Mariculture Committee **ICES CM 2003/F:04**
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REPORT OF THE

Working Group on Environmental Interactions of Mariculture

Vigo, Spain

31 March–4 April 2003

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

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1 OPENING OF THE MEETING

Dr. Edward Black (Chair), opened the 2003 meeting of Working Group on the Environmental Interactions of Mariculture (WGEIM) at the Centro Oceanográfico de Vigo of the Instituto Español de Oceanografía (IEO) in Vigo, Spain. This year's meeting was attended by 15 members from 9 countries (see Annex 1). The membership constituted a range of expertise able to cover fish, shellfish and marine plant mariculture integration into the array of coastal uses experienced in member countries from both an academic and applied perspective.

The group expressed its appreciation for the special effort the Director (Dr. Alberto González-Garcés) of the Centro Oceanográfico de Vigo made to ensure that the Working Group was technically well supported and for all the hospitality extended. Due to unforeseen circumstances Dr. González-Garcés was unable to give the welcoming address. In his absence the welcoming address was delivered by the Acting Director, Dr. Juan José González. In Dr. González's speech, on behalf of the IEO, he noted that the group's area of study is important in Galicia as aquaculture is a big economic factor in the local economy and recent experience has demonstrated the need to safeguard and better integrate aquaculture into the mix of local coastal resource users.

2 AGENDA

The proposed agenda was presented and adopted with only minor modifications. The adopted agenda is presented in Annex 2.

3 TERMS OF REFERENCE

C.Res. 2002/2F04 The Working Group on Environmental Interactions of Mariculture [WGEIM] (Chair: E. Black, Canada) will meet in Vigo, Spain from 31 March–4 April 2003 to:

a) prepare a draft discussion summary of the MARAQUA report with a view to assessing the implications of the Water Framework Directive (WFD) in EU member states, on the sustainability of mariculture in coastal and transitional waters;
b) prepare a review of the potential impacts of escaped non-salmonid candidates for aquaculture on localized native stocks in order to develop, at an early stage, risk assessment and management strategies;
c) formulate a strategy to protect aquaculture against the harmful effects of external influences (e.g., contaminants, habitat alterations) arising from other resource users and their environmental impacts, with the aim of gaining better cooperation in developing modern tools to prevent or mitigate negative interactions.
d) prepare a report on an evaluation of existing Decision Support Systems (DSS) tools, GIS and other expert systems in order to derive strategic advice on the content of a DSS for mariculture, and also to identify potential linkages to existing tools presently being developed, tested or already used in coastal management schemes;
e) prepare a multi-annual plan for completing the work embodied in the above terms of reference.

WGEIM will report by 6 April 2003 for the attention of the Mariculture and Diadromous Fish Committees and ACME.

Priority:	WGEIM is of fundamental importance to ICES.
Scientific Justification:	a) The EU Water Framework Directive will be the primary EU driver for the improvement of groundwater and surface water quality over the next decades. Under the Directive, definitions of good ecological quality will be agreed for a wide range of types of water body, covering all surface waters in the EU. Good ecological quality will then be the target for improvement measures to be adopted by member states and their environmental agencies. Aquaculture is not specifically mentioned in the Directive. However, it will be viewed as being the source of environmental pressures with the potential to adversely affect the primary indices of ecological quality in the transitional and coastal water bodies where mariculture operations are located. As such, it is likely that such areas will be subject to operational monitoring, as defined under the WFD. Specifically, fish farms will probably be assessed as potentially affecting the quality of the benthic fauna, the phytoplankton and angiosperm communities, and also hydrochemical conditions such as nutrient and dissolved oxygen concentrations. However, the position of aquaculture within the WFD also needs to be viewed from a different direction. Successful aquaculture requires good water quality. As the targets for improvements in water quality will be defined within the WFD system, it is important to assess the relationships between the WFD targets and the requirements of aquaculture. b) In order to foster a sustainable development of coastal and marine aquaculture, there is a need to diversify production and to cultivate new species. A pro-active approach is

	required to avoid mistakes made previously when salmonid farming was developing. Mitigation strategies based on sound scientific criteria in relation to the species under consideration need to be prepared at an early stage of development. Studies would have to consider the status of the natural stocks in the area, the potential genetic, trophic and behavioural interactions, and, foremost and specifically, the development of methods for recovery of escaped fish in the event of large-scale escapements. This subject seems to be of particular importance for non-migratory fish stocks with small, localized populations (e.g., sea bass and seabream), or migratory species with different migratory patterns than salmonids (e.g., cod, halibut, turbot, and wolffish and other species). c) A number of technologies and support systems are presently under development, some of which have been outlined in the WGEIM 2002 Report. These should be evaluated and compared, with the aim to prepare a review publication on the requirements for a DSS system tailored to the needs of mariculture, that builds on the state of the art and/or links to existing systems.

4 DRAFT DISCUSSION SUMMARY OF THE MARAQUA REPORT WITH A VIEW TO ASSESSING THE IMPLICATIONS OF THE WATER FRAMEWORK DIRECTIVE (WFD) IN EU MEMBER STATES, ON THE SUSTAINABILITY OF MARICULTURE IN COASTAL AND TRANSITIONAL WATERS

The Water Framework Directive (WFD) was examined concerning how it would allow implementation of MarAqua within the context of the EU Commission's Strategy for Sustainable Development of European Aquaculture. That strategy clearly builds on reports from the EU MarAqua Concerted Action in the areas of monitoring and aquaculture codes of practice. As well it contains elements that reflect the advice that has been offered by the WGEIM on subjects such as integrated coastal zone management. The EU member states' national competent authorities are now in the process of implementing guidelines associated with the WFD. Some aspects of the Directive implementation deserve consideration.

There are still significant uncertainties in the definition of what constitutes a water body and the subsequent classification process. It is not clear whether national authorities will define water bodies of sufficient size to allow for aquaculture to be considered as one of many pressures on water quality within a large body of water. Alternatively, pollution control authorities might call for definition of much smaller water bodies that allow for a direct relationship between individual significant sources of pollution and much smaller water bodies. In our opinion the former approach is desirable and more consistent with the philosophy of the WDF in that it deals with each potential polluter in relation to other activities operating within and impacting on the coastal zone.

In relation to the classification of water bodies, it is not presently clear how the national schemes, and subsequently the inter-compared schemes, will accommodate differences in the values of biological or hydro-chemical elements within water bodies. How this is to be done is clearly of importance to mariculture activities, as mariculture sites will present pressures on the environment and some of the elements of the assessment will be at less than reference status at these sites. Again, this question is not confined to mariculture. Many other anthropogenic activities that result in waste discharges are subject to the same uncertainties.

At this time it is not clear that member states have given much consideration to measures required to improve the ecological quality of water bodies (mitigation measures). However, it can be anticipated that additional management and mitigative actions may be required of aquaculture operations in some areas where good ecological status has not been achieved.

It is clear that the promotion of sustainable European aquaculture does not conflict with the requirements of the WFD. Aquaculture should therefore not seek "special treatment". Rather, aquaculture is to be viewed as a coastal zone activity in the same manner as other activities that can influence, and have requirements for, good coastal water quality, such as domestic waste disposal, agriculture, tourism and forestry. The contribution of aquaculture to ecological conditions assessed as less than good should be considered in the same manner as the contributions from other activities. In developing mitigation schemes, however, it should be noted that aquaculture can also contribute to improving the ecological status of surface water bodies.

The full analysis of this report is attached as Annex 4. Further review of the development of the WFD will be warranted as member states clarify their operational definition of what constitutes a water body and other uncertainties defined above.

5 REVIEW OF THE POTENTIAL IMPACTS OF ESCAPED NON-SALMONID CANDIDATES FOR AQUACULTURE ON LOCALIZED NATIVE STOCKS IN ORDER TO DEVELOP, AT AN EARLY STAGE, RISK ASSESSMENT AND MANAGEMENT STRATEGIES

The Working Group's considerations of this term of reference are divided into sections reviewing on a species-by-species basis the documented evidence of the impacts of escaped non-salmonid candidates for aquaculture on localized native stocks.

Work has been done reviewing the impact of a preliminary list of escaped non-salmonid aquaculture species on localized native stocks. That list includes: Plaice (*Pleuronectes platessa*), Sea bass *(Dicentrarchus labrax*), Seabream *(Sparus aurata),* Cod *(Gadus morhua),* haarder *(Mugil so-iuy),* White Sea bass *(Atractoscion nobilis),* California halibut *(Paralichthys californicus),* Asiatic flounder *(Parlichthys olivaceus),* Striped Bass *(Morone saxatilis),* Red Snapper *(Luthianus campechanus*), and *Penaeus japonicus*. Compilation of information from other species remains to be completed.

An attempt was made to identify a series of types of potential interactions that would be subject to risk assessment and potential management strategies. The list includes: competition and trophic interactions, breeding and genetic interactions, and pathogenic interactions. For each of these types of interaction operational strategies for mitigation are discussed and key areas for research are identified.

At this time no specific advice is offered to member states as the task is large and formation of recommendations is unwarranted.

The paucity of compiled information and the extent of the literature on the effects of introduced or cultured organisms suggests that when the compilation of information for this term of reference is complete, it should be considered for publication as an *ICES Cooperative Research Report*. A critical development required to control risks associated with escaped cultured organisms is the creation of cost-effective tools to discriminate between cultured and wild stocks of the same species. It was recommended that a workshop be convened with CIESM to review the Mediterranean experience with escaped non-salmonids and discuss the development of simple cost-effective tools to discriminate wild from cultured organisms. The completion of work associated with this term of reference is anticipated to span the next two years, with significant portions of the work occurring in intersessional periods.

For this term of reference, the material reviewed and preliminary discussions of that material are documented in Annex 5.

6 FORMULATE A STRATEGY TO PROTECT AQUACULTURE AGAINST THE HARMFUL EFFECTS OF EXTERNAL INFLUENCES (E.G., CONTAMINANTS, HABITAT ALTERATIONS) ARISING FROM OTHER RESOURCE USERS AND THEIR ENVIRONMENTAL IMPACTS, WITH THE AIM OF GAINING BETTER COOPERATION IN DEVELOPING MODERN TOOLS TO PREVENT OR MITIGATE NEGATIVE INTERACTIONS

A wide variety of external anthropogenic influences on aquaculture were discussed. They range from direct competition for space in the coastal zone, through eutrophication effects of upland coastal zone use, commercial fishing, toxic waste disposal, thermal discharges, effects of introductions of exotic species and others. A partial list of these activities that might affect aquaculture was tabulated with the types of interactions they might have with cage culture, seaweed culture, mollusc raft culture and mollusc bottom culture.

It is pointed out that effective control of these potential impacts requires both proactive and reactive approaches. As part of a larger picture, the possible employment of designating areas for coastal zone development on a thematic basis (e.g., food production, travel, or recreation) and/or specific use areas (e.g., shellfish culture, marinas, parks) was explored as one option. This approach addresses the spatial distribution of other activities relative to aquaculture. More work, however, is required to elaborate desirable management methods that will allow for the terms of tenure required to undertake some coastal activities in a financially and socially viable manner while promoting the flexibility to alter the mix of area uses in response to changing environmental, economic and social conditions. During the intersessional period other options will be explored for inclusion in the report from the next meeting.

Work completed on this term of reference at this meeting is documented in Annex 6. Completion of this term of reference will require two more working group meetings. The final document should be reviewed and considered for publication as an *ICES Cooperative Research Report*.

7 PRELIMINARY REPORT ON AN EVALUATION OF EXISTING DECISION SUPPORT SYSTEMS (DSS) TOOLS, GIS AND OTHER EXPERT SYSTEMS IN ORDER TO DERIVE STRATEGIC ADVICE ON THE CONTENT OF A DSS FOR MARICULTURE, AND ALSO TO IDENTIFY POTENTIAL LINKAGES TO EXISTING TOOLS PRESENTLY BEING DEVELOPED, TESTED OR ALREADY USED IN COASTAL MANAGEMENT SCHEMES

Mariculture is no longer the concern of only fish farmers and managers—it involves all other users of the coastal zone as well as consumers and environmentalists. The circle of stakeholders is expanding, with animal rights activists and other groups not obviously connected to mariculture becoming involved. Yet while the number of people who need to receive and understand scientific advice increases, the size of the research community is not growing proportionately to the work load.

As a result of these changes, mariculture can no longer be considered an isolated activity, but must rather be considered in the general context of Integrated Coastal Zone Management (ICZM), and in fact, especially given the growing crisis in wild fisheries, it has become an increasingly important component of the global food production system.

This has led to increased interest in the development of expert systems and related tools for the evaluation, presentation and communication of scientific as well as socio-economic information. These tools include Geographical Information Systems (GIS) to store spatial information in a way that can easily be accessed, displayed, and represented, and Decision Support Systems (DSS) to provide scientific advice in a form that can readily be understood and evaluated by managers and stakeholders without a scientific background. This report elaborates on ways in which these tools can be used, both within the sphere of mariculture proper and in the broader context of coastal zone management.

The Decision-Making Process

Development of decisions about coastal zone planning, including mariculture, involves several steps and requires a framework for ensuring adequate input from all concerned parties, including not only traditional stakeholders with an evident direct interest but also environmental groups, local residents, and consumers. First of all, there must be agreement on a set of environmental quality objectives, which is a key starting point for all aspects of ICZM.

It is important that the decision-making process be transparent and understandable by those affected, which means that while it may be very complex, both the results and the process which produces them must be presented in a way that can be reviewed and interpreted by people with a wide range of skills, training, and education. It also needs to be accessible to the stakeholders, which in practice means a degree of accessibility to the general public. If it is maintained under strict government or industry control, then it is unlikely to earn the trust of other stakeholders. For this reason it is important to design these systems with public accessibility in mind, similar to the practice of releasing official documents to libraries rather than restricting them to government offices.

This can lead to problems with proprietary data, such as confidential farm production figures and financial statistics. Access to databases containing such data must contain safeguards against improper use. There are mechanisms to deal with this, and many countries have online statistical databases where the data that a user can see depends on passwords and access codes. This type of approach offers a good model for access to mariculture data.

Conflict Resolution

The circle of stakeholders is so large that conflict is inevitable, and one of the major functions of an Expert System is to provide information that can be used in resolving these conflicts. It is not realistic to expect a DSS by itself to resolve conflicts — they ultimately have to be settled by human beings. It can however play a useful role in clarifying the scientific and technical issues.

In developing DDS there are economic, social and political factors that have to be considered. Additionally, it is not always clear what the objectives of the stakeholders are, since they often involve value judgements about which there is a degree of dissimulation. Expert systems need to be sufficiently robust to allow for these considerations, and ultimately a high degree of human intervention is required to interpret the results meaningfully.

Risk and Uncertainty

There are several sources of uncertainty in the complex models used in assessing and predicting the environmental interactions associated with mariculture. Uncertainty in scientifically measured parameter values should be the easiest to deal with, since responsible researchers should assign confidence regions to all measurements, and Expert Systems should be designed to accept ranges (rather than point estimates) as inputs and to carry out propagation of error analyses so that their outputs also are expressed in terms of confidence intervals. There are further uncertainties that arise from stochastic processes in the environment which are more difficult to deal with, although they can usually be estimated from historical data. Additional uncertainties may reflect bias in the data, and these uncertainties—whether real or perceived—can be a cause of distrust and dissension. Some stakeholders may question information provided by other stakeholders and may want to have the flexibility to adjust the inputs to fit their own estimates. In such a situation it is important that users of the Expert System have a high degree of flexibility in how they treat the data, including freedom to change any input values that they consider questionable.

A GESAMP Working Group has been charged with the task of producing a review report and guidelines for risk assessment of coastal aquaculture, aimed at promoting harmonisation and consistency in the treatment of risk and uncertainty, and improved risk communication. The work of the GESAMP working group will have major implications for the future work of WGEIM.

Geographical Information Systems

Geographical Information Systems (GIS) can be a powerful, versatile and comprehensive visual tool in any decision support system for Integrated Coastal Zone Management (ICZM) in the context of ICZM.

While it is clear that GIS can be a valuable tool for management of mariculture, especially in the context of ICZM, there is a need for guidelines to ensure proper use:

- The quality and permanence of data must be identified by the use of metadata (data about data) which specify the provenance of data along with information about their reliability;
- Proprietary data must be securely maintained so that access to it and also modification of the metadata are restricted;
- Maintenance of GIS databases is mandatory and is a significant task—for example, subsequent dredging or siltation may compromise old data on bathymetry, and tidal flows can be affected by construction;
- Since most GIS program involve expensive software and powerful computers, providing good public access to the information is difficult. Web-based readers may be the best solution, and some GIS packages now support this approach (although often at a loss of resolution). This method has the advantage that layers that contain proprietary data can be omitted from the web version and can be accessed only on secure computers. Alternatively, confidential data can be protected by password-based access methods.

Rule-Based Systems

While this report is not intended to go into the details of Expert System design, it should be noted that many of these are *rule-based*, meaning that they are formulated in terms of IF…THEN sets of rules.

There is growing interest in the development of fuzzy rule-based systems, which permit the introduction of factors which are difficult or impossible to quantify, but which in practice are often taken into account. Some of these fuzzy factors are technical ones for which there are no clear-cut definitions, such as depositional vs. erosional sites on the seabed, while others represent subjective assessments about recreational potential and natural beauty.

Perhaps the greatest advantage of rule-based systems is their transparency, since each rule can be expressed in comprehensible language that can be understood and discussed by the stakeholders.

Scale Issues

There are important issues of scale involved with consideration of mariculture interactions. Some concerns, such as the self-effects of a farm on itself, can be evaluated on a very small spatial scale. Others, such as the possibility of eutrophication of an entire inlet, involve larger spatial scales.

The Limits of Decision Support

Decision Support tools are attractive, and in some cases it appears that they may even be too attractive; there are cases where prototype systems based on hypothetical data have been misunderstood and implemented prematurely by hard-pressed bureaucrats. There are limitations to their use, and these need to be understood.

The most important single point to raise is that Decision Support is not the same thing as Decision-Making. The human element cannot be removed from the Decision-Making process, and any attempts to do so will almost certainly fail.

There are several reasons for this. The main reason is that human decisions inevitably include parameters that no one will enter into a computer program. For example, no politician will ever admit that one of his chief concerns is re-election, but this will inevitably affect his decisions. Even though decisions about mariculture need to be made in the broader context of ICZM, this does not ensure that all interactions are included, and it is not possible to circumscribe the scope of considerations that might ultimately arise.

The scope of Decisions Support is limited, and pragmatic solutions to environmental problems often go far beyond what can reasonably be included in a DSS. If DSS are to prove useful, it must be possible to use them as a starting point rather than a final answer. The part of the process that a DSS encompasses must be transparent and dynamic so that whatever advice it generates can be extended and applied. A "black box" whose workings are hidden and whose output is cryptic will ultimately never be accepted.

The full report of discussions on this term of reference is included in Annex 7. In that Annex a number of other aspects are discussed including: modelling, monitoring and mitigation; environmental impact assessments, metadata and knowledge; a general approach to site-specific monitoring and management; and the use of traffic-light methods to display the results of complex decision support systems.

The discipline covered in this term of reference is undergoing rapid evolution as many countries make progress towards implementation of ICZM. It is felt that another review of this area in the near future is warranted and would provide Member Countries with insight into significant new developments in this area.

8 A MULTI-ANNUAL PLAN FOR COMPLETING THE WORK EMBODIED IN THE ABOVE TERMS OF REFERENCE

Work on terms of reference:

a) prepare a draft discussion summary of the MARAQUA report with a view to assessing the implications of the Water Framework Directive (WFD) in EU member states, on the sustainability of mariculture in coastal and transitional waters;

and:

d) prepare a report on an evaluation of existing Decision Support Systems (DSS) tools, GIS and other expert systems in order to derive strategic advice on the content of a DSS for mariculture, and also to identify potential linkages to existing tools presently being developed, tested or already used in coastal management schemes;

has progressed to a stage where developments external to WGEIM are required before further elaboration on these terms of reference can be undertaken.

In the case of term of reference a), developments in member countries require on-going monitoring to address how the implementation of the WFD is ultimately likely to affect the sustainability of mariculture. It is felt that over the next two years the implications of the WFD implementation in member countries will become clearer and for this reason it is suggested that annual updates on the implementation strategies be undertaken with the intent of more clearly defining the impact of the WFD on sustainability of aquaculture.

In relation to term of reference d), it is noted that the implementation of integrated coastal zone approaches to marine resource management has only begun in many member countries and rapid evolution of this approach is anticipated over the next few years. It was felt that member countries would find it of great value to return to review progress in the use of these tools in two years as significant progress should be made towards the implementation of integrated management.

