 1995 oyster culture workship, Moncton, New Brunswick. Can. Ind. Rep. Fish. Aquat. Sci. 230: 26p.

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SPAULDING, M.L., HOWLETT, E. 199xxx. A Shell Based Approach to Marine Environmental Modeling. *J. Marine Env. Eng,* Vol.1 pp.175-198. A shell based approach to marine environmental modeling, suitable for worldwide application, is presented. The shell provides a unified framework for application of marine environmental models and consists of a color graphics based user interface, geographic information system, environmental data management tools, gridding software, interfaces to supply input and display output data from models and selected individual or linked process models. Through the interface the user can set-up an application area anywhere in the world or select from areas available in the system. The software is designed to operate on low cost personal computers and to be extremely user friendly. It employs clear, concise graphical procedures to facilitate data entry and display model output. Applications of the shell based system illustrate the utility of the approach to predict oil transport and fate, dispersion and bottom deposition of particulate material from dnll fluid and sewage effluent discharges, wave dynamics in a small harbor, and water quality impacts from combined sewer overflows into an urban estuary. Extensions of the system to other environmental modeling problems are described.

Spaulding, M.L., Howlett, E., 1995: A shell based approach to marine environmental modeling. J. Marine Env. Engg., Vol.1: 175-189.

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

Species interactions

Asmus,-R.M.; Asmus,-H. 1991. Mussel beds: Limiting or promoting phytoplankton? J.-EXP.-MAR.-BIOL.-ECOL. 1991. vol. 148, no. 2, pp. 215-232. Seasonal variation of phytoplankton over an intertidal mussel bed was measured in the Wadden Sea near the island of Sylt between Feb 1984 and Apr 1985. To quantify the uptake of phytoplankton by a mussel bed, an open flow-through system, the Sylt flume (20 x 2 x 2 m), canalized the tidal water over a bed of Mytilus edulis . Changes in the content of phytoplankton in the water passing through the flume were used to calculate phytoplankton uptake over three tidal cycles in the summer of 1986. Phytoplankton biomass was reduced by 37 plus or minus 20% between the inflow and outflow of the flume. This figure includes active filtration of mussels and sedimentation. Phytoplankton biomass was reduced by the mussel bed over the whole size range from the smallest cells of 4 mu m (or a few pg C/cell) up to the largest diatoms of several hundred mu m (or a few thousand pg C/cell). The higher the phytoplankton concentration, the higher the uptake by the mussel bed. There was a significant positive correlation between both concentration and uptake of phytoplankton. Parallel with the uptake of phytoplankton by the mussel bed, a high nutrient release by the mussel bed was measured.

Camargo,-J.A. 1992. Structural and trophic alterations in macrobenthic communities downstream from a fish farm outlet. HYDROBIOLOGIA. 1992. vol. 242, no. 1, pp. 41-

49. The changes generated by a Spanish trout farm, located in the upper Rio Tajuna (Central Spain), on benthic macroinvertebrates were studied by comparing biological characteristics of an upstream station (S-1) with those of three downstream sites placed 0.01 (S-2), 0.15 (S-3) and 1 (S-4) km below the fish farm outlet. Species richness and Shannon diversity were depressed downstream from the trout farm. However, density and biomass values were significantly higher at downstream stations during the summer, presumably due to an increase in water temperature and food supply. Amphipods, plecopterans and planarians were the macroinvertebrates most adversely affected by the fish farm effluent. Coleopterans, ephemeropterans and trichopterans were absent immediately below the outlet (S-2), but exhibited a partial downstream spatial recovery of their informative weights at S-3 and S-4. The abundance of tubificid worms, chironomids, simuliids and leeches increased below the trout farm, with dipterans predominating at all downstream sampling sites. The trophic structure was altered by a significant increase in collectors (gatherers and filter feeders) and predators, and a marked decrease in shredders and scrapers.