The term of reference:

b) prepare a review of the potential impacts of escaped non-salmonid candidates for aquaculture on localized native stocks in order to develop, at an early stage, risk assessment and management strategies;

represents a very sizeable review of the literature as well as the distillation of a series of general considerations that might form the framework for development of risk assessment and management strategies. In this context it was felt that the proposed collaboration with FAO Working Group 31 (see recommendations for further work) would provide substantial material for the completion of this term of reference. It is anticipated that this work will require two more years for completion. To accomplish that in two years there must be significant progress in the intersessional periods.

Term of reference:

c) formulate a strategy to protect aquaculture against the harmful effects of external influences (e.g., contaminants, habitat alterations) arising from other resource users and their environmental impacts, with the aim of gaining better cooperation in developing modern tools to prevent or mitigate negative interactions;

involves consideration of a broad array of potential options. Consideration of licensing regimes as well as developments in environmental economics and planning need to be more fully covered. The absence of the working group members who usually address these considerations has resulted in a need for intersessional work to more fully outline the breadth of the task. It is anticipated that completion of this term of reference will require an additional two years.

9 ANY OTHER BUSINESS

Building on the work carried out at the last meeting of WGEIM, and during the subsequent intersessional period, Ian Davies and Kats Haya presented a draft of the second edition of the *ICES Cooperative Research Report* on “Chemicals used in Mariculture”.

The structure of the report was similar to that employed in the first edition, and included sections on:

- Veterinary Medicines Licensing Controls;
- Mechanisms by which Mariculture Veterinary Medicines may Impact on the Environment;
- Efficacy and Safety of Chemotherapeutants;
- The Chemicals;
- Data Sheets and Bibliographies;
- Chemicals Displaced from 1st Edition;
- Quantities of Chemicals Used;
- Short listings (of chemicals that are very rarely used);
- And appendices covering:
  - Terms and Abbreviations Relating to Therapeutic Chemicals;
  - Names of Compounds: Cross Index;
  - References from Previous Edition (CRR 202).

WGEIM approved the report and recommended that the draft technical report on “Chemicals used in Mariculture” be passed to ACME for publication in the *ICES Cooperative Research Report* series.

10 ADOPTION OF THE REPORT AND RECOMMENDATION FOR NEXT MEETING

WGEIM approved the draft report and the recommendations resulting from the meeting (Annex 8), subject to final editorial work by the Chair.

11 CLOSING OF THE MEETING

This meeting in Vigo, Spain was formally closed on 2 April 2003.

ANNEX 1: LIST OF PARTICIPANTS

Name	Address	Telephone no.	Fax no.	E-mail
Hans Ackefors	Department of Zoology Stockholm University SE-10690 Stockholm Sweden	+46 8 164 020	+46 8 167 715	hans.ackefors@zoologi.su.se
Edward Black (Chair)	Department of Fisheries and Oceans Aquaculture Science Branch 200 Kent St. Ottawa, Ontario Canada	+1 613 990 0272	+1 613 993 7665	blacke@dfo-mpo.gc.ca
Scott Campbell	Dep.. of Fisheries and Oceans Northwest Atlantic Fisheries Centre P.O. Box 5667 St.John's, NL A1C5X1 Canada	+1 709 722 2000	+1 709 772 5315	campbells@dfo-mpo.gc.ca
Ian M. Davies	Fisheries Research Services Marine Laboratory P.O. Box 101 375 Victoria Road Aberdeen AB11 9DB United Kingdom	+44 1 224 876 544	+44 1 224 295 511	daviesim@marlab.ac.uk
Antoine Dosdat	IFREMER Scientific Direction 155 Rue Jean Jacques Rousseau 92138 Issy Les Moulineaux France	+33 146 482 256	+33 146 482 121	adosdat@ifremer.fr
Arne Ervik	Institute of Marine Research P.O. Box 1870 Nordnes N-5817 Bergen, Norway	+47 55 238 500	+47 55 238 531	arnee@imr.no
Kats Haya	Dept. of Fisheries & Oceans Biological Station 531 Brandy Cove Road St Andrews, N.B. ESB 2L9 Canada	+1 506 529 5916	+1 506 529 5862	hayak@mar.dfo-mpo.gc.ca
José Iglesias	Instituto Español de Oceanografia Centro Oceanográfico de Vigo Apartado 1552 36280 Vigo Spain	+34 986 492 111	+34 986 492 351	jose.iglesias@vi.ieo.es

Name	Address	Telephone no.	Fax no.	E-mail
Thomas Landry	Department of Fisheries and Oceans Gulf Region P.O. Box 5030 Moncton, N.B. E1A 4Y1 Canada	+1 506 851 6219	+1 506 851 2079	landryt@dfo-mpo.gc.ca
Terry McMahon	Marine Institute Snugboro Road Abbotstown Dublin 15, Ireland	+353 1 822 8200	+353 182 05078	terry.mcmahon@marine.ie
Teresa Nunes	Instituto Español de Oceanografia Centro Oceanográfico de Vigo Apartado 1552 36280 Vigo Spain	+34 986 492 111	+34 986 492 351	teresa.nunes@vi.ieo.es
José Benito Peleteiro	Instituto Español de Oceanografia Centro Oceanográfico de Vigo Apartado 1552 36280 Vigo Spain	+34 986 492 111	+34 986 492 351	tito.peleteiro@vi.ieo.es
Harald Rosenthal	Institut für Meereskunde an der Universität Kiel Düsternbrooker Weg 20 D-24105 Kiel, Germany and: Schifferstrasse 48 21629 Neu Wulmstorf Germany	+49 40 700 6514	+49 40 701 02676	Haro.train@t-online.de
William Silvert	IPIMAR Avenida de Brasilia s/n Lisbon Portugal	+351 919 355 925	+351 213 015 948	wsilvert@ipimar.pt
Uwe Waller	Institut für Meereskunde an der Universität Kiel Düsternbrooker Weg 20 D-24105 Kiel, Germany	+49–431–600–1630	+49–431–600–1631	uwaller@ifm.uni-kiel.de

ANNEX 2: AGENDA

Working Group on the Environmental Interactions of Mariculture

Vigo, Spain, 30 March–4 April 2003

Monday, 31 March

09:00 Greeting and Thanks to Local Organizer

09:15 Review, possible modifications and adoption of agenda

09:30 Official Welcome

09:40 Selection of Rapporteur

09:50 Review of terms of Reference

10:10 Miscellaneous

- Attendance at dinner
- Attendance at excursion
- List of Participants
- Degradation of environment and the roles of Aquaculture
- Comment on work of GESAMP WG32 on risk and uncertainty in governance of mariculture.
- Review of support documentation for work on MARAQUA and EU Water Framework Directive
- Review of support documentation for other terms of reference
- Identification of library resource requirements

10:30 Health Break

10:55 Examination of Water Framework and MARAQUA and other supporting documentation

13:00 Lunch Break

14:00 Discussion of MARAQUA and approach to comments on Water Framework

15:00 Identification further library resource requirements

15:15 Identification of subgroup members and break to drafting subgroups

15:30 Health Break

17:30 Bus to Hotel

Tuesday, 1 April

08:30 Review of previous days work

09:00 Identification of subgroup members and break to drafting subgroups

10:30 Health Break

13:00 Lunch Break

14:00 Suggestions for tentative recommendations

15:30 Health Break

17:30 Bus to Hotel

20:30 Group dinner -

Wednesday, 2 April

08:30 Review of previous days work

09:00 New issues and break to drafting subgroups

10:30 Health Break

13:00 Lunch Break

14:00 Afternoon Excursion – visit to mussel cultivation area and training centre for aquaculturlists

Thursday, 3 April

08:30 Review of previous days work

09:00 Suggestions for tentative recommendations and break to drafting subgroups

10:30 Health Break

13:00 Lunch Break

14:00 Suggestions for venue for next meeting then return to drafting sessions

15:00 Review of draft work to date and development of multiyear workplan for WG.

15:30 Health Break

17:30 Bus to Hotel

Friday, 4 April

08:30 Review and final daft of recommendations and work plan

09:00 Report review and final modifications

10:30 Health Break

13:00 Lunch Break

15:30 Health Break

15:00 Approval of contents of draft reports

17:30 Bus to Hotel

ANNEX 3: COUNTRY REPORTS

CANADA

Submitted by: K. Haya
Fisheries and Oceans, Biological Station, St. Andrews, New Brunswick

Production

Revenues from Canada's aquaculture industry declined moderately in 2001 after a decade of steady growth, in the wake of significantly lower prices for farmed salmon. The industry reported total operating revenues of $704.5 million in 2001, down from $722.9 million in 2000. Sales of products and services totalled $675.2 million, down 2.5%. Sales of finfish, mostly salmon, accounted for $602.0 million, or almost 90 %, of total sales. Despite an increase in production and a jump in exports, finfish sales fell 4.4 %. Significantly lower prices for farmed salmon, mainly the result of larger supplies in the United States, had a major impact on revenues.

Sales of shellfish, however, reached $65.2 million, representing 9.7 % of total sales in 2001, compared with 8.0 % in 2000. Prince Edward Island shellfish farmers generated $28.2 million in shellfish sales in 2001, more than 40 % of the national total. British Columbia remained the largest aquaculture-producing province, with sales of $293.4 million. Farmers there accounted for 43 % of the country's total aquaculture sales. An increase in finfish production was offset by falling prices of farmed salmon. As a result, total sales of finfish in 2001 fell 2.8%; sales of shellfish totalled $18 million, up 38 % from 2000. The moratorium on new site licenses that has been in effect in British Columbia was lifted in 2002. New Brunswick is the second largest aquaculture producer with sales of $279.1 million in 2001, also down as a result of lower prices. There were 94 licensed marine salmon farms, 6 sites licensed for alternate species and 24 inland freshwater smolt facilities in New Brunswick during 2002. British Columbia and New Brunswick accounted for 84% of aquaculture revenues in 2001.

Nationally, product expenses (the cost of products and services purchased from other businesses excluding capital and labour costs) totalled $466.4 million in 2001, down 1.7 % from 2000. Feed costs, which accounted for over 40 % of all product expenses for finfish producers, increased slightly to $191.8 million.

During the past decade, the export market has consistently expanded, driven in large part by demand for salmon in the United States. In 2001, the value of aquaculture exports, which totalled $444.3 million, increased 17 % from 2000, more than triple 1992 levels. The aquaculture industry produced a gross output—including sales, subsidies and growth in inventories—of $738.9 million in 2001, down 4.8 %. The gross value added by the industry to the economy, the difference between gross output and total product expenses, reached $274.7 million, down 9.6 % from 2000.

Table 1. 2001 Canadian Aquaculture Production Statistics (tonnes).

	Nfld	PEI	NS	NB	Que	Ont	Man	Sask	Alta	BC	CANADA
Finfish											
Salmon	1,092	x	2,614	33,900	-	-	-	-	-	67,700	105,306 (2)
Trout	-	x	-	550	875	4,100	16	875	x	100	6,516 (2)
Steelhead	1,719	-	2,986	-	-	-	-	-	-	-	4,705 (2)
Other (1)											1,558 (1)
Total Finfish (3)	2,811	76	5,600	34,450	875	4,100	16	875	x	67,800	118,161
Clams	-	-	-	-	-	-	-	-	-	1,400	1,400
Oysters	-	2,731	438	744	-	-	-	-	-	6,800	10,713
Mussels	1,452	17,506	1,619	750	339	-	-	-	-	-	21,666 (2)
Scallops	-	-	8	-	-	-	-	-	-	120	128 (2)
Other	-	-	402	-	53	-	-	-	-	-	455
Total Shellfish	1,452	20,237	2,467	1,494	392	-	-	-	-	8,320	34,362
Total	4,263	20,313	8,067	35,944	1,267	4,100	16	875	x	76,120	152,523

Table. 2001 Canadian Aquaculture Production Statistics (' $000).

	Nfld	PEI	NS	NB	Que	Ont	Man	Sask	Alta	BC	CANADA
Finfish											
Salmon	5,200	x	14,361	180,010	-	-	-	-	-	269,400	468,971 (2)
Trout	-	x	-	6,100	4,674	16,900	62	3,859	x	500	32,095 (2)
Steelhead	9,752	-	9,777	-	-	-	-	-	-	-	19,529 (2)
Other (1)											17,659 (1)
Total Finfish (3)	14,952	733	24,138	186,110	4,674	16,900	62	3,859	x	269,900	538,987
Shellfish											
Clams	-	-	-	-	-	-	-	-	-	7,700	7,700
Oysters	-	6,324	1,327	2,040	-	-	-	-	-	7,300	16,991
Mussels	3,929	23,200	2,002	825	543	-	-	-	-	-	30,499 (2)
Scallops	-	-	88	-	-	-	-	-	-	700	788 (2)
Other	-	-	2,096	-	82	-	-	-	-	-	2,178
Total Shellfish	3,929	29,524	5,513	2,865	625	-	-	-	-	15,700	58,156
Total	18,881	30,257	29,651	188,975	5,299	16,900	62	3,859	x	285,600	597,143

(1) Includes Char, Other Finfish and Total Alberta Finfish.

(2) Excludes Confidential Data.

(3) Excludes "Other" for provinces.

The data, collected from each of the provincial departments responsible for aquaculture, are considered accurate and reliable.

The data will continue to be collected in the year following the reference year and released that September.

Issues:

Sea Lice and Pinks in BC

Fisheries and Oceans Canada (DFO) implemented new initiatives designed to assess and protect the health of the wild Pink Salmon resource in the Broughton Archipelago. The Pacific Fisheries Resource Conservation Council (PFRCC) released an advisory in November 2002 indicating there was strong anecdotal evidence to suggest the pink salmon declines were linked to sea lice infestations associated with salmon farms in the area. While the PFRCC acknowledged that there is scientific uncertainty over the cause of the decline, it is important that DFO take immediate action to ensure that Broughton Archipelago pink returns are protected. In addition, it is equally important that additional research be carried out to clarify scientific understanding and ensure the long-term well-being of the pink salmon resources.

The department is working on developing a five-part comprehensive Action Plan to address potential risks to wild pink salmon stocks. The Action Plan will include a freshwater monitoring program, a marine monitoring programme, an active salmon farm management approach, a long-term research plan and a public consultation/dialogue process. A key focus of the plan being developed is related to providing a migratory corridor in the area during the pink salmon out-migration. A workshop was held in February 2003 which identified the scientific information gap and proposed research plans for environmental effects, management of sea louse out beaks in the cage sites and potential impact of sea lice on wild salmon.

Infectious Salmon Anemia (ISA)

ISA continues to be a problem in New Brunswick where 1.3 million fish in 43 cages and 8 salmon aquaculture sites were positive for ISA in 2002. The problem was significantly more advanced than the previous two years but reduced from the peak in 1999. This represents a direct cost of $6.9M and lost revenues of $34M. Research and development of vaccines is encouraging but current industry/government management practices do not appear to be effective in controlling the epidemic.

Super Chill

Within the southwest New Brunswick of the Bay of Fundy in 2003, subzero degrees Celsius water temperatures were recorded during both February and March. Water temperatures in more offshore waters of the Bay of Fundy were less than 1C in March. These temperatures are not unusual and similar values have been recorded in previous years in the inshore areas. Eighty years of historical offshore temperature records indicate that such temperatures have been recorded in the past. During most winters, the offshore water temperatures are generally a few degrees above zero. However, an unusually long period of cold atmospheric temperatures in January–February 2003 caused water temperatures in shallow inshore areas and areas near extensive inter-tidal flats to be reduced by several degrees relative to offshore temperatures. Water temperatures in some salmon cage sites approached −0.2 degrees. Consequently it is estimated that at least 2 million salmon died from this unusual situation. It is expected that the final count may reach 3 million dead salmon in New Brunswick and Maine (USA) aquaculture sites. Haddock and halibut die-off have also been observed at four of six alternate species experimental sites.

Harmful Algal Blooms

The Pacific Coast mariculture industry experienced salmon moralities associated to the following algae species bloom: *Heterosigma* (14,000,000 cells/L), *Chaetoceros convolutus* (180,000 cells/L), *Chatonella* (200,000 cells/L) and *Chaetoceros concavicornis*. In the Bay of Fundy, low levels of salmon moralities were observed during an extended *Eucampia* bloom (962, 000 cells/L).

Contamination of shellfish with paralytic shellfish toxins is an annual occurrence in many regions of Canada. In 2002 the concentrations of PSP toxins above the regulatory levels resulted in shellfish harvesting closures in the following regions: the West Coast (*Alexandrium catenella*), the St. Lawrence Estuary (*A. tamarense*) and the Bay of Fundy (*A. fundyense*). Shellfish harvesting was closed due to domoic acid (probable cause - *Pseudo-nitzschia seriata*) in Newfoundland and the St. Lawrence Estuary, which represents the largest closure on record. This could also represents the first closure associated to the occurrence of this species of *Pseudonitzchia* as well as the timing (early spring) of this closure for Atlantic Canada. This also affected the southern Gulf of St. Lawrence where most of the shellfish aquaculture is occurring on the east coast of Canada. Organisms observed included: *P. multiseries*, *P. pseudodelicatissima*, *P. fraudulenta* and *P. pungens*.

Tunicate infestation on mussel farms in Prince Edward Island

The club tunicate (*Styela clava*) is an invasive species that was found for the first time in Canada in 1999, in Georgetown Harbour, Prince Edward Island. Since that time it has spread to several economically significant mussel production areas of PEI. The club tunicate reduces mussel productivity and increases costs associated with defouling on site, as well as at the processing plant. The tunicate also impedes seed collection and relay for grow out, as well as transfers for open-effluent processing. Another impact is the seasonal die-off of the tunicates and associated environmental degradation. A related tunicate (*Ciona intestinalis*) in Nova Scotia resulted in the abandonment of the mussel farm in the affected area (1997–1999).

DFO is collaborating with the Atlantic Veterinary College, the PEI Shellfish Aquaculture Alliance and the PEI Department of Fisheries, Aquaculture and Environment, on monitoring and research projects. These are aimed at biological factors which contribute to tunicate proliferation as well as chemical control measures.

Requests for shellfish transfers are reviewed and transfers that pose a high risk are not approved. The tunicate infestation has been particularly devastating for processing PEI mussels as well as on mussel seed sales to NS and NB. To date, the club tunicate appears restricted to PEI while the sea squirt (*C. intestinalis*) is mainly found in Nova-Scotia.

MSX infection of shellfish

Multinucleate Sphere X (MSX) is a parasite that infects oysters and is a health problem with the American oyster (*Crassostrea virginica*). MSX was detected in oysters from St. Patrick's Channel, Bras d' Or Lake, Cape Breton. Fisheries and Oceans Canada (DFO) and provincial fisheries departments collected oysters from 22 sites throughout the Maritimes. Since 23 October 2002, four out of nine sites sampled in Cape Breton showed the presence of MSX (in addition to the original sites in St. Patrick's Channel). DFO has found MSX at very low levels in samples from Prince Edward Island. Six samples from the Gulf of St. Lawrence shore of New Brunswick, one from Gulf shore of Nova Scotia and one from south-west Nova Scotia have shown no evidence of MSX. MSX is not a human health concern. DFO has contacted the provinces to discuss control options.

Research

Fisheries and Oceans:

- Monitored water temperature, salinity, DO, nutrients, phytoplankton and zooplankton at an oceanographic monitoring station located in the Bay of Fundy.
- Monitored annual and geographical variations in shellfish productivity and water temperature in several embayments in the southern Gulf of St-Lawrence.
- Developed circulation and transport models to help address Bay Management and Disease Management issues.
- Studied the balance between oxygen removal by fish respiration and oxygen insertion by water flow through the cages. The ratio of oxygen utilisation rate to cage or bay flushing rate models will aid in determining carrying capacity of specific areas.
- As a result of concerns over recent siting decisions in southern Grand Manan a research project to address harvest fishery displacement and wild lobster health concerns was initiated.
- Applied an ecosystem approach to study environmental interactions on two mussel farms in coastal Newfoundland.
- Studied the interactions between suspended mussel culture activities in Prince Edward Island, Canada, and the coastal ecosystem. Biological-physical models were developed to address broad-scale questions regarding system productive capacity, aquaculture/land-use interactions, and ecosystem health.
- Studied the interactions between suspended oyster culture activities in New-Brunswick, Canada, and the benthos.
- Evaluate the use of acoustic methods to assess and monitor benthic characteristics in relation to shellfish aquaculture.
- Evaluate mussel reproduction biology and genetic changes in relation to husbandry practices in aquaculture.
- Study the impact of the invasion of tunicates in coastal systems on shellfish aquaculture. Develop control and management approaches.
- Develop management strategies to coordinate new and existing aquaculture activities to traditional and developing fisheries activities to optimise productivity and environment health of coastal systems.
- Particulate matter and dissolved nutrients released from cages (as excretory products, faeces and uneaten food

pellets) were detected in water and sediments away from farm sites.

- Mass balance models were developed to assess the relative contributions from salmon aquaculture with respect to other natural and anthropogenic sources of nutrient loading.
- Increased levels of copper, zinc and organic contaminants in fish feed measured in sediments at variable distances away from farm sites were observed. High values for copper and zinc were correlated with enrichment in sedimentary organic matter.
- A traffic light decision system (DSS) was developed to serve as a management tool to assess far- and near-field variables potentially affected by marine finfish aquaculture.
- Effects of sea lice chemicals on wild indigenous species were studied. Included are studies on the effects of emamectin benzoate on spawning success and induction of premature molt in lobsters.
- Studied the occurrence of antibiotic resistant aerobic bacteria in relation to salmon aquaculture facilities.

Environment Canada

- Published an EPS Surveillance Report (EPS-5-AR-02-01) titled, "Metal levels in sediment samples collected under salmon aquaculture net pens in the Bay of Fundy" which summarised sediment monitoring results from 1999 to 2001 for metals, primarily copper and zinc.
- Conducted amphipod toxicity tests on sediment samples collected near salmon farms and on reference sediment spiked with copper-based antifouling compounds. Even at 5 times the CCME "Probable Effects Level"; we did not observe any increased mortality among the amphipods.
- In conjunction with a couple of community groups, an investigation of the potential for endocrine disruption and the incidence of mussel leukaemia near aquaculture sites was initiated. Wild blue mussels and sediments were collected from aquaculture areas, municipal waste water sites, near industries (pulp mill, fish processing plant), and control areas along the Annapolis Basin in Nova Scotia and in Passamaquoddy Bay in New Brunswick..
- Assessed the potential ecological risk to the marine environment of chemicals used in Atlantic Canada aquaculture operations, based on their aquatic toxicity, physical-chemical properties, and exposure potential issues (including an evaluation of use pattern information compiled by Muise and Associates, 2000). Prioritised or ranked these chemicals, based on potential ecological risk to marine species.
- Monitored sediments around a salmon farms for traces of emamectin benzoate following sea lice treatment.

Aquaculture Collaborative Research and Development Programme (ACRDP)

The ACRDP is a Department of Fisheries and Oceans (DFO) initiative to increase the level of collaborative research and development activity between the aquaculture industry and the Department. ACRDP funding is approximately $4.5 million per year for 5 years starting in 2000. ACRDP is an industry-driven program that partners industry with DFO researchers. Industry establishes research priorities and helps fund research. The programme allocates ACRDP funds to collaborative research projects that are proposed and jointly funded by aquaculture producer partners. Research funding remains within DFO and 40 projects are presently funded.

Aquanet

AquaNet is a Network of Centres of Excellence for aquaculture in Canada funded by Natural Sciences and Engineering Research Council and Social Sciences and Humanities Research Council through Industry Canada. Networks of Centres of Excellence are unique partnerships among universities, industry, government and non-governmental organisations aimed at turning Canadian research and entrepreneurial talent into economic and social benefits for all Canadians. Currently, AquaNet funds over 40 aquaculture research projects, engaging approximately 90 industrial partners, and over 250 researchers at 20 universities and other research facilities throughout Canada.

AquaNet has recently developed a strategic research framework as part of its goal to develop a more focused approach to research, education/training, communications and business development activities. The AquaNet Strategic Research Framework is based on the underlying principles of *innovation, risk management and traditional and local ecological knowledge*. This new strategic approach will help AquaNet in its efforts to team up and coordinate Canada's top researchers in universities, government and industry, pool skills and resources to advance and exploit leading R&D, and turn results into marketable products, processes and services. In the new round of funding for 2003–2006, AquaNet will invest in projects that address key research questions that support its goal of fostering a sustainable aquaculture sector in Canada.

On 5 February 2003, AquaNet and the Norwegian Fiskeriforskning, Institute of Fisheries and Aquaculture Research, signed a formal agreement for aquaculture research collaboration. AquaNet will facilitate the placement of research personnel from Fiskeriforskning into AquaNet core facilities and network research laboratories across Canada and the Norwegian Institute will receive AquaNet researchers to jointly conduct research in advancing sustainable aquaculture through partnerships with industry and government.

A collaborative project between Fisheries and Oceans, University of BC and Simon Fraser University to evaluate of the flesh quality of market-size farmed and wild Canadian salmon was initiated in February 2003. This study will compare the flesh quality of each of the three species of farmed salmon (coho, Atlantic and chinook, that have originated from oceanographically distinct regions) to that of wild Pacific salmon (from same regions as well as from the open ocean and before packaging at the processing plant). Collectively, the foregoing information is essential to ensure that BC salmon, regardless of their origin, are of the highest quality for the consumer with respect to issues related to their concentrations of potential contaminants, antibiotics, antimicrobials, sensory, and nutritional attributes.

Recent Fisheries and Oceans Documents

- Interim guide to the application of Section 35 of the fisheries act to salmonid cage aquaculture developments, January 23, 2002.
- Interim guide to information requirements for environmental assessment of marine finfish aquaculture projects, January, 18, 2002.
- Interim guide to information for environmental assessment of marine shellfish aquaculture projects, January 18, 2002.
- Interim guide to fisheries management sector role in the evaluation of aquaculture site applications, January 18, 2002.
- Interim guide to consideration of effects of environmental change on socio-economic conditions under CEAA relative to aquaculture projects. Operational policy guidance, January 18, 2002.
- A scientific review of the potential environmental effects of aquaculture in aquatic ecosystems. Volume 1: Far-field environmental effects of marine finfish aquaculture (B.T. Hargrave); Ecosystem level effects of marine bivalve aquaculture (P. Cranford, M. Dowd, J. Grant, B. Hargrave and S. McGladdery); Chemical use in marine finfish aquaculture in Canada: A review of current practices and possible environmental effects (L.E. Burridge).

GERMANY

Submitted by: Uwe Waller, Harald Rosenthal,
Institute fur Meereskunde, Kiel, Germany.

Production

Coastal mariculture activity in Germany is still relatively small in comparison with other European countries. This may be expected, given the limited coastal area available.

Finfish production in marine and brackish waters remains minimal. There are a few family-operated small-scale cage farms (Kiel Fjord, Mecklenburg-Vorpommern) that produce rainbow trout. One large farm produces turbot (*Scophthalmus maximus*) and sea bass (*Dicentrarchus labrax*) on land in Schleswig-Holstein, and is based on a large-scale recirculation system. Another recirculation facility is working with *Peneaus vannamei* in Thüringen in the south-east of Germany, i.e., far away from the coast. Some available data[1] are summarised in the following table:

Year	*Oncorhyncus mykiss* (mt)	*Dicentrarchus labrax* (mt)
1998	60	16
1999	65	8
2000	90	53
2001	77	75

[1] FAO, Fishstat database (http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp)

Major production originates from extensive shellfish, blue mussel (*Mytilus edulis*), farming in the Wadden Sea of Lower Saxony and Schleswig-Holstein. Trends in the production over the past years are shown in the following table:

Year	*Mytilus edulis (mt)*	*Crassostrea gigas (mt)*
1998	9932	750
1999	12901	850
2000	15884	850
2001	15693	850

One oyster farm on the North Sea coast continues to operate a successful rack culture system with imported seed oysters (*Crassostrea gigas*) from an Irish hatchery.

Research

Mariculture research in Germany is directed towards

- **recirculation technology** and **integration of mariculture** systems (Institut fur Meereskunde, Kiel, http://www.marikultur.info),

- **microalgae production** with emphasis on the production of specialised substances/chemicals (Forschungs- und Technologiezentrum Westküste, http://www.uni-kiel.de/ftzwest),

- **macroalgae production** (Institut fur Meereskunde, Kiel, Alfred-Wegener Institut, www.awi-bremerhaven.de),

- and production of specialised substances/chemicals from **microorganisms** (Institut fur Meereskunde Kiel, http://www.ifm.uni-kiel.de, http://www.bioregio.com/english/regionen/rosgre.htm)

to name a few examples.

A new programme for the development of mariculture technology was announced by the Federal Research Ministry of Germany with the following justification:

In view of the local environmental loads already presented by mariculture operations in many places it is essential to develop **ecologically sound technologies**. This may allow the sustainable expansion of this type of food production. The aim is to develop **closed system technologies that embrace the entire life cycle of a species**. This programme does not apply only to the production of fish, shellfish, and crustacean but also to organisms producing valuable substances for the medicine, pharmaceutical and the health sectors.

IRELAND

T. McMahon,
Marine Institute, Snugboro Road Abbotstown, Dublin 15

1. Production statistics for finfish and shellfish inn 1999 and 2000

The available statistics for the aquaculture production of finfish and shellfish in Ireland in 2001 and 2002 are given in the table below.

	2001		2002	
Species	Volume (tonnes)	Value (€)	Volume (tonnes)	Value (€)
Atlantic Salmon	23,312	70,869,336	22,294	71,686,451
Sea Reared Trout	977	2,837,199	1,273	3,421,110
Freshwater Trout	720	1,997,949	890	2,392,000
Finfish other*	63	555,981	54	425,000
Bottom mussels	22,793	12,690,846	18,500	11,100,000
Rope mussels	7,580	4,205,141	9,000	6,840,000
Pacific oyster	4,909	7,992,654	5,500	11,000,000
Native oyster	431	2,060,160	515	2,626,500
Clam	91	426,122	100	360,856
Scallop	49	249,884	60	300,000

*Arctic char, eel, turbot

All production values are ex farm, except salmon. Salmon figures are estimated from processor monthly returns.

Production of finfish was relatively static in the years under review but the production of Atlantic salmon represented an increase of approximately 15 %–20 % relative to the production in 2000 previously reported.

Rope mussel production increased from 4,045 tonnes during 2000 to approximately 9,000 during 2002. This was due to significantly fewer closures of production areas due to the presence of biotoxins. There was a decrease in the output of bottom cultured mussels in 2002 relative to previous years. The output of pacific oysters increased during both 2001 and 2002 relative to 2000 as previously reported.

2. Fish Health (2001)

Finfish

ISA isolation and management

In July 2002, ISAV was isolated from rainbow trout on two isolated marine sites in Clew Bay owned by SeaStream Ltd. The virus was isolated as a result of an Industry approved National Screening Programme, which has been running since 2000. Clinical disease was not observed at any stage on either site.

One of the infected sites was in the process of harvesting at the time the virus was isolated. The harvesting schedule was accelerated and full bio-security measures were put in place both at the site itself and at the company's processing plant. Once empty, the site was fully cleaned and disinfected under official supervision. The site is currently undergoing a six-month fallowing period prior to restocking.

The second site had smaller (500 g) fish which were of no commercial value at the time the virus was isolated. A Risk Assessment Group was convened to determine what degree of on-growing might be considered under the circumstances. Because of the very isolated geographical location of the infected site and the fact that the fish continued to remain clinically healthy, it was decided that provided mortality levels did not exceed 0.05 % per day attributable to ISA, then the fish should be allowed to remain on site at least until the end of March, 2003. This date was chosen because it would allow all fish to be removed from the bay prior to the spring/summer wild salmonid runs and would thus minimize the chance of the virus being carried to other aquaculture facilities in the area by wild fish. However, hard information as to the exact prevalence of wild fish in the bay was unavailable to the Group at the time when the first report was written.

Industry responded to the first Risk Assessment with a request to on-grow the fish past the end of March and onto the end of June. A Second Risk Assessment Report was then prepared which concluded that the fish could only be on-grown past the end of March, provided the level of risk which was previously attributed to leaving them on site did not increase. This assessment could only be made if solid information could be gathered with respect to the number of wild salmonids (particularly sea trout) present in the bay. It has now been decided to carry out netting experiments during the months March, April and May. The information gathered during these experiments will be fed into a population model which exists for an adjacent bay, with the aim of determining whether in fact wild salmonids are present in the bay in biologically significant numbers. It has also been decided that the Risk Assessment Group will meet monthly from March to June to assess results both from the wild fish netting experiments and the results of ongoing virological testing of the rainbow trout. These fish continue to be tested virologically and to date, the virus has not been isolated since summer 2003. The conclusions of the Risk Assessment are that the fish may remain on-site until the end of March. After that date, a combination of biologically significant numbers of wild fish in the bay, plus the shedding of ISAV by the rainbow trout, will trigger the implementation of an Emergency Harvesting Plan which will empty the site in the shortest possible time frame. If the numbers of wild fish are found to be small, the fish may remain on-site until the end of June, 2003. Once empty of fish, the site will be cleaned, disinfected and fallowed for 6 months.

As required by Article 4(h) of Council Directive 93/53/EEC, an Epidemiological Study to determine the possible origin of the virus and the length of time it may have been on-site prior to detection, is currently underway. Results will be reported to the EU Commission as they become available.

All other farms in the country have been tested for ISA (using virus isolation), and found to be negative.

Shellfish

Ireland has nine exploited native oyster (*O. edulis*) beds and one producer is cultivating native oysters. The health situation in the country has not changed since 1993 with 4 areas (Clew Bay, Ballinakill Bay, Galway Bay and Cork Harbour) affected by Bonamiosis and none by Marteiliosis. Ireland has a monitoring programme for both diseases (Decision 93/56/EEC). Approved zone status was obtained from the European Commission in 2002.

3. Shellfish Biotoxins

During 2002 some 60 production areas were monitored on a weekly basis throughout the year for the presence of DSP and AZP toxins. Overall in 2002 the number of samples testing positive by the Yasumoto 1984 mouse bioassay was approximately 3 % compared with approximately 17 % during 2001. No oyster, cockle, clam or razor fish sample submitted gave a positive result. Some 2887 samples were tested by LC-MS methods during 2002. The results of the analysis showed that Okadaic acid and DTX-2 were the main toxins detected. Only 1 % of mussel samples tested had a level of AZP above the regulatory limit of 16 µg /100 g of shellfish flesh. A comparison of the results of samples tested by mouse bioassay and LC-MS showed that there was a 98 % agreement between both methods.

A total of 128 samples were submitted for PSP testing in 2002, compared with 322 samples during 2001. PSP toxicity was detected above the regulatory limit in both mussels and oysters from Cork Harbour for a 3-week period during July.

During 2002 a total of 741 ASP analyses were carried out. In June ASP toxicity above the regulatory limit (20 µg/g whole flesh) was recorded in a sample of mussels from Donegal. This was the first time that the ASP toxicity exceeded the regulatory limit in mussels in Ireland. In scallops (*Pecten maximus*) approximately 10 % of samples of gonad, 2 % of samples of adductor muscle and 32 % of total tissue analysed exceeded the regulatory limit.

4. Coordinated Aquaculture Management Systems (CLAMS)

The development of Co-ordinated Aquaculture Management Systems (CLAMS) continued during 2002. CLAMS plans were prepared and published for the north Shannon Estuary and Dungarvan Bay.

5. Aquaculture Projects under the National Development Plan 2000 –2006

Post Graduate Fellowships

PhD Fellowship will investigate survival/mortality, causes of disease and death, whether “Brown Ring Disease” is involved, and the factors contributing to the health, survival, and successful culture of the clam *Ruditapes philippinarum*.

Location: Department of Zoology and Animal Ecology, National University of Ireland, Cork

Post Doctoral Fellowship

"Investigations into the hatchery rearing of Cod (Gadus morhua) in Irish conditions"

The specific objective of this fellowship is to identify and harness potentially exploitable research and technology so as to enable the establishment of a commercially viable cod hatchery in Ireland.

The deliverable is a detailed methodology, developed in collaboration with industry, for the hatchery production of juvenile cod in commercial conditions. This methodology will include a review of previous work, identification of, and practical solutions for, constraints encountered in the production chain.

Location: MRI Carna Laboratories, National University of Ireland Galway, Carna, Connemara, Co, Galway.

Duration: May 2002–June 2005

"Investigations into a reliable supply of scallop (Pecten maximus) for the inshore and aquaculture industries."

The deliverable will be a detailed methodology, developed in collaboration with industry and other relevant agencies, for the production, transport and ongrowing of scallop spat in commercial quantities for restocking and aquaculture ventures. This methodology will include a review of previous work, identification of, and practical solutions for, constraints encountered in the production chain.

Location: Department of Zoology and Animal Ecology, University College Cork, Cork

Duration: May 2002–November 2005

"Sealice biology and interactions"

1) Compile and review results of all available work on sea lice biology and larval development as it applies to the problem of control.
2) Support original research on larval biology and development of sea lice (*Lepeophtheirus salmonis)* with particular reference to host selection and location mechanisms of commercially relevant species in Ireland.
3) Contribute to the development of enhanced management and control strategies for sea lice on cultivated salmonids based on a deeper understanding of lice biology and behaviour.
4) Transfer any commercially applicable results from this research to industry.

Location: Department of Environmental Sciences, Galway Mayo Institute of Technology, Galway

Duration: May 2002–November 2005

Applied (Industry) Marine RTDI Programme

A novel On-growing system for Abalone –

Project Partners: Awabi Teo and Aquaculture Development Centre, University College Cork

Technology & Scientific development of turbot and broodstock management and larviculture in Ireland

Project Partners: Turbard Iarthar Chonamara Teo and Aquaculture Development Centre, University College Cork

Strategic RTDI Programme

Resource and risk assessment of mussel seed in the Irish Sea - Aquaculture Development Centre, University College Cork

Full details of all projects funded as part of the Marine RTDI programme can be found at www.marine.ie/marinertdi

NORWAY

Submitted by Arne Ervik, Institute of Marine Research, Bergen

Salmonids

The total harvest of salmonids in Norway in 2002 amounted to 517,000 tonnes. Of this, 440,000 tonnes were Atlantic salmon, an increase of 8 % from the previous year and constituting 42 % of world production. The production of rainbow trout was 77,000 tonnes, up 17 percent from 2001. During the first part of 2002, delayed harvest due to low market prices, led to an increase of the standing stock at the fish farms, while high summer temperatures resulted in growth depression during this period with subsequent compensatory growth the rest of the year. The market situation remained the same throughout the year, partly due to an unfavourable exchange rate.

The unusually high temperatures throughout the summer resulted in health problems at farms in Southern Norway, related to both temperature stress and the presence of large jellyfish blooms.

The general health situation of farmed Norwegian salmonids is acceptable and the use of medicines remains low, particularly with regard to antibiotics. The experience from 2002 showed, however, that once again new diseases appeared while known ones turned up again, a situation, which emphasizes the need for continuing measures to combat diseases and infections. Also, the system for reporting diseases needs to be improved to get a better overview of the occurrence and consequences of all disease types. The health situation was characterised by problems of deformities due to "production diseases" and the presence of cataracts, winter sores and infectious pancreatic necrosis (IPN). There was a drop in the number of outbreaks of infectious salmon anaemia (ISA) (Table 1). The salmon louse situation is being controlled at the farms using chemical delousing, however there is still a problem vis-à-vis the severe effect on wild fish.

Table 1. An overview of diagnosed new cases of furunculosis, bacterial kidney disease (BKD), infectious pancreatic necrosis (IPN) and infectious salmon anaemia (ISA) in the period 1997–2002. (Source: Bruheim *et al.* 2003).

	1997	1998	1999	2000	2001	2002
furunculosis	4	1	2	6	3	0
BKD	15	0	3	3	3	1
IPN*						174
ISA	6	13	14	23	21	12

* The numbers from 1997–2001 are omitted because of uncertainty in the reporting

Marine species

A breakthrough in the production of cod fry occurred in 2002 when about 3 million were produced (Figure 1). The increase is both due to improved knowledge and an increased number of enterprises. A production target of 10 million fry is expected in the next few years, which will be followed by a subsequent substantial increase in on-growing production. As can be seen from the figure, intensive fry production is dominating. The on-growing production stages take place in sea cages, similar to salmon, but there is a need for R&D to optimise the production with regard to rearing technology, feed development and maturation prevention.

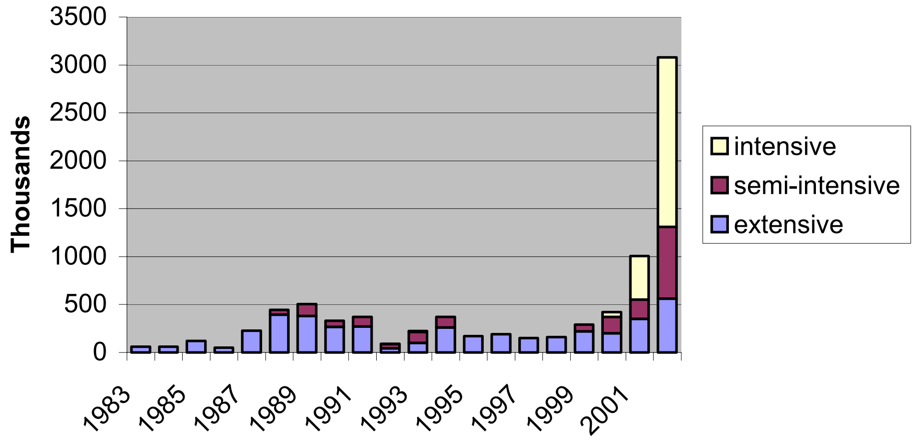

Figure 1. Total production of cod fry in Norway 1983–2002 (Karlsen and Adoff, 2003).