Davies I M , P Smith, T D Nickell, and P G Provost, 1996 in press. Interactions of salmon farming and benthic microbiology in sea lochs. Porceedings of Conference on Aquaculture and Sea Lochs, joint meeting of SAMS and Challenger Society, June 1995. Probably the most widely described impacts of salmon cultivation on the sea loch environment arise from the increased flux of organic matter to the sea bed in the vicinity of the farm compared with adjacent areas in similar depths of water (Gowen and Ezzi, 1991). In areas where water movements are comparatively slow, a layer of organically-enriched material can accumulate on the sea bed beneath, and immediately adjacent to, the fish cages (Lumb, 1989). There are accompanying changes in the physical characteristics of the sediment, and combined with the increased input of carbon, these commonly lead to a reduction in the diversity of the benthic fauna, an increase in the biomass of opportunistic species (Brown et al, 1987), and changes in the microbial processes in the sediment (Blackburn et al, 1988). It was concluded that the concentrations of antimicrobial compounds in sediment that can result from mariculture will suppress the metabolic activity of bacterial populations in sediment. Many of the microrganisms present will be sensitive to the concentrations of antibiotic present, even though a large proportion of the total concentration present will be biologically inactive. A resistant subpopulation will maintain its normal level of activity, but the overall metabolic rate will probably be reduced. If cell division is occurring, the resistant population will be able to increase and restore normal rates of metabolism, with accompanying increase in the frequency of resistant bacteria, ie metabolic rates will recover as the resistant population grows. If cell division rates are low, the metabolic rate and frequency of resistance will remain low. Therefore, in addition to the concentration of antibiotic in the sediment, the response of the microbial population will depend upon the biologically active concentration, and the growth (cell division) rate of the microrganisms. It is therefore suggested that the response of microcosm systems critically depends on the amount of cell division that is occurring, and further experimental work must take this into account. The rates of cell division in natural systems are not known, so this presents a major problem. The rate of addition of feed will be an important parameter. A further difficulty related to grazing organisms, and whether their activity influences cell division rates. Microcosm systems of sufficient complexity to give the necessary control have not yet been designed.

Frechette,-M.; Booth,-D.A.; Myrand,-B.; Berard,-H. 1991. Variability and transport of organic seston near a mussel aquaculture site. THE-ECOLOGY-AND-MANAGEMENT-ASPECTS-OF-EXTENSIVE-MARiCULTURE.-A-SYMPOSIUM-HELD-IN-NANTES,-20-23-JUNE-1989. Lockwood,-S.J.-ed. 1991. vol. 192 pp. 24-32. (ICES-MAR.-SCI.-SYMP. vol. 192). Biological and physical observations were made (in July 1987) around a blue mussel (Mytilus edulis) aquaculture site measuring 650 m x 375 m situated in the Lagune de la Grande-Entree, Iles-de-la-Madeleine. The study took place just before spawning. The site was found to be a net exporter of organic seston as defined by total pigments (chlorophyll a + phaeopigments). Further, net horizontal transport of seston by both advection and diffusion was found to be small compared to consumption by mussels, plankton growth, and vertical mixing. The horizontal flux into the site, and thus the seston available to the mussels, was however larger than consumption. Therefore, on the basis of total seston concentration and midsummer conditions, sites could be placed in close proximity without adverse effects on the downstream site, and the density of mussels within the site could be increased.

Newell,-C.R.; Gallagher,-S.M. 1992. Short-term variability in seston flux and physiological responses of bottom-culture mussels (Mytilus edulis) im Maine. AQUACULTURE-'-92:-GROWING-TOWARD-THE-21st-CENTURY. 1992. pp. 169-170. Mussel (Mytilus edulis) feeding physiology and scope for growth were monitored during spring and fall in efflux (flow-through) containers, benthic ecosystem tunnels, and with a time-lapse benthic video monitor over a 1-2 tidal cycles at a mussel bottom lease site in Stonington, Maine, USA. Tidal cycle variations were observed in mussel shell gape, seston consumption, oxygen consumption and scope for growth. During periods of shell closure (correlated with low particle concentrations), oxygen consumption reduced to 25% of levels during active feeding. Tidal rhythms in

feeding physiology indicate an important role of vertical flux at the site causing a period of maximal ingestion during high and ebb tides. Scope for growth calculations should consider reductions in time of feeding during periods of low seston concentrations in order to balance low respiration rates during those times. Spring vs. fall comparisons indicate that mussel shell gape during periods of low food (fall) range from 30% to 100% while in the spring, gape varies from 70% to 100%. The time-lapse benthic video provides a cost-effective method for determining high frequency and seasonal changes in filtration activity of bivalves under undisturbed, field conditions, and can improve the prediction capabilities of production models.