The upward trend for production of halibut fry continued in 2002, with intensive production taking over also for this species (Figure 2). The harvest from on-growing production has been at the same level the last few years (300 to 550 tonnes), but several producers have built up the biomass, and a harvest above 1,000 tonnes is expected in 2004. This will exceed the commercial catch of halibut.

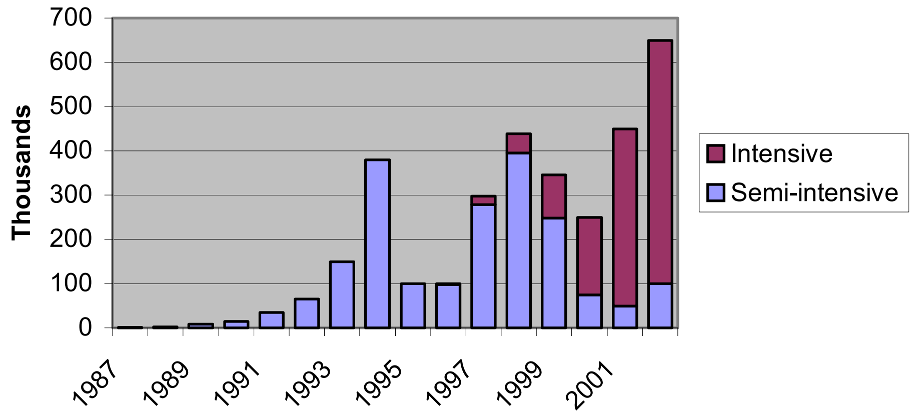

Figure 2. Total production of halibut fry in Norway 1987–2002 (Kristiansen *et al.*, 2003).

The bottlenecks for further development include low and unstable fry production, as well as variable fry quality. In addition, R&D is needed to restrict early maturation in male fish, which can hopefully be resolved by light manipulation, to develop a better understanding of halibut basic requirements to improve the cage environment and improved feed and feeding methodology. It is also urgent to commence brood stock selection and to start breeding programmes to produce offspring suitable for domestication.

Other species

Other interesting cultured marine species being considered include turbot reared in waste heated effluent water as well as spotted wolf fish. The latter, is well suited for cultivation in cold-water regions, and the main problems related to biology and the up-scaling of the production seems to be resolved. One commercial fry producer is in operation with an annual output of about 100,000 fry. An equal amount is produced at experimental facilities for research purposes. There are two on- growing farms in operation and others are about to start. Activity on spotted wolf fish is occurring in Iceland, Canada and Chile.

Shellfish

Reported production levels of shellfish varies from source to source; the numbers presented in Table 2 are provided by the Directorate of Fisheries. Apart from blue mussels, all species showed a decrease in production from 1997 to 2001.

Table 2. Amount of bivalves produced in Norway 1997–2001 (Andersen *et al.*, 2003).

Year	Scallops (Number)	Oyster (Number)	Blue mussel (Tonnes)
1997	150.000	147.000	502
1998	169.000	510.000	309
1999	536.000	650.000	662
2000	188.000	134.000	852
2001	112.000	38.000	913

Cultivated scallops are not marketed yet in Norway; figures shown in the above table relate to wild production. The catch in 2002 is estimated at 570 tonnes, which equals 2.2–2.6 million individuals. Present research focuses on improving the production and early growth stages of spat. High mortality in bottom- culture of the great scallop due to predation by crabs (*Cancer pagurus*), has been a serious problem in scallop cultivation. Trials to enclose the cultivation areas using fences on the sea bed have proven to be successful, and have led to a survival of 86 % of *Pecten maximus* over 26 months.

Several attempts to enhance the commercial cultivation of blue mussel in Norway have failed. A main reason for this has been the lack of knowledge on how to obtain high quality and avoid shellfish toxins. This situation is now changing, and the increasing harvest and interests in shellfish cultivation that has taken place in the last few years indicate that mussel cultivation is about to become established as a significant industry.

A lack of understanding on how to adjust the location, size and proportions of the shellfish farms to the carrying capacity in the oligotrophic Norwegian coastal waters has been a difficulty in mussel cultivation. Tools for resolving these problems are now being developed (Figures 3 and 4), and implemented in the industry. Adjustment to local carrying capacity may also help in solving toxin problems, as it is shown that levels of DST fall with improved quality (Figure 5).

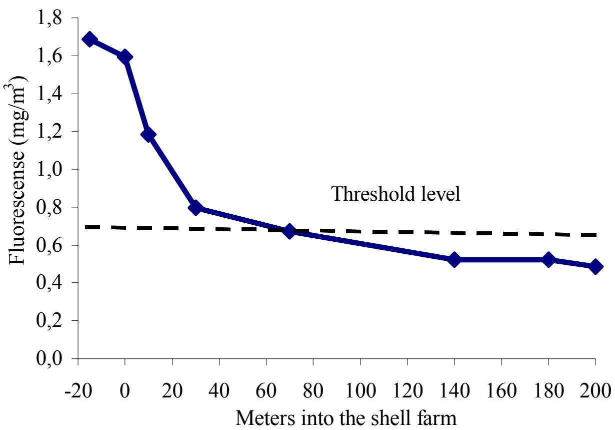

Figure 3. Mean fluorescence (chlorophyll per mg/m^3) measured at 4 metres depth during incoming tide in a shellfish farm. The threshold level indicates the minimum feed requirements of the shellfish. The figure shows that the consumption of the shellfish farm exceeds the carrying capacity of the site (Strohmeier *et al.* 2003).

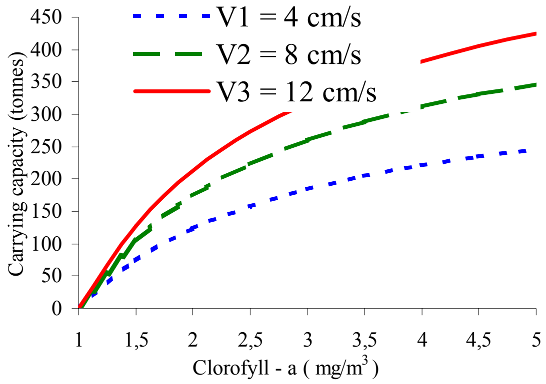

Figure 4. Calculated blue mussel biomass in a farm with a surface area of 3000 m^2, total length of long lines 2000 m, with /length ratio 0.53 and chlorophyll *a* at a threshold value of 1.0 mg/m^3 as a function of current velocities (V1 to V3) (Strohmeier *et al.* 2003).

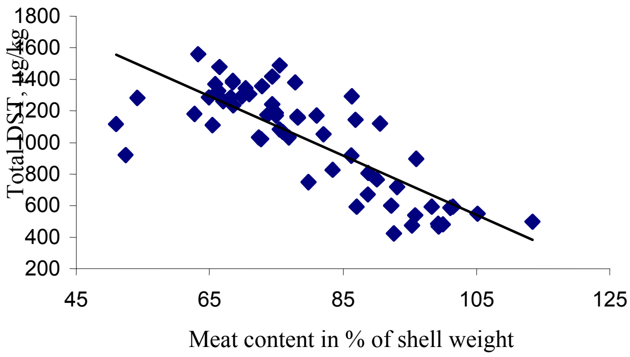

Figure 5. The relationship between level of DST toxins and meat content in blue mussel. (Strohmeier *et al.* 2003).

<u>Marine fish health</u>

With regard to infectious diseases, the health situation for marine species remains good; this is particularly the case in fry production. Several cod fry producers suffered losses due to inflated swim bladders and deformities, the reasons to this are not known. VER (*Viral encephalopathy and retinopathy*) is a disease of the central nervous system, which has caused serious problems in the mid-1990s. During last two seasons, there have been fewer outbreaks; this is believed to be a result of improved management routines, less stress and better hygiene.

As for salmonids, the on-growing of cod and halibut in Southern Norway suffered from high summer temperatures. At temperatures above 18 °C, cod started to die. Cod is susceptible to many parasites, and several parasite species were reported although substantial losses did not occur, however parasites are a matter for concern in the development of cod cultivation.

The halibut seems to be relatively easy to maintain in the on-growing phase, but high sea temperatures must be avoided. It has difficulty above 15 ° C , while temperatures above 20 ° C are fatal. In cage farms, high temperatures can be avoided by using deep net cages where the fish can get access to colder water at the bottom.

<u>Location of fish farms</u>

Lack of areas available for mariculture is a problem in many regions of Norway. This is partly a consequence of the regulatory framework and the traditional localization strategy with many relatively small fish farms concentrated along the coast. An alternative to this is now required. New aspects such as animal welfare, documentation of production conditions and environmental consequences must now be considered. The large holding capacity sites for fish farming should be utilized, and the less suitable sites abandoned.

When locating fish farms, decisions regarding maximum farm size and husbandry practices are required. One must be able to determine the holding capacity of the recipient area as well as to monitor and regulate the impact of the aquaculture activity according to this holding capacity. As large fish farms or clusters of farms located at exposed sites will influence large areas, it is crucial to take into account main cumulative regional impacts such as genetic interactions, spread of disease (bacterial and viral infections and parasites) and eutrophication.

A method for location of fish farms is now being developed to meet these needs. The holding capacity must be determined for each of the main impacts, this requires determining the relationship between the effluents from the fish farms (the dose) and the environmental impact (response), determining the limits for acceptable impact (the environmental quality standards) which defines the maximum effluent from the farms (production). This procedure must be undertaken for each for the main impacts, and the one that gives the lowest holding capacity will determine the holding capacity for whole the region (Figure 6).

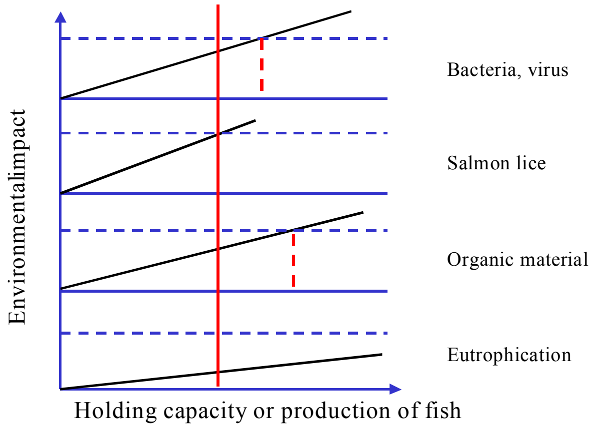

Figure 6. Determining the regional holding capacity. The holding capacity for each individual impact is first determined, and the one that gives the lowest production determines the holding capacity for the whole region. Black lines represent the relationship between the production and the environmental impact, blue broken lines indicate the environmental quality standards and red broken lines, the holding capacity for the individual impacts. The solid red line represents the holding capacity of the whole region (Ervik, 2003).

Research priorities

The main focus on mariculture research in Norway has been on increased and efficient production. A growing appreciation of environmental issues has occurred, and it is now widely accepted that the future fate of the industry depends on how it deals with its environmental affects. In this situation, the need for environmental quality objectives and standards, adequate management systems and a knowledge-based regulatory framework is essential.

Accordingly, research on these topics must be high priority. This implies a holistic approach from the scientific community, with a strong focus on the needs of the regulatory authorities. It is essential that the system development process be open and transparent, and that the different stakeholders be fully engaged.

Sources

The report is compiled from: Ervik, A., Kiessling, A., Skilbrei, O. and van der Meeren, T. (red) 2003. Havbruksrapport 2003: Fisken og havet, særnr. 3-2003. 117 pp., which is an annual report on mariculture research from the Institute of Marine Research, Norway The quoted authors have published in this report.

PORTUGAL

Submitted by: Dr. W. Silvert
Portuguese Institute for Fisheries and Sea Research

Information on aquaculture in Portugal is in a state of flux as the Department of Fisheries has recently been absorbed by the Department of Agriculture, with different and often incompatible protocols for data collection and archiving. The information contained in this report is gathered from a number of different sources. Economic data by species for 1998 and 1999 were not available.

Growth of Fish Farming

Aquaculture production of major species for the period 1990–2001 is shown in Figure 1. Trout (mostly Rainbow) are grown in fresh water and have been omitted from this chart, but they are an important species, second only to clams in some years. Eels were an important product until 1994 (grown in both fresh and salt water), when they were worth as much as all other fish species combined, but they ceased to be economical because of the high cost of juveniles. Eel production currently is less than 1 % of its peak value and is not shown in these charts.

The other finfish species are produced mostly in pens and land-based facilities. Offshore pen culture is being explored, and there are two large cages in deep water to the south of Portugal (the Algarve), but the rocky coast of Portugal is not well suited for fish farming.

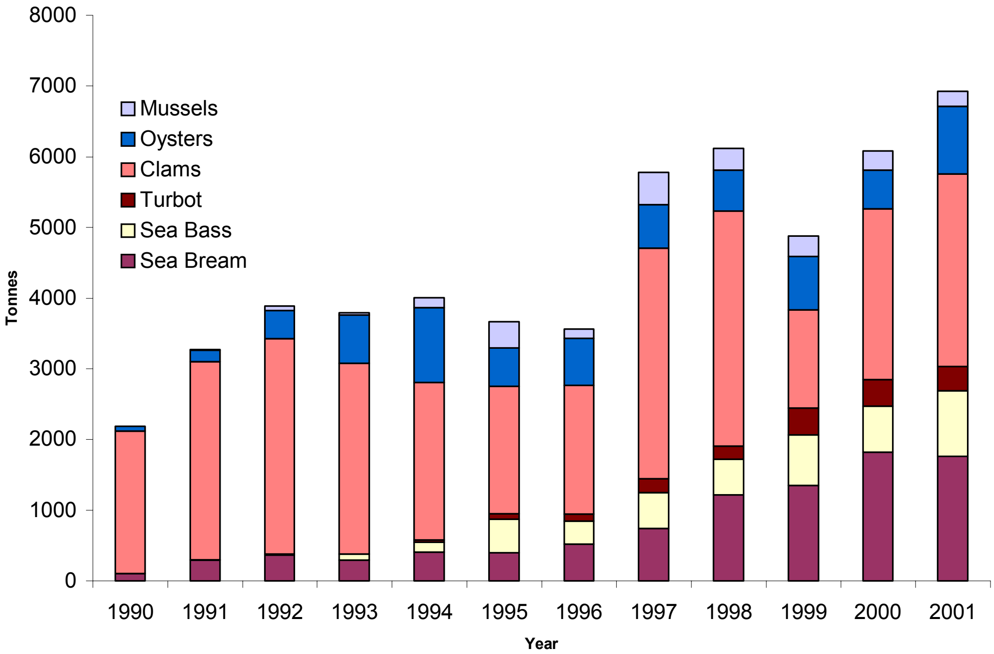

Figure 1. Production (tonnes).

As of 2000 there were 30 fresh water and 1,375 marine farms in Portugal, approximately the same number as in 1996. The marine installations were as follows (data from the National Institute of Statistics):

- hatcheries (47 ha)
- 110 tanks (1058 ha)
- cages (26 ha)
- 1240 bottom culture sites (533 ha? – I suspect that this figure is incorrect)

Most of these, especially the bottom culture sites, were in the Algarve, the southern province of Portugal. Except for the number of bottom culture sites, these figures all represent a decrease from 1996.

The value of aquaculture production is shown in Figure 2 (data for 1998 and 1999 are missing), and it is clear that clams are the most important product. So far as marine finfish are concerned, sea bream is the major species, followed by sea bass. Turbot is a relatively new species being farmed.

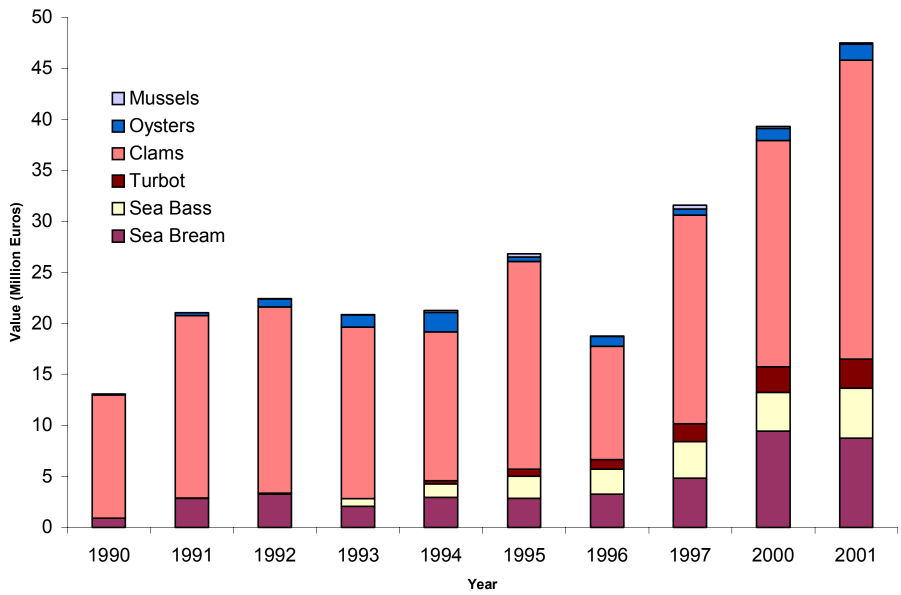

Figure 2. Value (Million Euros).

Fish farming is not growing rapidly in Portugal. The total production of farmed fish is shown in Figure 3 (both tonnage and value), and the increase is relatively modest. Most of the farming, especially of shellfish, is in the Algarve, and there is not a great deal of room for expansion as most of the farming is confined to the Ria Formosa region. Many farms are converted salt pans (*salinas*).

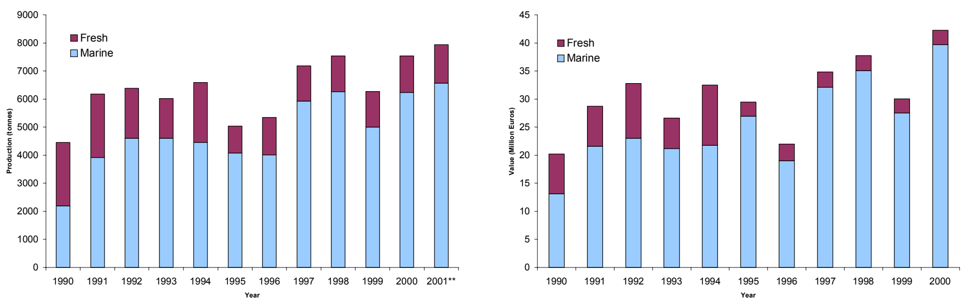

Figure 3. Total Aquaculture Production.

There is not much evidence of serious impact of marine aquaculture on the environment, although some farmed stocks have suffered from overcrowding – this has been a problem with clams. Since finfish are mostly farmed in pens rather than cages, there is little chance for disease exchange, and genetically modified species are not used so escapes are not an issue.

Salt Pan Fish Farms

Figure 4. Salinas near Figueira da Foz.

Much of the finfish farming is carried out in converted salt pans, or *salinas* (there are over 1000 ha of salinas still in use for production of sea salt). A typical system of salinas is shown in Figure 4, and the way in which they are used for fish farming is indicated in Figure 5. Water enters reservoir **R** at high tide and flows through the fish tanks **F**. The effluent goes into a settling tank **S** (this is required by law) before being released back into the marine environment.

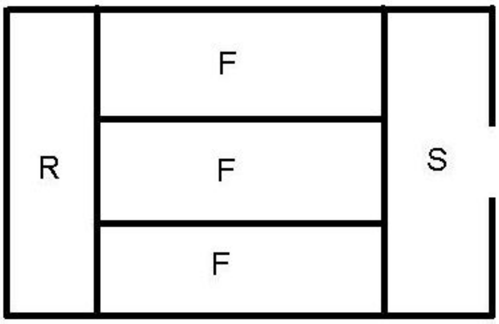

Figure 5 - Typical Salt Pan Fish Tank

There has been increasing interest in growing shellfish in the settling tank, which accomplishes the twin goals of growing shellfish in an environment with lots of food, and also removing labile carbon and nutrients from the effluent.

Research

There is not a great deal of research on environmental interactions of mariculture, in large part due to the relatively low degree of impact expected. Most of the research is in the Algarve, where fish farming (especially shellfish) is largely centred, and there are several projects at the University of the Algarve.

Portugal is one of the partners in the AQCESS project (Aquaculture and coastal economic and social sustainability) led by the University of Aberdeen, and the site to be used for biological and socio-economic analysis has been selected as the Ria Formosa, in particular the town of Fuzeta. Maria Teresa Dinis is the chief scientist for this project. A Masters thesis (Diplome d'Études Superieures from the University of Bordeaux, France) by François Noel Hubert on "Effects of exposure to semi-intensive fish-farming effluents on the Ria Formosa lagoon system (Algarve, South Portugal)" was completed in December 2001 and concluded that there were some very localized effects near the outflows of semi-intensive ponds, but because of good water renewal in the Ria Formosa there were no significant far-field effects. This work was supervised by Sofia Gamito. A project in the Ria de Alvor in conjunction with Aqualvor resulted in a paper on the cultivation of *Ulva rotundata* in raceways using semi-intensive fishpond effluents by Rui Santos and Leonardo da Mata. Rui Santos is also investigating the Ria Formosa carbon production (both dissolved and particulate), and export/import dynamics through the inlets. All of these studies are being (or were) carried out at the University of the Algarve in Faro. Another project called SEAPURA (Species Diversification and Improvement of Aquatic Production in Seaweeds Purifying Effluents from Integrated Fish Farms, coordinated by the Alfred Wegener Institute for Polar and Marine Research in Germany) deals with the development of procedures and systems for cultivation of high-value seaweed species not used before in poly-aquaculture and investigation into providing some of the food for fish by re-using the seaweed biomass. This work involves Rui Santos along with Leonardo da Mata and Andreas Schünhoff at the University of the Algarve and Isabel Sousa Pinto along with Inês Domingues, Joana Matos and Rui Pereira at the University of Porto (Oporto).

Earlier work in the Sado estuary (near Setubal, south of Lisbon) by researchers at IPIMAR indicated that there were no serious chemical impacts from sea bream tanks, although some observed changes in plankton community structure suggested that expansion of fish farming in this region would require treatment of the effluents. The final report on this work was published in 2000 and there is no current work being done in this area.

IPIMAR is carrying on a project for the study of Aquaculture-Environment interactions in connection with clam production in Faro-Olhão lagoon, supervised by Manuela Falcão at CRIP-Sul. IPIMAR is currently constructing a large experimental facility for aquaculture research at the branch in Olhão (in the Algarve, near Faro), but so far only the hatchery component is ready. These facilities (both the land-based station and an off-shore fish cage) include studies of the impact of aquaculture on the environment in their objectives. IPIMAR has been monitoring the sea cage activity since its beginning, focusing on the impact on bottom sediments and benthic communities.

Summary

Portugal has not encountered serious environmental problems associated with mariculture and therefore there has been only limited research in this area. The scale of mariculture is small, and Portuguese production figures are among the lowest in the EU. Given current practice—mostly land-based production of finfish, no use of special genetic strains, and relatively low production densities—the situation is not expected to change in the immediate future.

SCOTLAND

Shellfish Production 2001

Submitted by: D I Fraser and I M Davies, FRS Marine Laboratory, Aberdeen

Production

The shellfish species cultivated at farms in Scottish waters and for which production returns were received in 2001 were:

Common Name	**Scientific Name**	**Production**	**Year 2001**
Pacific oyster	*Crassostrea gigas*	(000s)	3483
Native oyster	*Ostrea edulis*	(000s)	103
Scallop	*Pecten maximus*	(000s)	236
Queen	*Chlamys opercularis*	(000s)	1182
Common mussel	*Mytilus edulis*	(tonnes)	2988

The number of registered companies and the sites that placed shellfish on the market, decreased by 3 during 2001 however, the number of active sites increased by 6 %, reflecting the development of new sites, particularly for mussel production. Many unproductive sites held stock not yet ready for market, others were fallow or were positioned in remote areas where the cost-effective production and marketing of shellfish proved difficult. The number of staff in full-time (137) or part-time (235) employment did not change significantly.

The production of most species of shellfish showed an increase over 2000 levels. Pacific oyster production increased by 13 % and the small native oysters production more than doubled. Mussel production increased significantly by 49 % as new markets emerged and prices remained high. Mussel production in Shetland increased by more than 100 %, and the continuing registration of new sites in Shetland suggests that further increases are to be expected. By contrast, the production of queen scallops fell by 43 %, mainly as a consequence of scarcity of natural seed. Scallop production also fell, and was strongly influenced by closure of some production areas arising from the presence of algal toxins. Markets for scallops and queens were strong throughout the year.

Disease and environmental issues

Approved Zone status for the notifiable diseases Bonamiasis and Marteiliasis was maintained in 2001 (under EC Directive 91/67), following testing to confirm the absence of those diseases in Scottish waters. Samples were taken from 10 sites holding native oysters, a species known to be susceptible to these diseases. Approved Zone status continued to offer benefits to both wild and farmed native oyster stocks in Scottish waters.

EC Council Directive 95:70 establishes minimum measures for ensuring that controls on certain diseases of bivalve molluscs are in place. Each year, FRS Inspectors visit one third of all shellfish sites under this Directive.

Annual Survey of fish production 2001

Submitted by: I M Davies, C E T Allan and R M Stagg
Fisheries Research Services Marine Laboratory
Aberdeen, UK

Production

Production survey information for Scotland was collected from all 87 companies actively involved in Atlantic Salmon production, farming 320 marine sites, of which 163 sites were actively producing. The total production of Atlantic Salmon during 2000 was 138,519 tonnes, an increase of 9560 tonnes (7.4 %) on 2000 production. This is the ninth consecutive annual increase in production. The projected production for 2002 is 159,060 tonnes.

The use of photoperiod and "early" smolts, combined with the rapid rates of growth achieved using high energy feeds and modern husbandry methods, resulted in a further increase in average harvest weight of zero sea winter fish to 4.2 kg. This is only 0.3 kg less than that attained for one sea winter fish of the previous year class, and presumably reflects the market preferred harvest weight.

Survival and Production in Smolt year-classes

In 1999, the last year-class for which survival can be calculated, the survival rate from smolt input to harvest was 80.6 %. This was a increase of over 11.5 % compared to the 1998 year-class (although has not yet returned to the high level of 89.6 % achieved in 1997), and can be attributed to a variety of causes. These include recovery from the mortality and culling associated with the ISA outbreak, losses in clinical IPN outbreaks, and losses associated with plankton blooms.

Production methods

Almost all (99.8 %) of the production, 138,287 tonnes was produced in sea water cages. The small quantity produced in seawater tanks on shore reflects the high installation and running costs incurred in operating such tank systems. Most seawater tank capacity has now been re-deployed to the production of alternative species such as halibut, turbot, cod, etc.

Sea cage capacity increased by 470,000 cubic metres in 2001, reflecting the rise in the size of sites in production. Production efficiency in cages, measured as the ratio of fish weight in kilograms produced per cubic metre, increased by 0.4 kg in 2001 to 9.3 kg m^{-3}.

Company Productivity

There were 81 companies registered with SEERAD as actively producing salmon in 2001, and increase of 13 on the 2000 figure. The west of Scotland, the Western Isles, the Orkney and Shetland Islands, remain the principal locations for the Scottish salmon industry. This is due to the requirements for relatively clean, sheltered areas in which to locate marine fish farms. The salmon industry continued to be a major provider of local employment in these areas. Production per employee can be used as a measure of efficiency, and is related to the scale of production. The greatest productivity (137 tonnes per person, up from 114 tonnes per person in 2000) was achieved in those companies having production greater than 2000 tonnes.

Fallow periods

Of the 320 sites recorded as being active in 2001, 195 farms were fallow for a variable period, whilst 45 farms were fallow for the whole year in 2001. The accepted normal production cycle in seawater varies in length between eighteen months and two years, and a fallow period at the end of production can break the cycle of disease or parasitic infections. There were 80 sites that had no fallow period in 2001. These may have been stocked late in 2000 with out of season smolts, or may not have followed recommended practice of including a fallow period in the production cycle.

Escapes

There were 12 reported escapes from seawater Atlantic salmon farms in 2001, involving the loss of 67, 000 fish.

Other species

There is an increased interest in the production of other species, particularly in diversification into emerging marine species. Production of brown trout and sea trout in salt water was 105 tonnes, and there was a small production (3.75 tonnes) of Arctic charr in 2001. However, the main current expansion is in cod and halibut, of which 15 and 80 tonnes were produced respectively. Estimates for 2002 are for 207 and 257 tonnes respectively.

Conclusions

The production tonnage of salmon in seawater increased by 7.4 % in 2001, due mainly to an increased average weight and increased survival giving a higher yield per smolt put to sea. The estimated number of smolts put to sea in 2002 was 49.3 million, which would indicate an increased harvest in 2003 and 2004. The estimated harvest forecast for 2002 is 159,060 tonnes, an increase of 14.8 % on the 2001 total.

Despite the increase in production, the number of producing sites fell from 346 to 320. This reflects continuing trends towards increasing the size of producing sites. The average production in Scotland is now 866 tonnes per site, and the number of sites producing more than 1000 tonnes increased by 5 % in 2001.

ANNEX 1 TO SCOTTISH COUNTRY REPORT

Locational Guidelines for Scottish Fish Farms

The Scottish Executive has recently issued a Policy Advice Note (PAN) to Local Authorities on the execution of their role in relation to planning aspects of fish farm development. The purpose of the PAN is:

- to provide guidance on the factors to be taken into account when considering proposals for new marine fish farms or modifications to existing operations; and
- to establish the national context for the preparation by planning authorities of non-statutory marine fish farming framework plans for guiding the location of future marine fish farms;

having regard to the particular needs and safeguards for a successful industry.

The guidance in the PAN draws on:

- advice from Scottish Natural Heritage (SNH) on natural heritage designations and sensitive areas for biodiversity;
- analysis of the relative sensitivity of sea loch systems to nutrient loading by fish farm development prepared by the Scottish Executive Fisheries Research Services;
- data on the location and size of existing marine fish farms;
- additional information obtained in the course of consultations with other regulatory agencies, the fish farming industry and other interested parties; and
- current concerns about wild salmon and sea trout populations reflecting the status of Atlantic salmon under the Habitats Directive (Annex ll and V species).

In order to provide a positive framework for the location of new developments while safeguarding the environment and other interests, Scottish Ministers consider it necessary to identify those areas which are likely to be particularly environmentally sensitive to new or expanded developments, and in which stringent environmental sensitivities relating to both nutrient loading and the natural heritage should be required to be fully addressed before development consent might be given.

Therefore, a presumption is made against further development on the east and north coasts (to protect important wild salmonid stocks). Scottish Ministers also propose three categories of areas of coastal waters, based on the level of nutrient loading and associated benthic impact within each area arising from existing fish farm developments:

- **Category 1:** where the development of new or the expansion of existing marine fish farms will only be acceptable in exceptional circumstances[2].
- **Category 2:** Where new development or expansion of existing sites would not result in the area being re-categorised as category 1.
- **Category 3:** where there appear to be better prospects of satisfying nutrient loading and benthic impact requirements, although the detailed circumstances will always need to be examined carefully.

In addition, proposals most likely to succeed are those which form part of a package designed to reduce the overall impact of aquaculture on the marine environment, e.g., by adopting feeding techniques which minimise the discharge of waste food pellets and by adoption of integrated sea lice management practices which reduce the need for repetitive use of chemo-therapeutants.

In addition to the nutrient loading categories, Natural heritage and other interests (see paras 26–28) form an equal part of the determination process and will be taken into account in determining individual applications.

For marine and terrestrial Special Protection Areas (SPAs) and Special Areas of Conservation (SACs), designated under the EU Natura Directives, particular arrangements must be applied in considering any proposals that might affect them. Any proposal, which is likely to have a significant effect on the interests for which the site was designated, must be subject to an appropriate assessment. If this assessment cannot demonstrate that the proposal will not adversely affect the integrity of the site it can only proceed in very exceptional circumstances. In addition to the legal obligation to ensure the adequate protection of designated sites, European Member States are required to ensure the protection of the various species and habitats listed in the Natura Directives within the wider environment. Careful consideration of the potential impact of proposed developments on these conservation interests is necessary before any consent or permission may be granted.

Scientific approach to modelling environmental impact of fish farms in relation to the Locational Guidelines

A simple box model is used to predict the level of enhancement of soluble nutrient nitrogen from fish farming sources, treating nitrogen as a conservative substance. This model is a function of the flushing rate of a sea loch, the total consented biomass of all the finfish farms in the loch and the nitrogen source rate. A mass balance model was used to estimate the rate of release of nitrogen at 48.2 kgN per tonne of salmon produced per year. These data are used to calculate an equilibrium concentration enhancement (ECE) for nitrogen, expressed in $\mu mol\ l^{-1}$. Non-salmonid species are accounted for in this model, by the application of appropriate 'species factors' to correct for the different rates of soluble nitrogen release from the farming of such species.

Benthic impact is estimated using a modified "Gowen" model to predict the area of seabed impacted by the deposition of organic matter in the form of solid waste from finfish farms. Using the modified technique described, the along- and across-loch dispersion of solid waste is estimated for each farm in a sea loch. These distances, together with an estimate of the surface area of the farms are used to predict an elliptical area of seabed impacted by organic carbon deposition. An appropriate distribution of particle settling velocities and associated quantities of excreted carbon are applied in order to estimate areas of seabed impacted by different levels of organic carbon deposition within the impacted area. The results of this model are used to estimate the total percentage area of the seabed of a loch impacted by a level of enhanced organic carbon deposition greater than 0.70 $kgC\ m^{-2}\ y^{-1}$. Above this critical value, it has been shown that the infaunal diversity of sediments is reduced, and the seabed can be considered "degraded".

The models described here predict the relative levels of nutrient enhancement and percentage areas of seabed degraded by organic carbon deposition for 111 sea lochs. The results of both models are scaled from 0–5, and the two scaled values are added together to provide a single combined index. On the basis of this combined index, areas are designated

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[2] **Exceptional Circumstances**: circumstances that are of more than local significance, e.g.,

- National or regional disease control measures – for example, temporary sites to mitigate the effects of evacuation of other sites;
- Emergency measures to mitigate the effects of natural disasters, or shipping incidents;
- To permit experimental trials of new measures with the potential for widespread environmental benefits.

as Category 1, 2 or 3, where Category 1 areas are considered to be the most environmentally sensitive to further fish farming development due to high predicted levels of nutrient enhancement and / or benthic impact.

MODEL RESULTS

The results from the nutrient enhancement model (accurate for July 2002) are summarised in Table 3 below and are presented in Figure 4 as a function of consented biomass (M) and flushing rate (Q). The results from the carbon deposition model are also summarised in Table 4 below. The “degraded” percentage seabed area results are shown as calculated in July 2002.

Table 3. Predicted nutrient enhancement results for Scottish sea lochs (July 2002).

ECE (µmol l^{-1})	Number of Scottish sea lochs
> 10.0	5
3.0–10.0	15
1.0–3.0	23
0.3–1.0	22
< 0.3	46
TOTAL	**111**

Table 4. Predicted “degraded” seabed areas, expressed as a percentage of the total sea loch surface area (July 2002 data).

Predicted “degraded” seabed area (%)	Number of Scottish sea lochs
> 10.0	0
3.0–10.0	6
– 3.0	31
0.3–1.0	31
<0.3	43
Total	**111**

Categorisation for locational guidance

In order to interpret the results of both these models in the context of the Locational Guidelines, the predicted ECE values and percentage areas of “degraded” seabed were combined in a manner which identified the relative potential sensitivity of sea lochs to further fish farming development. The approach adopted involves a semi-logarithmic scaling of ECE values from 0–5, such that each sea loch can be assigned an index of nutrient enhancement (see Table 5). In a similar manner, the percentage area of degraded seabed is scaled from 0–5, allowing each sea loch to be assigned an index of benthic impact (see Table 6).

Table 5. Index of nutrient enhancement, derived from predicted levels of equilibrium concentration enhancement (ECE) for nitrogen, using the “nutrient enhancement model” described above.

Predicted ECE for nitrogenous nutrients arising from fish farming (µmol l^{-1})	Nutrient enhancement index
> 10	5
3–10	4
1–3	3
0.3–1	2
< 0.3	1
0	0

Table 6. Index of benthic impact, derived from the percentage area of seabed of a loch, predicted to show reduced Infaunal Trophic Indices (ITI) as a result of the deposition of organic matter from fish farms. Percentage areas are derived from the "carbon deposition model" described above.

Percentage area of seabed predicted to be "degraded" by organic deposition (%)	Benthic impact index
> 10	5
3–10	4
1–3	3
0.3–1	2
< 0.3	1
0	0

These two scaled indices are then added together to give a single combined index for each sea loch. The resultant single index, scaled from 0–10, is subsequently used to provide an indication of the relative sensitivity of a sea loch system to further fish farming development. Sea lochs with the highest combined index value are considered most sensitive to the expansion of fish farming operations and as such are considered as Category 1 areas in the Locational Guidelines. All 111 sea lochs modelled are categorised on the basis of the combined index as indicated in Table 7 below.

Table 7. Derivation of Categories 1–3 for locational guidance, based on the sum of the nutrient enhancement and benthic impact indices.

Combined 'nutrient enhancement' and 'benthic impact' indices	Category
7–10	1
5–6	2
0–4	3

This derivation of Categories on the basis of a combined index is such that the modelling results for Category 1 sea lochs are towards the top of the scale for either nutrient enhancement or benthic impact. Category 1 areas will necessarily have at least one individual index of 4 or greater (3–>10 μmol l^{-1} nutrient enhancement or 3–>10 % degraded sea-bed area). In these areas the most precautious approach to further fish farming development should be adopted. Category 2 areas have at least one individual index value of 3 or greater and a degree of precaution should also be applied to consideration of further fish farming development in these areas.

Reviews of categorisation of coastal waters for fish farming

The current (2003) revision of the Locational Guidelines replaces the initial Guidelines published in 1999. It was agreed in 1999 that periodic review would be necessary, and experience subsequently suggested that it would have been advisable to review the document more frequently than every 3–4 years. There was increasing comment during the life of the first Guidelines on the details of the underlying science and modelling. It was therefore decided to make the full details of this available on the Fisheries Research Services website (www.marlab.ac.uk).

Consequently, the method of presentation of the Guidelines has been changed. Firstly, review of the underlying policy documents (Advice Note, and Policy Advice Note) may occur approximately every 3 years. However, the Categorisation of coastal inlets, and the maps showing the results of the Categorisation, are also held on the Fisheries Research Services website (www.marlab.ac.uk). These will be reviewed every three months and updated as necessary to reflect changes in the pattern of Consented production (biomass of fish) and/or changes in the underlying scientific assessment.

Suggested links between nutrients released from fish farms and harmful algal blooms

Submitted by: Ian Davies, FRS Marine Laboratory, Aberdeen

There has been considerable pressure over the last 1–2 years in various fora raising concerns that the perceived increase in harmful algal blooms (and the occurrence of shellfish toxins) in Scottish coastal waters may be linked to the discharge of nutrients from fish farms. The Scottish Executive has commissioned several reports on the subject, all of which have concluded that there is no good evidence linking the growth of fish farming with harmful algae.

One of the assessments carried out in this area was to apply the European Regional Seas Ecosystem Model (ERSEM) to assessing the eutrophication status in the OSPAR Maritime Area, with particular reference to nutrient discharges from Scottish salmonid aquaculture. The background to this project, and the results of the assessment, are summarised below. The text of the full report of this project can be found at:http://www.scotland.gov.uk/library5/fisheries/ersem_report_final.pdf

ANNEX 2 TO SCOTTISH COUNTRY REPORT

Application of the European Regional Seas Ecosystem Model (ERSEM) to assessing the eutrophication status in the OSPAR Maritime Area, with particular reference to nutrient discharges from Scottish salmonid aquaculture

M Heath, FRS Marine Laboratory, Aberdeen

Background

1. Aquaculture production of salmonids in Scotland has grown over the last 15 years, exceeded 150,000 tonnes in 2001. There have been conflicting views as to the likely ecological impact of nutrient discharges from this activity.

2. Whilst quantitative assessments of aquaculture nutrient discharges have been carried out, the debate regarding possible eutrophication impacts of these discharges has so far been largely speculative. In order to provide a quantitative basis for this discussion, a marine ecosystem model was used to simulate the consequences of a 50 % reduction in aquaculture nutrient discharges, and the results are presented here.

Activity

3. The European Regional Seas Ecosystem Model (ERSEM) represents a state of the art standard in eutrophication modelling. Nutrient loading scenario analyses derived from a North Sea-wide version of this model have previously been published in the scientific literature and OSPAR documents. In order to carry out the study described here, the spatial domain of the North Sea ERSEM was extended to cover north-west European waters out to the shelf edge in the west, and from the Brittany coast in the south to north of the Shetland Islands in the north. Around Scotland, the spatial resolution of the model was 50 km × 50 km.