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Sugunan,-V.V. 1987. Changes in phytoplankton species diversity indices due to artificial impoundment in River Krishna at Nagarjunasagar. SYMPOSIUM-ON-THE-IMPACT-OF-CURRENT-LAND-USE-PATTERN-AND-WATER-RESOURCES-DEVELOPMENT-ON-RIVERINE-FISHERIES.-APRIL-25-27-1987.-ABSTRACTS. 1987. p. 55. Different components of diversity indices provide good indication of changes in community stability due to temporal and spatial changes in the environment. The lotic sector, shows significantly high Shannon-Weaver diversity index and variety index, compared to the main reservoir sectors where fluviatile and lacustrine conditions are alternated due to impoundment and drawdown of water. Though the stress factors are responsible for keeping the diversity index low, they do not bring down productivity in the main sectors of the reservoir as stability is more directly related to diversity than does productivity.

T D Nickell (ed), 1995. Report to Scottish Salmon Growers Association on Benthic Recovery Programme, 1992 - 1995, Dec 1995.

Toxic algae, algal blooms

Albright, L.J., Yang, C.Z., Johnson S., 1993. Sub-lethal concentrations of the harmful diatoms, Chaetoceros concavicornis and C. convolutus, increase in mortality rates of penned Pacific salmon. Aquaculture 117: 215-225.

Anonymous, 1989. Bloom kills fish in B.C. sea cages. Fish Farming Int. 16: 2.

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"brown tides". These blooms may be noxious for aquatic species and especially marine and freshwater fish, either causing anoxia through the process of decay and clogging of fish gills, or producing specific toxins. Intensified scientific and public awareness together with an increased concern for fishery and industries are leading to a growing number of reports on harmful algal blooms in the world, and especially in European coastal waters (ICES, 1992), the US and Canada (WHITE, 1982a, 1984) as well as in Australian waters and the Indo-Pacific region (HALLEGRAEFF, 1993). Most blooms appear to be harmless events, but, under exceptional conditions, they may become so densely concentrated that they deplete oxygen or produce toxins noxious to fish. There is evidence of toxic blooms from prehistoric and historic times (presence of fossil cysts in bottom sediments: DALE et al., 1993) but it appears that the incidence and diversity of blooms has been increasing in recent years due to anthropogenic and non-anthropogenic factors (DALE and NORDBERG, 1993). Harmful algal blooms (HABS) are of immense importance causing damage to ecosystems, fisheries, aquaculture and human health. Thus, bloom algae are becoming not only one of the major economic threats to fisheries and fish culture industries (WHITE, 1988) but are also a public health hazard. This paper reviews the literature available on the occurrence of toxic algal bloom and fish kills (50 references up till 1975 and more than 250 from 1976 to 1993) and discusses their noxious effects on fish resulting in economic losses. Harmful effects associated with red tides have been reviewed in many scientific papers (TANGEN, 1977; SHUMWAY, 1990; HALLEGRAEFF, 1987, 1993; WHITE,1982a, 1984; WALDICHUK, 1990; ICES, 1992) and are reported on the proceedings of many international workshops, especially over the past 20 years (GRANELLI et al., 1990; FREMY, 1991; GORDON; 1991; HALLEGRAEFF, 1991; PARK and KIM, 1991; SMAYDA and SHIMIZU, 1993). Three types of data are available in the ever expanding literature currently available: a) wild fish in natural habitats, b) cultured fish in fish farms, and c) experimental investigations on fish tested in laboratory conditions. Their total number is nearly 300.

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Lundholm, N., Skov, J., Pocklington, R., Moestrup, O. 1994. oxic and potentially toxic Pseudonitzschia in Danish coastal waters. Canadian Tech. Rep. Fish. Aquat. Sci. 2016: 22.

McKenzie, C.H., Paranjape, M., Powell, C., Gilgan, M.W., Quillam, M.E. 1994. A Dinophysis norvegica bloom and its implications in the occurrence of a diarrhetic shellfish poisoning episode in mussels from Newfoundland during the late Autumn in 1993. Canadian Tech. Rep. Fish. Aquat. Sci. 2016: 26. In october of 1993 in Bonavista Bay, Newfoundland, several persons who had consumed mussels developed symptoms of what appeared to be diarrhetic shellfish poisoning. Mussel tissue was tested and was confirmed to contain DTX-1. Water samples collected from several locations within Bonavista Bay were examined to determine the phytoplankton organisms present in the water column. The water samples were found to contain primarily Dinophysis norvegica, however, other dinoflagellates were also present. Some samples where the highest mussel toxicity had occurred contained 2,000 D. norvegica cells per L. Examination of the digestive tissue of the contaminated mussels revealed D. norvegica concentrations of up to 40,000 cells per mussel. This is the first confirmed occurrence of diarrhetic shellfish poisoning in Newfoundland and only the second such occurrence in North America.