4. Natural runoff of nutrients to each of the Scottish coastal compartments of the ERSEM was calculated for 3 contrasting climate scenario years (1984, 1987 and 1990). Urban waste and industrial discharges were derived from data for 1999, and aquaculture discharges from production figures for 2001, using HARPNUT guidelines.

Approach

5. The model output variables selected for assessing eutrophication status were those used by the 1996 ASMO Workshop on eutrophication modelling (winter concentrations of dissolved inorganic nitrogen and phosphorus, mean and maximum chlorophyll concentration and net primary production, and the ratio of diatom:non-diatom chlorophyll content). These criteria match the Category I and Category II Harmonised Assessment Criteria (direct and indirect effects of nutrient enrichment respectively) agreed for use in the initial application of the OSPAR Comprehensive Procedure. Model criteria were analysed for a number of designated assessment regions around Scotland. The criteria were combined into an integrated water quality index for summarising the simulated eutrophication status.

6. Reference runs of the model were carried out using meteorological forcing for each of the three climate scenario years. The results were used to derive indices of the natural climate-driven variability in the eutrophication criteria.

7. The model was then used to simulate eutrophication criteria for each climate year with the aquaculture nutrient load reduced by 50 %, and the results compared to those from the reference runs.

Results

8. The simulated reduction in nutrient load due to a 50% decrease in Scottish aquaculture discharges produced less than 0.3 % change in water quality in all but one of the assessment regions. Even in the worst case region (Minches) the change was only 1.1 %. At the local scale, the worst case change in water quality (around the Isle of Skye) was 1.7 %, equivalent to around 4 gC m^{-2} yr^{-1} decrease in annual net primary production, or less than 0.05 mg chlorophyll m^{-3} averaged over May-September. These changes were clearly smaller than the 50 % threshold defined in the Comprehensive Procedures for designation of elevated levels of assessment criteria, and were less than half the natural variation due to climate (3.6 %).

9. On the basis of these results it is concluded that, at the spatial scale of these simulations (50 km × 50 km), there is no case for suggesting that nutrients from Scottish aquaculture have a discernible eutrophication impact on the coastal and offshore waters west and north of Scotland.

SPAIN

Presented by: Jose Benito Peleteiro

In the recent years, marine aquaculture has been one of the most active and dynamic industrial sectors in Spain, with the introduction of new technologies and the technical development of culture of new species. At present, marine aquaculture production in Spain is about 277,577 tonnes per year (Spanish Secretaría General de Pesca, 2001 data). Approximately 250,000 tonnes of mussels are produced, and 4,000 tonnes of turbot. Practically all of this is produced in Galicia. There, aquaculture is a major economic activity, and is also socially important due to the great impact of the farmed mussel sector on the social structure in the Galician rías.

Marine fish culture started in Galicia in the beginning of the 1980s (1982). At that time the IEO created the Department of Marine Aquaculture, located in the Centro Oceanográfico de Vigo. At later stage, the Galician Regional Government (Xunta de Galicia) created its Consellería de Pesca – for several years a joint team Consellería/Department of Marine Aquaculture of the IEO worked together on aquaculture issues in the area.

The species selected for this project was turbot (*Scophthalmus maximus L*), mainly due to its biological characteristics. At that time, preliminary results from experiments in France, Denmark and United Kingdom suggested that the species was promising for industrial exploitation. Equally, the prices for wild turbot were high both in the Spanish and international market.

During the 1980s the culture technique for turbot was developed, and included participation of some pioneer companies from the sector. All the scientific experience coming from the research in that area in the IEO Centro Oceanográfico de Vigo during the 1980s was transferred to the industrial sector by means of transfer of technology projects. This allowed this type of aquaculture production to grow rapidly.

The turbot research project at the Centro Oceanográfico de Vigo progressed during the 1990s. Specific techniques were developed as a support to the industrial sector (e.g., control of maturation through handling of environmental factors, and induction to spawning by hormone methods, by sperm and embryo cryoconservation with liquid Nitrogen).

After 2000 new work was started in the Centro Oceanográfico de Vigo on genetic control techniques for broodstock selection, and on the production of triploids of fast growth. Nevertheless, and in spite of the possibilities these techniques may offer, they were not well accepted by the industrial sector as a result of perceived reluctance by the consumer to use genetically manipulated food.

In addition, a programme of turbot mark and recapture was initiated, with results of a 12 % recovery of labelled individuals. This result suggests the possibility of using these techniques in larger projects.

In the beginning of the 1990s turbot started to be commercially produced. Then, a research project examining the potential for on cultivation of new species was undertaken by our Department. The idea was to diversify the risks of the industrial companies, and to increase their profits, as well as to enlarge the range of products to the consumer.

Several species were considered. They were selected according to their commercial importance, and to their potential for introduction into both the Spanish and international markets. Species examined for cultivation potential from the biological point of view of included: black-spot seabream (*Pagellus bogaraveo*), white seabream (*Diplodus sargus*), striped red mullet (*Mullus surmuletus*), pollack (*Pollachius pollachius*), sole (*Solea solea*), axillary seabream (*Pagellus acarne*).

The results were presented at the VII Spanish National Aquaculture Congress (1999). Among the possible options, the Department decided to give first priority to black-spot seabream, due to its commercial value, and due to the over exploitation status of this species in Spanish fishing areas.

During the 1990s the culture technique for this species was developed and transferred to a group of aquaculture companies through a technological transfer project financed by the European Fund of Regional Development. As a result of this project, farmed black-spot seabream has been consumed in Spain since last year. At present, two lines of research are still underway on this species: one of them deals with control of reproduction, and the other with the definition of a nutritionally balanced feed which avoids accumulation of perivisceral fat - a very common problem in cultivation of this species.

In 1994 work was started examining the potential for cultivation of octopus (*Octopus vulgaris*). First results showed that once 500 g is reached, octopus weight increase rate was about 1 kg per month. The species also showed a great appetite for a wide range in types of food. Great interest was shown by the Spanish and international sector, and consequently, a new research area was opened in the Department, with involvement of practically all of the Departments research teams.

At present, the research on this species is in progress. Difficulties exist in the larval culture, due to mass mortalities when the octopus enter the benthic phase of their life cycle. This means that the culture of octopus depends presently on the capture of wild juveniles – the consequence is a requirement for exhaustive controls on capture of this species to avoid an over-exploitation of juveniles.

As a result of the research carried out by the Department, a new research line on the culture of spider crab (*Maja esquinata*) was started, with the aim of obtaining larvae, as food source for the octopus zoeas, in an attempt to solve the a feeding problem of the larval phase of this species.

The research with spider crab was fruitful from the biological point of view. Nevertheless, the culture of this species is presently more for restocking of natural beds, than as commercial cultivation, due to the difficulties posed by grow out of this species.

Importations of sea bream (*Sparus aurata*) from the Mediterranean were a threat to the local aquaculture industry from the Spanish South-Atlantic area. In response the sole *Solea senegalensis,* became a priority species in the Spanish National Research plans. In this context, experiments are being carried out in Galicia in both public research institutes and in private companies, to investigate the possible culture of this species in Galicia. In general, growth results obtained to date suggest this might be an alternative species to the more traditional turbot, seabream, sea bass, and black-spot seabream cultures.

Although the direction of the work in the marine aquaculture department of the Centro Oceanográfico de Vigo has been mainly towards research on the development of culture techniques which may be applicable to the industrial sector, the research experiments which have been carried out by us with a number of species that, for one reason or another, have not been subject of subsequent industrial culture, are now a basis for a new restocking programme, which has the support of the Galician Regional Government. This programme is planned to start next year, and in relation to it a workshop will be held on restocking, to study in depth the possibilities of this activity in the Galician coast.

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SWEDEN

Submitted by: Hans Ackefors

Introduction

The development of aquaculture has been slow in Sweden in contrast to the rest of Europe. We still produce only a small amount of fish and shellfish by aquaculture. However, it looks like eventually that the people's attitude to some aquaculture is better that it used to be. This is not to say that we have got problems and obstacles for further development. The legal structure for getting licences is complicated and according to the Swedish law you can oppose to new establishments if you happen to be an owner of a ground in the near of the potential aquaculture establishments. Aquaculture industry is very much dependent on the attitude from the Green Movement. Surprisingly enough the WWF (World Wide Fund) is now in favour of some aquaculture establishment. On the other hand other "greens" are heavily against it as well as a large community within universities and agencies as Environmental Protection agency.

Relation between aquaculture and fisheries

Although aquaculture is heavily dependent on fisheries the environmental problems in our waters imply that the fish caught in Swedish waters cannot be used as raw material for aquafeed. The fish is not suitable for producing fish oil and fish meal. The content of dioxin, PCB, DDT and PAH is too high. For this reason all feed used in Swedish aquaculture is imported from other countries. And those countries are using either raw material from the Pacific e.g., anchoveta or from the Norwegian sea as capelin.

On the other hand the fisheries are very much dependent on aquaculture. The stock enhancement of salmon in the Baltic and on the Swedish west coast of salmon and brown trout is very important. This is also true for the eel population in the Baltic area. Every year imported glass eel is going through a quarantine process before they are raised to a juvenile stage and stocked into lakes and rivers supporting the Baltic area. Another important fish species is pike-perch which is raised in ponds to a 5–8 cm length and then stocked in lakes and coastal areas. In fresh water pike-perch is the most important species in lakes, as well in the brackish waters of the Baltic areas.

Fisheries and the environment

The fisheries have suffered very much from chemical contaminants accumulated in fish flesh. Although the amount of PCB and DDT has decreased to a rather low level, in fish from the Baltic the concentration curve is not decreasing. The measures taken by the authorities to diminish the concentrations in the water do not seem to help decrease the levels of those substances in some fish species in the Baltic. The facts can be summarised in the following way according to Anders Bignert (Contamination Research Group at the Swedish Museum of Natural history):

1. Lead concentrations in herring and cod livers from the Baltic are decreasing.
2. The increasing trends of cadmium concentrations in herring liver from the Baltic proper and from the Bothnian Sea reported for the period 1980 to 1997 seems to have stopped.
3. Cadmium concentrations in blue mussels from the Baltic proper are about 5 times higher than the suggested background level for the North Sea.
4. PCB concentrations in herring from Landort (the Baltic) have not continued to decrease during the last ten years' period.
5. HCHs are decreasing at almost all sites with series long enough to permit a statistical trend analysis.

6. HCB is decreasing in herring, cod and guillemot from the Baltic proper and also herring and cod at the Swedish west-coast.
7. TCDD-equivalents have not decreased in various areas as Harufjärden, Karlskrona (the Baltic) and Fladen (Swedish west coast) during the investigated time period.

Aquaculture and environment

Recently National Food Administration has made a study on the dioxin content in fish both from the wild and from aquaculture. The stocked salmon in the Baltic are feeding in the southern Baltic before returning to rivers in the northern Baltic. The dioxin levels for mixed samples of salmon from some Swedish rivers are close to or slightly exceed the recommended limits of fish (mean concentration of 3.8–5.4 pg WHO-TEQ/g fresh weight) for the different locations. Brown trout, which live most of their lives in areas close to rivers, show a great variation in the concentration of dioxin. The variation in mean levels range from 1.4–4.8 pg WHO-TEQ/g fresh weight.

For farmed Swedish rainbow trout (*Onchorhynchus mykiss*) the levels in the pooled sample were low or 0.43 pg WHO-TEQ/g fresh weight and are well below the recommended limit.

Wild mussels from Skagerrak show low levels. In a pooled sample the value was 1.1. pg WHO-TEQ/g fresh weight.

Swedish aquaculture production

The stock enhancement for salmon, brown trout and eel is important in Sweden. The smolt production varies a bit from year to year but usually the number is more than two million smolts. Most of those smolts are stocked in Swedish rivers supporting the Baltic area. A small part of it is stocked in rivers supporting the Skagerrak and Kattegat areas. The stocking of eel varies also from year to year. The statistics in this case are not reliable and is very much dependant on the amount of money allocated from year to year by the authorities.

The aquaculture production for the market of rainbow trout, salmon, eel, Arctic charr, brown trout and blue mussels according to the official statistics is rather small compared to other Nordic countries. The production for the last five years is as follows:

Table. Production of food fish by production line, live weight, tonnes.

Year	Rainbow trout	Salmon	Eel	Arctic char	Brown trout	SUM Foodfish	Mussels
1997	4875	0	215	183	3	5276	1425
1998	4457	0	232	347	4	5040	455
1999	4458	…	253	386	0	5109	954
2000	4452	…	311	395	0	5171	443
2001	5255	18	228	786	0	6286	1444

It is a well-known fact that real production is likely to be more than double the amount mentioned above for rainbow trout.

In addition to that a lot of salmonid fish is produced for put-and-take fisheries and sport fisheries.

Research in aquaculture

The Department of Aquaculture at the Swedish University of Agriculture in Umeå performed a 5-year programme on the environmental effect of aquaculture and published about 10 reports about the results. The reports are in Swedish but you can get some ideas of the content by going to the web address; www. vabr.slu.se. If you click on that address you can get some idea of the programme. They also made a simulation programme that can be used by the farmers to investigate the release of nutrients from their own farms.

The project can be summarised as follows:

1. Nutrient loads for aquaculture—real levels and future developments.
2. Optimisation of feeding regimes at commercial level.
3. Education of fish farmer and optimisation of feeding
4. Eutrophication of fish culture in freshwater
5. A model for dimension of fish cultivation in coastal areas.
6. The effect of increased nutrient loads on food webs in lakes
7. The diseases of cultured fish and their influences for wild populations of fish
8. Genetic risks with cultivated fish for wild populations
9. Criteria for localisation of waters suitable for fish cultivation
10. Handbook for the descriptions of the fish culture and its consequences for the environment.

ANNEX 4: SYNERGIES BETWEEN THE EU STRATEGY FOR SUSTAINABLE AQUACULTURE, THE EU WATER FRAMEWORK DIRECTIVE AND THE MARAQUA CONCERTED ACTION IN RELATION TO THE FUTURE OF MARICULTURE IN THE ICES AREA

1 Introduction

The implementation of the EU Water Framework Directive represents a major step towards the harmonisation of the approaches taken throughout the European Union to water quality monitoring, assessment, and improvement. At the same time, the EU Commission has recently published document COM(2002) 511 on "A strategy for the sustainable development of European Aquaculture". This document clearly builds upon the reports and other publications of the EU MarAqua Concerted Action on monitoring and codes of practice in aquaculture. It also contains elements that reflect some of the advice that has been offered by WGEIM (e.g., on Integrated Coastal Zone Management) over the last few years. The current situation therefore offers opportunities to the aquaculture industries to become more firmly established in the economic, social, planning and environmental activities in the coastal zone.

The following paper links the objectives of sustainable development in the coastal zone and the desirability for harmonisation of monitoring, as discussed by MarAqua, with the state of progress of the implementation of the WFD in Europe.

2 EU Strategy for Sustainable Development of Aquaculture

A particularly important recent development has been the publication of EU Commission document COM(2002) 511 on "A strategy for the sustainable development of European Aquaculture". Some pertinent extracts from the document are printed below:

> "Aquaculture is highly diverse and consists of a broad spectrum of species, systems and practices. Its economic dimension creates new economic niches, i.e., employment, a more effective use of local resources, and opportunities for productive investment. The contribution of aquaculture to trade, both local and international, is also increasing.
>
> The European Commission recognised the importance of aquaculture in the frame of the reform of the Common Fisheries Policy and the necessity to develop a strategy for the sustainable development of this sector. This strategy will be coherent with the other Community's strategies and in particular with the European Strategy for Sustainable Development and the conclusions of the Göteborg European Council of 15/16 June 2001."
>
> "The Commission strategy for a sustainable development of the European aquaculture industry aims at:

- Creating long term secure employment, in particular in fishing-dependent areas;
- Assuring the availability to consumers of products that are healthy, safe and of good quality, as well as promoting high animal health and welfare standards;
- Ensuring an environmentally sound industry."

> "A critical limiting factor for production development is the availability of space and clean water. Developing certain technologies such as water re-circulating systems, offshore cages and long-lines will allow for a reduction of dependence on local resources. Nevertheless, this cannot solve all the problems; Integrated Coastal Zone Management will be needed for a proper integration of aquaculture with the other activities carried out on the coast."
>
> "It is important to reduce the negative environmental impacts of aquaculture by developing a set of norms and/or voluntary agreements which prevent environment degradation. Conversely, the positive contribution of certain aquaculture developments to the environment must be recognised and encouraged, including by public financial incentives."
>
> *"Mollusc farming.* In traditional mollusc farming areas competition for space is not a major issue but finding space for new concessions is hard because this kind of farming is highly sensitive to external pollution and requires large amounts of space to thrive. Technological development of offshore rafts and long-lines has been successful. Therefore the Commission believes Member States should give greater priority to FIFG financing of this technology that will help to expand the sub-sector, even if it is more burdensome in terms of initial capital investment and running costs.

Integrated Coastal Zone Management (ICZM). The perspective of moving aquaculture further away from the coast should not prevent it from being considered as user of the coastal territory with the same rights as other human activities. Future aquaculture development should be based on Integrated Zone Strategies and Management Plans, which consider aquaculture in relation to all other existing and potential activities and take account of their combined impact on the environment.

The Commission has submitted to the Council and the European Parliament a European Strategy for ICZM, following which the European Parliament and the Council adopted an EU Recommendation on ICZM. The Strategy should lead to improved management of coastal zones. The Recommendation identifies aquaculture among the sectors and areas to be addressed in the future National ICZM strategies. The approach outlined in the Strategy and the Recommendation could serve as a model for introducing sustainable development in other parts of the European territory (e.g., river catchments are the most appropriate management unit in inland waters)."

WGEIM considers that the emphasis on ICZM in the Commission document is a particularly important development for aquaculture. For several years, WGEIM reports have presented the environmental, social and economic arguments that support the utilisation of ICZM in relation to mariculture developments. The Commission document now presents an opportunity to the industry, and Member States, to take full advantage of the developing capabilities of ICZM and related tools, such as GIS, DSS (see Section 7 of the report below).

3 MARAQUA

As a follow up to the Workshop on "Fish Farm Effluents and their control in EC Countries" (Rosenthal *et al*, 1993, 1994), during 2000 and 2001 the EU MARAQUA (The Monitoring and Regulation of Marine Aquaculture in Europe) Concerted Action project revisited the issues related to the monitoring and regulation of the impact of Mariculture within the European Union. The outcome of the project has been published as special issues in the Journal of Applied Ichthyology (Volumes 16 and 17).

In summary the MARAQUA project showed that:

- Most EU Member States have environmental quality standards (EQS) for mariculture activities, mainly in relation to water quality and nutrient output.
- The use of medicines and pesticides in marine aquaculture is generally permitted in European Countries, subject to permission from the appropriate authorities.
- Environmental monitoring by the competent authorities is commonplace throughout Europe, mainly to ensure compliance with EQS. The competent authorities are mainly concerned with monitoring the quality of shellfish-growing waters as well as the environmental impacts from finfish farms.
- While monitoring programmes related to the environmental impacts are in place in most EU Member States the type and extent of the programmes vary considerably from country to country.
- Self-monitoring programmes are evident for finfish farming with water and sediment quality being the main parameters sampled.

MARAQUA prepared details of the regulatory regime, in terms of the type of mariculture, carrying capacity, EQS, food standards, and medicines and pesticides licensed, as well as details of the monitoring programmes in place in each Member State and these are presented in summary form in Tables 1 and 2 below.

COUNTRY	TYPE OF MARINE AQUACULTURE	REGULATORY CONTROL CARRYING CAPACITY	ENVIRONMENTAL STANDARDS
DENMARK	FINFISH (landbased and sea cages) (mainly rainbow trout) some SHELLFISH (extensive)	effluent released to marine waters (maximum of 550 tonnes N and 54 tonnes P)	nutrient output (560t N and 54t P annually); feed type, feed conversion ratio
FINLAND	FINFISH (mainly rainbow trout)	no figure	discharge(8g P/kgfish produced, 70g N/kg fish produced
FRANCE	SHELLFISH (mainly oysters and mussels) some FINFISH (mainly seabream)	20 tonnes/year for finfish; no figure for shellfish	shellfish growing water quality; EIS can dictate standards for finfish; threshold levels for chemical residues
GERMANY	SHELLFISH (mainly mussels) some FINFISH (mainly rainbow trout)	no figure	effluent water quality; closed season for mussel harvest; shellfish growing water quality
GREECE	FINFISH (mainly sea bass and bream) SHELLFISH (mainly mussels)	no figure	cage location; stocking density; feed type; water and sediment quality; sanitary measures
ICELAND	FINFISH (mainly salmon) some char and rainbow trout	no figure	cage location; water quality; nature conservation
IRELAND	FINFISH (mainly salmon) SHELLFISH (mainly mussels)	15kg/m^3 stocking density for finfish	cage location, escape prevention, fallowing period; abundance of sealice; water and seabed quality
ITALY	FINFISH (mainly trout); some SHELLFISH (mussels, clams)	no figure	water quality
NORWAY	FINFISH (mainly salmonids) SHELLFISH (mainly mussels)	maximum fish density of 25 kg/m^3	nutrients, organic matter, micropollutants, dissolved oxygen, sediment quality, benthos
PORTUGAL	SHELLFISH (clams, oysters, cockles) some FINFISH (sea bass, sea bream, turbot)	no figure	water quality (maximun admissable values of pH, temperature, water colouration, suspended solids, salinity, dissolved oxygen, biotoxins, microbes
SCOTLAND	FINFISH (mainly salmon with some rainbow trout and turbot) SHELLFISH (oysters, scallops, mussels)	maximum weight of fish to achieve sustainability at a farm	hydrological character, biological, sediment and water quality
SPAIN	SHELLFISH (mainly mussels, cockles, clams) some FINFISH (salmon, turbot)	no figure	water quality for shellfish
SWEDEN	FINFISH some SHELLFISH (mussels)	no figure for finfish 10,000 - 100,000 tonnes for shellfish	water classification according to organic matter and metals in mussel tissue; farm sites; extraction and discharge of water; nutrients
THE NETHERLANDS	SHELLFISH (cockles, mussels, oysters)	100,000 metric tons (fresh weight) mussels 10,000 metric tons cockles	safeguard of food reserves for wild birds; biotoxins and microbes in shellfish growing waters

COUNTRY	TYPE OF MARINE AQUACULTURE	MONITORING		
		ENVIRONMENTAL		
		SELF MONITORING	AUTHORITY MONITORING	SELF MONITORING
DENMARK	FINFISH (landbased and sea cages) (mainly rainbow trout); some SHELLFISH	water quality monitored 12 times per year (finfish); sediment monitored twice per year (finfish)	compliance with finfish standards (periodic)	bivalves checked for algal toxins post harvest
FINLAND	FINFISH (mainly rainbow trout)	water quality; Farmers keep daily records of operation for inclusion in annual report	water quality (chemistry, plankton and macroalgae); sediment quality(sediment, benthic macroinvertebrates)	-
FRANCE	SHELLFISH (mainly oysters and mussels); some FINFISH (mainly seabream)	quality of effluent (finfish)	benthic survey and nutrient analysis of the water column twice per year; chemical residues and microbiology of water twice per month; shellfish water quality (algal toxins and phytoplankton) monitored twice per month;	bacteria, phytoplankton toxins in finfish flesh (before marketing)
GERMANY	SHELLFISH (mainly mussels) some FINFISH (mainly rainbow trout)	-	control of fishing vessels during mussel harvest and seed fishing; water quality monitored five times in three years	-
GREECE	FINFISH (mainly sea bass and bream); SHELLFISH (mainly mussels)	regular water quality, sediment and benthic community monitoring	-	-
ICELAND	FINFISH (mainly salmon with some char and rainbow trout)	all accessible knowledge collected to control environmental effects	chemical residues and microorganisms in fishing grounds;	internal quality control to ensure compliance
IRELAND	FINFISH (mainly salmon); SHELLFISH (mainly mussels)	-	sea lice monitored 14 times per year; water at salmon farms monitored monthly; benthic monitoring depends on tonnage (finfish)	-
ITALY	FINFISH (mainly trout); SHELLFISH (mussels, clams)	-	macro-descriptors' in water monitored seasonally (twice per week from June - September; ground parameters' once per year; maximum trophic index of 5.5	-
NORWAY	FINFISH (mainly salmonids); SHELLFISH (mainly mussels)	-	mollusc water quality once per month 15% of finfish farms monitored every year using the MOM-system on sediments under finfish farms	-
PORTUGAL	SHELLFISH (clams, oysters, cockles); some FINFISH (sea bass, sea bream, turbot)	-	mollusc water quality once per month or once every three months depending on the parameter	-
SCOTLAND	FINFISH (mainly salmon with some rainbow trout and turbot); SHELLFISH (oysters, scallops, mussels)	near-field sampling following an agreed programme (finfish)	audit self-monitoring of finfish farms; consent compliance of medicines; environmental impact from finfish farms; shellfish growing waters quality (periodic)	
SPAIN	SHELLFISH (mainly mussels, cockles, clams); some FINFISH (salmon, turbot)	-	periodic water quality; weekly red tide monitoring	-
SWEDEN	FINFISH some SHELLFISH (mussels	-	water classification according to organic matter and metals in mussel tissue	check for algal toxins in shellfish prior to harvest
THE NETHERLANDS	SHELLFISH (cockles, mussels, oysters)		aerial photography and ground counts of intertidal mussel stocks;	

4 Water Framework Directive

4.1 Background

The EU Water Framework Directive 2000/60/EC (WFD) will be the primary EU driver for the improvement of groundwater and surface water quality over the next decades. Under the Directive, definitions of good ecological quality will be agreed for all types of water body, covering all surface waters (and groundwater) in the EU. Good ecological quality will then be the target for improvement measures to be adopted by member states and their environmental agencies.

Aquaculture is not specifically mentioned in the Directive. However, mariculture will be viewed as being a source of environmental pressures with the potential to adversely affect primary indices of ecological quality in the transitional and coastal water bodies where mariculture operations are located. As such, it is likely that such areas will be subject to operational monitoring, as defined under the WFD.

The implementation of the WFD is a major exercise and the timetable for its completion stretches ahead during the first decades of the 21st century, towards the target of achieving "good" ecological status in all water bodies by 2015. In recognition of this, the EU established a Common Implementation Strategy, which consisted of a series of international projects addressing particular processes within the overall implementation. These groups have now prepared their reports, and it is now possible to make preliminary analyses to identify the areas where mariculture activities, discharges etc may come within the scope of WFD.

In order to do this, it is first necessary to describe the general processes involved in the implementation of the WFD. The following text has largely been derived from the output documents of the EU Common Implementation Strategy projects, particularly those concerned with Coastal and Transitional waters (Project 2.4) and Monitoring (Project 2.7).

4.2 Purpose of the Directive

The Directive establishes a framework for the protection of all waters (including inland surface waters, transitional waters, coastal waters and groundwater) which:

- Prevents further deterioration of, protects and enhances the status of water resources;
- Promotes sustainable water use based on long-term protection of water resources;
- Aims at enhancing protection and improvement of the aquatic environment through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances;
- Ensures the progressive reduction of pollution of groundwater and prevents its further pollution;
- Contributes to mitigating the effects of floods and droughts.

The concept central to the WFD is *integration,* which is seen as key to the management of water protection within the river basin district:

- **Integration of environmental objectives**, combining quality, ecological and quantity objectives for protecting highly valuable aquatic ecosystems and ensuring a general good status of other waters;
- **Integration of all water resources**, combining fresh surface water and groundwater bodies, wetlands, coastal water resources **at the river basin scale**;
- **Integration of all water uses, functions and values** into a common policy framework, i.e., investigating water for the environment, water for health and human consumption, water for economic sectors, transport, leisure, water as a social good;
- **Integration of disciplines, analyses and expertise,** combining hydrology, hydraulics, ecology, chemistry, soil sciences, technology engineering and economics to assess current pressures and impacts on water resources and identify measures for achieving the environmental objectives of the Directive in the most cost-effective manner;
- **Integration of water legislation into a common and coherent framework.** The requirements of some old water legislation (e.g., the Freshwater Fish Directive) have been reformulated in the WFD to meet modern ecological thinking. After a transitional period, these old Directives will be repealed. Other pieces of legislation (e.g., the

Nitrates Directive and the Urban Wastewater Treatment Directive) must be coordinated in river basin management plans where they form the basis of the programmes of measures;

- **Integration of all significant management and ecological aspects** relevant to sustainable river basin planning including those which are beyond the scope of the Water Framework Directive such as flood protection and prevention;
- **Integration of a wide range of measures, including pricing and economic and financial instruments, in a common management approach** for achieving the environmental objectives of the Directive. Programmes of measures are defined in **River Basin Management Plans** developed for each river basin district;
- **Integration of stakeholders and the civil society in decision making,** by promoting transparency and information to the public, and by offering an unique opportunity for involving stakeholders in the development of river basin management plans;
- **Integration of different decision-making levels that influence water resources and water status,** whether local, regional or national, for effective management of all waters;
- **Integration of water management from different Member States,** for river basins shared by several countries, existing and/or future Member States of the European Union.

4.3 Actions required under the Directive

The main activities required of Member States are:

- To identify the individual river basins lying within their national territory and assign them to River Basin Districts (RBDs) and identify competent authorities by 2003 (Article 3, Article 24*)*;
- To characterise river basin districts in terms of pressures, impacts and economics of water uses, including a register of protected areas lying within the river basin district, by 2004 (*Article 5, Article 6, Annex II, Annex III*);
- To carry out, jointly and together with the European Commission, the intercalibration of the ecological status classification systems by 2006 (*Article 2 (22), Annex V*);
- To make operational the monitoring networks by 2006 (*Article 8*)
- Based on sound monitoring and the analysis of the characteristics of the river basin, to identify, by 2009, a programme of measures for achieving cost-effectively the environmental objectives of the WFD (*Article 11, Annex III*);
- To produce and publish River Basin Management Plans (RBMPs) for each RBD including the designation of heavily modified water bodies, by 2009 (*Article 13, Article 4.3*);
- To implement water pricing policies that enhance the sustainability of water resources by 2010 (*Article 9*);
- To make the measures of the programme operational by 2012 (*Article 11*);
- To implement the programmes of measures and achieve the environmental objectives by 2015 (*Article 4*)

This sequence of activities is summarised in Figure 1. The following text will look at some of these processes in more detail.

a) Defining surface water bodies within transitional and coastal waters

The WFD requires that all surface waters are assigned to river basin districts (RBDs), which will be the primary management units. Within RBDs, surface waters will be allocated into water bodies. These will be the primary units for monitoring, classification and subsequent improvement (if necessary).

The Directive requires surface waters within the River Basin District to be split into water bodies (Figure 1). Water bodies represent the classification and management unit of the Directive. A range of factors will determine the identification of water bodies. Some of these will be determined by the requirements of the Directive and others by practical water management considerations. In particular, the definition of water bodies has to take account of the particular pressures that may impact the ecological quality of surface waters in the area.

In deriving an appropriate system of water bodies, the Directive only requires sub-divisions of surface water that are necessary for the clear, consistent and effective application of its objectives. Sub-divisions of coastal and transitional waters into smaller and smaller water bodies that do not support this purpose should be avoided.

For example, the need to keep separate two or more contiguous water bodies of the same type depends upon the pressures and resulting impacts. For example, a discharge may cause organic enrichment in one water body but not in the other. Such an area of one type could therefore be divided into two separate water bodies with different classifications. If there were no impact from the discharge it would not be necessary to divide the area into two water bodies as it would have the same classification and should be managed as one entity.

According to Annex II of the Directive, Member States shall assign surface water bodies to one of the following categories: rivers, lakes, transitional, coastal, artificial or heavily modified surface water bodies. These categories must then be further divided into types. The Directive indicates that Types can be defined using one of two systems (A and B). Most Member States have expressed the opinion that system B will be applied. This is because the differences in biological compositions and community structures normally depend on more descriptors than the very limited range included in system A.

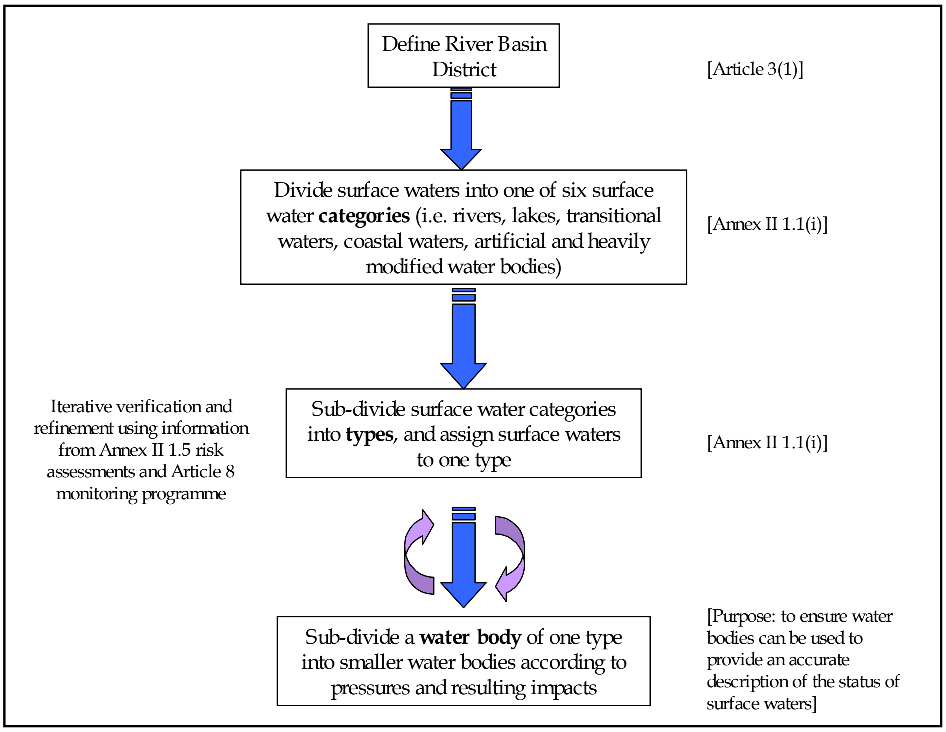

Figure 1. Summary of suggested hierarchical approach to the identification of surface water bodies.

The factors listed in Annex II of the Directive for defining typologies for coastal and transitional waters under System B are as follows:

Transitional Waters

Alternative Characterisation	Physical and chemical factors that determine the characteristics of the transitional water and hence the biological population structure and composition
Obligatory factors	Latitude longitude tidal range salinity
Optional factors	Depth current velocity wave exposure residence time mean water temperature mixing characteristics turbidity mean substratum composition shape water temperature range

Coastal Waters

Alternative Characterisation	Physical and chemical factors that determine the characteristics of the coastal water and hence the biological population structure and composition
Obligatory factors	Latitude longitude tidal range salinity
Optional factors	current velocity wave exposure mean water temperature mixing characteristics turbidity retention time (of enclosed bays) mean substratum composition water temperature range

4.4 Classification

Once typology has been established, water bodies are then assigned to types. Each water body must be assigned to only one type. The ecological quality of each water body is then assessed against the reference condition defined for that particular type. The reference condition is a description of the biological quality elements that exist, or would exist, at high status, that is, with no, or very minor disturbance from human activities. The objective of setting reference condition standards is to enable the assessment of ecological quality against these standards.

In defining biological reference conditions, criteria for the physico-chemical and hydromorphological quality elements at high status must also be established. The reference condition is a description of the **biological** quality elements only. High **ecological status** incorporates the biological, physico-chemical and hydromorphological elements.

The classification of ecological status is based upon the status of the biological, hydromorphological and physico-chemical quality elements (Figure 2). The quality elements to be included in classification of transitional and coastal waters are listed in Annex V 1.1.3. and 1.1.4, and reproduced below. The hydromorphological and physico-chemical elements are also referred to as the supporting elements.

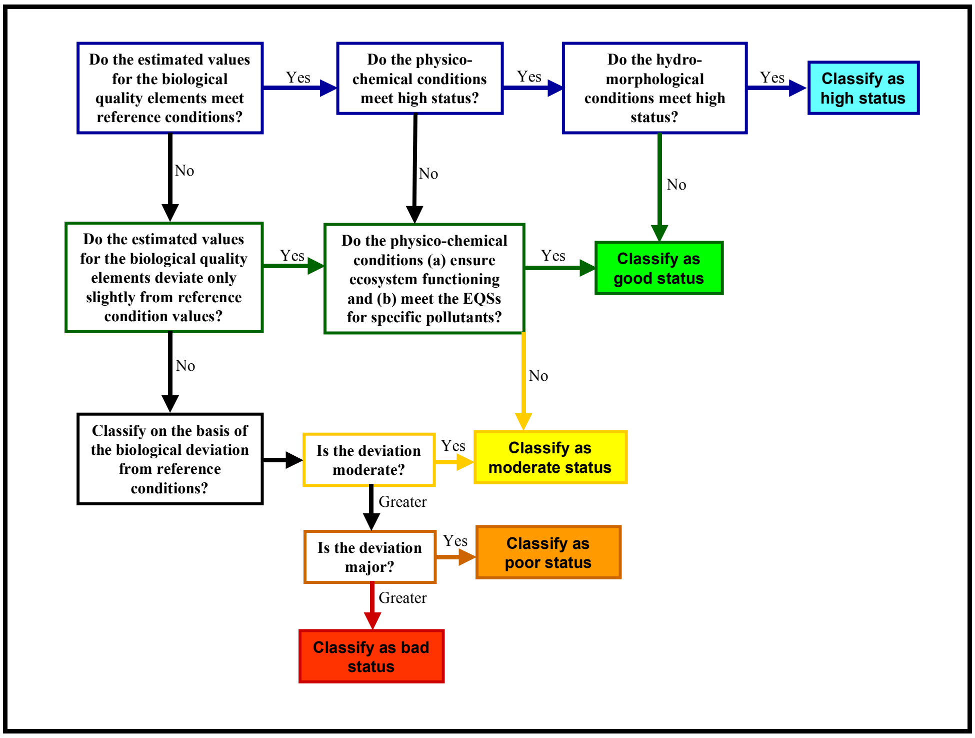

Figure 2. Indication of the relative roles of biological, hydromorphological and physico-chemical quality elements in ecological status classification according to the normative definitions in Annex V 1.2. A more detailed understanding of the role of physico-chemical parameters in the classification of the ecological status will be developed in specific guidance on this issue during 2003.

Annex V 1.1.3. Transitional Waters	**Annex V 1.1.4. Coastal Waters**
Biological elements	
• Composition, abundance and biomass of phytoplankton • Composition and abundance of other aquatic flora • Composition and abundance of benthic invertebrate fauna • Composition and abundance of fish fauna	• Composition, abundance and biomass of phytoplankton • Composition and abundance of other aquatic flora • Composition and abundance of benthic invertebrate fauna
Hydromorphological elements supporting the biological elements:	
Morphological conditions: • depth variation • quantity, structure and substrate of the bed • structure of the inter-tidal zone Tidal regime: • freshwater flow • wave exposure	Morphological conditions: • depth variation • structure and substrate of the coastal bed • structure of the inter-tidal zone Tidal regime: • direction of dominant currents • wave exposure
Chemical and physio-chemical elements supporting the biological elements:	
General: • Transparency • Thermal conditions • Salinity • Oxygenation conditions • Nutrient conditions Specific Pollutants: • Pollution by all priority substances identified as being discharged into the body of water • Pollution of other substances identified as being discharged in significant quantities into the body of water.	General: • Transparency • Thermal conditions • Salinity • Oxygenation conditions • Nutrient conditions Specific Pollutants: • Pollution by all priority substances identified as being discharged into the body of water • Pollution of other substances identified as being discharged in significant quantities into the body of water.

The Directive definitions of the biological elements at high status are shown below:

Biological elements at high status in transitional waters, taken from Annex V table 1.2.3.

Element	High Status
Biological Quality Elements	
Phytoplankton	The composition and abundance of the phytoplanktonic taxa are consistent with undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physico-chemical conditions.
Macroalgae	The composition of macroalgal taxa is consistent with undisturbed conditions. There are no detectable changes in macroalgal cover due to anthropogenic activities.
Angiosperms	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in angiosperm abundance due to anthropogenic activities
Benthic Invertebrate Fauna	The level of diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions. All the disturbance-sensitive taxa associated with undisturbed conditions are present.
Fish Fauna	Species composition and abundance is consistent with undisturbed conditions.

Biological elements at high status in coastal waters, taken from Annex V table 1.2.4.

Element	High Status
Biological Quality Elements	
Phytoplankton	The composition and abundance of the phytoplanktonic taxa are consistent with undisturbed conditions. The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physico-chemical conditions.
Macroalgae and Angiosperms	All disturbance-sensitive macroalgal and angiosperm taxa associated with undisturbed conditions are present. The levels of macroalgal cover and angiosperm abundance are consistent with undisturbed conditions.
Benthic Invertebrate Fauna	The level of diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions. All the disturbance-sensitive taxa associated with undisturbed conditions are present.

Physico-Chemical Elements

There are two groups of “chemicals” listed in the WFD. The first is Priority Hazardous Substances, and these are listed in Table 2 below. The Directive requires that Member States aim to cease releases of priority hazardous substances into the environment.