McKenzie, C.H., Schwinghamer, P. 1994. Alexandrium cyst distribution in sediments collected from shellfish aquaculture sites in Atlantic Canada (Newfoundland). Canadian Tech. Rep. Fish. Aquat. Sci. 2016: 26-27. Sediment cores from seven aquaculture sites were collected by SCUBA divers in November and December of 1992 to determine the distribution and abundance of cysts in the coastal waters of Newfoundlynd in Atlantic Canada. These cores were analyzed using a density gradient method to concetrate the cysts. They were then examined microscopically for identification and enumeration. Sediments from six of the seven sites tested conctained cysts (<4-1130 cysts pre cm2), mostly only in trace amounts. The site with high cyst concentrations has been permanently closed to shellfish aquaculture. Cyst distribution within the closed site was studied along three transects through the cove, and a vertical profile for each core was compiled. The bottom sediments of this cove contained of fine silt and clay over a meter deep. Highest cyst concentration (1130 cysts per cm2) occurred in shallow (3m(sediment on the eastern edge of the cove.

Rensel, J. 1994. Harmful effects of the marine diatom Chaetoceros concavicornis on Atlantic salmon: the role of gill mucus. Canadian Tech. Rep. Fish. Aquat. Sci. 2016: 31. The effects of the spiny, chain-forming marine diatom Chaetoceros concavicornis on seawter-acclimated Atlantic salmon were studied in laboratory bioassays. Partial pressur of blood-oxygen (PO2) in fish exposed to environmentally common and greter concentrations of the diatom was significantly less than control fish; partial pressure of blood-carbon dioxide (PCO2) was elevated. Histopathology of fish exposed for short periods (2-12hrs) showed massive discharge of gill mucus that obstructed interlamellar spaces. Longer exposure (24-48 hrs) caused exhaustion of the supply of mucus cells and mucus and led to lamellar degeneration and separation. None of the several hundred sections of gill tissue examined showed compelling evidence of penetration by the diatoms' primary spines, as previously reported from observations of wet mounts. Scanning electron microscopy showed that cells and chains of C. concavicornis may lodge betweent the secodary lamellae of the gills but many diatoms were also present in overlaying mucus if special tssue preparation techniques were used. Fish cough rate frequency was generally correlated with diatom concentration or morphology. Chains and spines of C. concavicornis grown in non-aerated cultures were longer than in those grown in aerated cultures; fish exposed to longer chains and spines had lower PO2 and increased cough rates. The study supports earlier conclusions that the diatom has a physical action on the fish gills not a chemical one. Overall, fish gills appear to be protected from the effects of the diatom by mucus production which bundles the algal cells and allows them to be removed by coughing and normal flow of water over the gills. Conversely,if mucus production is too great, blood-hypoxia leads to immediate death of the fish. Although oxygen supplementation could be an effective mitigation measure for short-term exposure of auaculture fish to C. concavicornis, longer exposure could exhaust the supply of mucus cells and lead to major degradation of the gill epithelium and death. The economics of supplying water of high oxgygen level to net cages appears to be unfavorable compared to other preventive and management practices.

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Our previous wor k has shown that when the cells of the harmful diatom, Chaetoceros concavicornis, become trapped between the primary and secondary lamellae of salmonids they cause the production and accumulation of excessive amounts of mucus, which greatly inibits oxygen uptake by the fish. If the finfish become sufficiently hypoxic, mortalities occur. Mucolytic agents, such as L-cystein ethyl ester, can suppress mucus production of the secondary lamellae of salmonids: Our data show that oral treatment of coho salmon (Oncorhynchus kisutch) with L-cystine ethyl ester, greatly reduces mucus production by the secondary lamellae upon exposure to lethal concentrations of C. concavicornis; these coho live in what would otherwise be a lethal concentration of C. concavicornis cells.

Waste water treatment

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