Priority substances identified under the Water Framework Directive

PRIORITY SUBSTANCES		
Priority Hazardous Substances	**Priority substances subject to review to priority hazardous substances**	**Priority substances**
1. Brominated diphenylether (only pentabromodiphenylether); 2. Cadmium; 3. Chloroalkanes, C10–13; 4. Hexachlorobenzene; 5. Hexachlorobutadiene; 6. Hexachlorocyclohexane; 7. Mercury and its compounds; 8. Nonylphenols; 9. Polycyclic Aromatic Hydrocarbons (PAHs); 10. Pentachlorobenzene; 11. Tributyltin compounds.	1. Anthracene; 2. Atrazine; 3. Chlorpyrifos; 4. Di (ethylhexyl) phthalate (DEHP); 5. Diuron; 6. Endosulfan; 7. Isoproturon 8. Lead and its compounds; 9. Naphthalene; 10. Octylphenols; 11. Pentachlorophenol; 12. Simazine; 13. Trichlorobenzenes; 14. Trifluralin.	1. Alachlor; 2. Benzene; 3. Chlorfenvinphos; 4. Dichloromethane; 5. 1,2-Dichloroethane; 6. Fluoranthene; 7. Nickel and its compounds; 8. Trichloromethane.

The second group of "chemicals" is listed in Annex VIII of the Directive, and is tabulated below. They are commonly referred to as the 'Specific pollutant' physico-chemical elements.

These physico-chemical elements are used to describe water bodies and include specific pollutants which are being discharged into the water bodies. They include non-synthetic and synthetic substances, as well as more general water quality parameters.

"Specific pollutant" physico-chemical elements (Annex VIII)

1. Organohalogen compounds and substances which may form such compounds in the aquatic environment.
2. Organophosphorus compounds.
3. Organotin compounds.
4. Substances and preparations, or the breakdown products of such, which have been proved to possess carcinogenic or mutagenic properties or properties which may affect steroidogenic, thyroid, reproduction or other endocrine-related functions in or via the aquatic environment
5. Persistent hydrocarbons and persistent and bioaccumulable organic toxic substances.
6. Cyanides.
7. Metals and their compounds.
8. Arsenic and its compounds.
9. Biocides and plant protection products.
10. Materials in suspension.
11. Substances which contribute to eutrophication (in particular, nitrates and phosphates).
12. Substances which have an unfavourable influence on the oxygen balance (and can be measured using parameters such as BOD, COD, etc).

For the purposes of classification of the physico-chemical quality elements in transitional and coastal waters, the WFD requires that the following are included:

General:

- Transparency
- Thermal conditions
- Oxygenation conditions
- Salinity
- Nutrient conditions

Specific Pollutants:

- Pollution by all priority substances identified as being discharged into the body of water
- Pollution of other substances identified as being discharged in significant quantities into the body of water

It is understood that the word “specific” should be taken to indicate that not all the elements listed in Annex VIII need be assessed in each water body, rather that classification should consider those elements which the preceding pressures assessment as indicated to be potentially significant.

The WFD also presents normative definitions of the physico-chemical elements at high, good and moderate status for **transitional** and **coastal waters,** as shown below: (Annex V, 1.2.3, 1.2.4).

High status	**Good status**	**Moderate status**
General conditions:		
The physico-chemical elements correspond totally or nearly totally to undisturbed conditions. Nutrient concentrations remain within the range normally associated with undisturbed conditions. Temperature, oxygen balance and transparency do not show signs of anthropogenic disturbance and remain within the ranges normally associated with undisturbed conditions.	Temperature, oxygenation conditions and transparency do not reach levels outside the ranges established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements. Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific synthetic pollutants:		
Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<environmental quality standard).	Conditions consistent with the achievement of the values specified above for the biological quality elements.
Specific non-synthetic pollutants:		
Concentrations remain within the range normally associated with undisturbed conditions (background levels).	Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6. without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<environmental quality standard).	Conditions consistent with the achievement of the values specified above for the biological quality elements.

It should be noted that the general area of the definition of EQS values, appropriate analytical techniques, quality assurance, etc., is the subject of continuing debate. Key definitions (e.g., of "close to zero") have not been agreed. These issues are being examined by a sub-group of the Expert Advisory Forum on Priority Substances (EAF PS) dealing with Analysis and Monitoring (AMPS). It has been recommended that the approaches adopted by the EAF PS, AMPS group, be adopted for substances for which national detection limits and background concentrations require to be set.

4.5 Monitoring requirements for the Directive

Article 8 of the Directive establishes the requirements for the monitoring of surface water status (and also groundwater status and protected areas). Monitoring programmes are required to establish a coherent and comprehensive overview of water status within each river basin district. The programmes have to be operational at the latest by 22 December 2006, and must be in accordance with the requirements of Annex V.

Annex V indicates that monitoring information from **surface waters** is required for:

- The classification of status. Supplementing and validating the Annex II risk assessment procedure;
- The efficient and effective design of future monitoring programmes;
- The assessment of long-term changes in natural conditions
- The assessment of long-term changes resulting from widespread anthropogenic activity;
- Estimating pollutant loads transferred across international boundaries or discharging into seas;
- Assessing changes in status of those bodies identified as being at risk in response to the application of measures for improvement or prevention of deterioration;
- Ascertaining causes of water bodies failing to achieve environmental objectives where the reason for failure has not been identified;
- Ascertaining the magnitude and impacts of accidental pollution;
- Use in the intercalibration exercise;
- Assessing compliance with the standards and objectives of Protected Areas; and,
- Quantifying reference conditions (where they exist) for surface water bodies should.

Three types of monitoring for surface waters are described in Annex V: surveillance, operational and investigative monitoring. These types are to be supplemented by monitoring programmes required for Protected Areas registered under Article 6. Annex V only describes requirements for Drinking Water Protected Areas in surface water and for Protected Areas for habitats and species. Member States may wish to integrate monitoring programmes established for other Protected Areas within the programmes established under the Directive. This is likely to improve the cost-effectiveness of the various programmes.

The text above has described the process by which surface water bodies are identified, categorised and then assigned to types. Type-specific reference conditions have to be identified for each surface water body type. It is the type-specific reference conditions from each surface water body type that the monitoring results will be compared with to give an assessment of the status of a water body categorised in the water body type. Information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are subject has to be collected and maintained. There must then be an assessment of the susceptibility of the surface water status of bodies to the pressures identified, and of the likelihood that surface water bodies within the river basin district will fail to meet the environmental quality objectives set under Article 4. This assessment will use any available existing monitoring data. Also expert judgement and/or modelling approaches (i.e., risk assessment) can be used. For the first assessment, data will not be available from Article 8 monitoring programmes, as they do not have to be operational until the end of 2006: data should be available for subsequent assessments for future RBMPs. However, many countries already have extensive monitoring programmes. The general relationship between the requirements of Articles 5 and 8 in relation to monitoring are summarised in Figure 3 below.

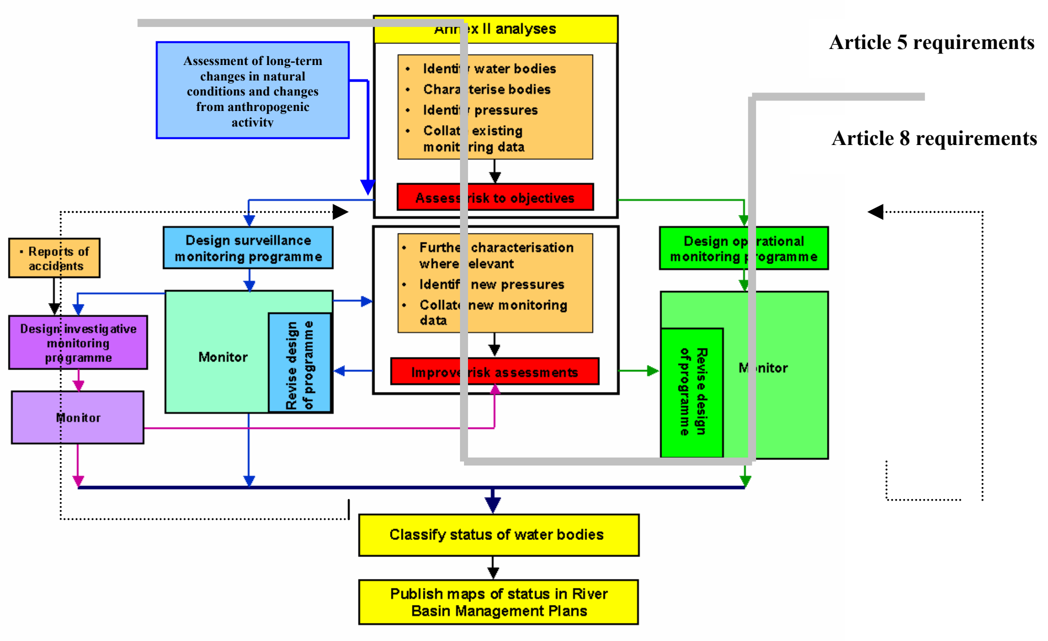

Figure.3. Schematic diagram illustrating the relationship between Article 5 and Article 8 in the design of surface water monitoring programmes.

Specifically, fish farms will probably be assessed as potentially affecting the quality of the benthic fauna, the phytoplankton and angiosperm communities, and also hydrochemical conditions such as nutrient and dissolved oxygen concentrations.

However, the position of aquaculture within WFD also needs to be viewed from a different perspective. Successful aquaculture requires good water quality. As the targets for improvements in water quality will be defined within the WFD system, it is important to assess the relationships between the WFD targets and the requirements of aquaculture.

4.5.1 What Water bodies should be monitored

The Water Framework Directive covers all waters including inland waters (surface water and groundwater) and transitional and coastal waters up to one sea mile (and for the chemical status also territorial waters which may extend to 12 sea miles) from the territorial baseline of a Member State, independent of the size and the characteristics. For the purpose of the implementation of the directive the totality of waters is attributed to geographical or administrative units, in particular the river basin, the river basin district, and the "water body". In addition, groundwater and stretches of coastal waters must be associated with a river basin (district).

Whereas the river basin is the geographical area related to the hydrological system, the river basin district must be designated by the Member States in accordance to the directive as the "main unit for management of river basins"

One key purpose of the Directive is to prevent further deterioration of, and protect and enhance the status of aquatic ecosystems, and with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems. The success of the Directive in achieving this purpose and its related objectives will be mainly measured by the status of "water bodies". "Water bodies" are therefore the units that will be used for reporting and assessing compliance with the Directive's principal environmental objectives.

Monitoring is a cross-cutting activity within the Directive and as such there are important interrelationships with other Articles and Annexes of the Directive. A key Article in relation to monitoring and the design of appropriate programmes for surface waters and groundwater is Article 5. Article 5 requires river basin districts to be characterised and the environmental impact of human activities to be reviewed in accordance with Annex II.

Annex II describes a process by which surface water bodies are identified, categorised and then typified according to one of two systems A or B given in section 1.2 of the Annex. Type-specific reference conditions have to be identified for each surface water body type. It is the type-specific reference conditions from each surface water body type that the monitoring results will be compared with to give an assessment of the status of a water body categorised in the water body type. Information on the type and magnitude of the significant anthropogenic pressures to which the surface water bodies in each river basin district are subject has to be collected and maintained. There must then be an assessment of the susceptibility of the surface water status of bodies to the pressures identified, and of the likelihood that surface water bodies within the river basin district will fail to meet the environmental quality objectives set under Article 4. This assessment will use any available existing monitoring data: the extent of existing data will vary greatly from country to country. Also expert judgement and/or modelling approach (i.e. risk assessment) can be used. For the first assessment there will not be data arising from the Article 8 monitoring programmes as they do not have to be operational until the end of 2006: data should be available for subsequent assessments for future RBMPs. Many countries already have extensive monitoring programmes.

The objective of monitoring is to establish a coherent and comprehensive overview of water status within each River Basin District and must permit the classification of all surface water bodies into one of five classes and groundwater into one of two classes. However, this does not mean that monitoring stations will be needed in each and every water body. Member States will have to ensure that enough individual water bodies of each water body type are monitored. They will also have to determine how many stations are required in each individual water body to determine its ecological and chemical status. This process of selecting water bodies and monitoring stations should entail statistical assessment techniques, and should ensure that the overview of water status has an acceptable level of confidence and precision.

For surface water bodies, the Directive requires that sufficient surface water bodies are required to be monitored in surveillance programme to provide an assessment of the overall surface water status within each catchment and sub-catchment within the river basin district. Operational monitoring is to establish the status of those water bodies identified as being at risk of failing their environmental objectives, and to assess any changes in their status from the programmes of measures. Operational monitoring programmes must use parameters indicative of the quality element or elements most sensitive to the pressure or pressures to which the body or group of bodies is subject. This means that the least number of estimated quality element values may be used in status classification.

The scale of monitoring programmes will be dependent to some degree on the numbers of water bodies—or more accurately—on the extent of, and variability in, impacts on the water environment. However, the amount of monitoring required will also depend on the degree to which the characteristics of, and range of pressures on, a Member State's water bodies allow them to be grouped for monitoring purposes.

Article 2.10 of the Directive provides the following definition of a body of surface water: "Body of surface water" means a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water.

4.5.2 Surveillance monitoring of surface waters

Objectives and timing

The objectives of surveillance monitoring of surface waters are to provide information for:

- Supplementing and validating the impact assessment procedure detailed in Annex II;
- The efficient and effective design of future monitoring programmes;
- The assessment of long-term changes in natural conditions; and
- The assessment of long-term changes resulting from widespread anthropogenic activity.

The results of such monitoring should be reviewed and used, in combination with the impact assessment procedure described in Annex II, to determine requirements for monitoring programmes in the current and subsequent River Basin Management Plans (RBMP).

As has already been described, there will be no information arising from surveillance monitoring for the first risk assessment undertaken under Article 5 – monitoring programmes have to be operational by December 2006, and the first Article 5 characterisation/risk assessment completed by December 2004. However, any existing monitoring data should be used in the assessment. Many countries have already established extensive monitoring programmes, including monitoring programmes at fish farm locations.

Surveillance monitoring has to be undertaken for at least a period of one year during the period of a RBMP. The deadline for the first RBMP is 22 December 2009. The monitoring programmes must start by 22 December 2006. The first results will be needed for the first draft RBMP to be published at the end of 2008, and then for the finalised RBMPs at the end of 2009. These plans must include status maps.

Surveillance monitoring is also required to provide information on long-term natural changes and long-term changes resulting from widespread anthropogenic activity. Information on the first will be important if such changes are likely to affect reference conditions. Monitoring for long-term natural changes is likely to be focused on high and maybe good status water bodies. This is because such changes (possibly relatively small and gradual) are more likely to be detectable in the absence of the impact of anthropogenic activities which may mask natural changes. In terms of changes resulting from widespread anthropogenic activity, monitoring will be important to determine or confirm the impact of, for example, long range transport and deposition of pollutants from the atmosphere. If this is likely to lead to a risk of water bodies deteriorating in status (any status level down to poor) then those water bodies or groups of bodies will have to be included in operational monitoring programmes.

Selection of quality elements

For surveillance monitoring, Member States must monitor at least for a period of a year parameters indicative of all biological, hydromorphological and general physico-chemical quality elements. The relevant quality elements for each type of water are given in Annex V the Directive. Thus for rivers, the biological parameters chosen to be indicative of the status of each biological element such as the aquatic flora, macro-invertebrates and fish must be monitored. For example, in the case of the aquatic flora, the parameters might be presence or absence of indicator species or the population structure. The Directive indicates that monitoring of the biological quality elements must be at an appropriate taxonomic level to achieve adequate confidence and precision in the classification of the quality elements. This applies equally to the three types of surface water monitoring.

Those priority list substances discharged into the river basin or sub-basins must be monitored. Other pollutants (Annex VIII) also need to be monitored if they are discharged in significant quantities in the river basin or sub-basin. No definition, however, of ‘significance’ is given but quantities that could compromise the achievement of one of the Directive’s objectives are clearly significant, and as examples, one might assume that a discharge that impacted a Protected Area, or caused exceedence of any national standard set under Annex V 1.2.6 of the Directive or caused a biological or ecotoxicological effect in a water body would be expected to be significant.

A structured approach should be used to inform the process of selecting which chemical should be monitored in the surveillance monitoring programme. This should be based on a combination of knowledge of use patterns (quantity and locations), pathways for inputs (diffuse and/or point source) and existing information on potential ecological impacts.

Additionally the selection should be informed by information on the ecological status where indications of toxic impacts are found or from ecotoxicological evidence. This will help to identify situations where unknown chemicals are entering the environment and which need investigative monitoring.

4.5.3 Operational monitoring of surface waters

Objectives

The objectives of operational monitoring are to:

- Establish the status of those bodies identified as being at risk of failing to meet their environmental objectives, and
- Assess any changes in the status of such bodies resulting from the programmes of measures.

Operational monitoring (or in some cases investigative monitoring) will be used to establish or confirm the status of bodies thought to be at risk. It is highly focused on parameters indicative of the quality elements most sensitive to the pressures to which the water body or bodies are subject.

Selection of monitoring sites

Operational monitoring has to be undertaken for all water bodies that have been identified, by the review of the environmental impact of human activities (Annex II) and/or from the results of the surveillance monitoring, as being at risk of failing the relevant environmental objectives under Article 4. Monitoring must also be carried out for all bodies into which priority substances are discharged. This implies that monitoring in all such bodies will not necessarily be required as the Directive allows similar water bodies to be grouped and representatively monitored.

In addition, monitoring sites for those priority list substances with environmental quality standards should be selected according to the requirements of the legislation establishing the standards.

For diffuse sources, the selected water bodies need to be representative of the relative risks of the occurrence of the diffuse source pressures, and of the relative risks of the failure to achieve good surface water status. However, in selecting the representative water bodies for operational monitoring it should be taken into account that water bodies can only be grouped, for example, where the ecological conditions are similar or almost similar in terms of the magnitude and type pressure as well as in terms of hydrological and biological conditions such as retention time and food web structure. In all cases grouping must be technically or scientifically justifiable.

Selection of quality elements

For operational monitoring, Member States are required to monitor for those biological and hydromorphological quality elements most sensitive to the pressures to which the body or bodies are subject. For example, if organic pollution is a significant pressure on a river then benthic invertebrates might be the most sensitive and appropriate indicator of that pressure. Thus in the absence of other pressures, aquatic flora and fish populations may not need to be monitored in those bodies of water. However, the monitoring and assessment system must still be based on the concept of ecological status and not just reflect degrees of organic pollution without comparison to the appropriate reference conditions. This is because its ecological status must be defined.

4.5.4 Investigative monitoring

Investigative monitoring may also be required in specified cases. These are given as:

- where the reason for any exceedence of Environmental Objectives are unknown;
- where surveillance monitoring indicates that the objectives set under Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established, in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives; or
- to ascertain the magnitude and impacts of accidental pollution.

The results of the monitoring would then be used to inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution.

Investigative monitoring will thus be designed to the specific case or problem being investigated. In some cases it will be more intensive in terms of monitoring frequencies and focused on particular water bodies or parts of water bodies, and on relevant quality elements. Ecotoxicological monitoring and assessments methods would in some cases be appropriate for investigative monitoring.

Monitoring for Protected Areas

There are additional monitoring requirements for protected areas. Protected Areas include bodies of surface water and groundwater used for the abstraction of drinking water and habitat and species protection areas identified under the Birds Directive or the Habitats Directive.

In terms of habitat and species protection areas, bodies of water forming these areas must be included in operational monitoring if they are identified (by the Annex II risk assessment and surveillance monitoring) as being at risk of not meeting their environmental objectives. Monitoring must be carried out to assess the magnitude and impact of all relevant significant pressures on these bodies, and where necessary, to assess changes in the status of such bodies resulting from the programmes of measures. Monitoring should also continue until the areas satisfy the water-related requirements of the legislation under which they are designated and met their objectives under Article 4.

Locations of water bodies to be monitored

It is not economically feasible to monitor all water bodies for all conditions. Therefore, it is necessary to group "similar" water bodies and to select appropriate representative sites for the determination of ecological status for that particular group of sites. While the Directive requires that monitoring be undertaken for all surface and groundwater bodies, grouping is permitted as long as sufficient water bodies are monitored within a group to provide an accurate assessment of status for that group.

Member States should firstly determine which water bodies are required to be monitored in accordance with the Directive. The water bodies selected will vary depending on the objectives of the programme. For example, Annex V of the Directive provides different criteria for the selection of water bodies, depending on whether the objectives of the programme are established to satisfy the requirements for surveillance, operational or investigative monitoring, or for protected areas. Therefore each Member State must first discriminate according to the specific requirements of the Directive (e.g., size/population boundaries) and eliminate those water bodies in which monitoring is not required.

Once the relevant water bodies have been identified, further grouping may be required due to economic constraints. Water bodies may be grouped based on similar hydrological, geomorphological, geographical or trophic conditions. Alternatively water bodies could be grouped based on similar catchment impacts or land-uses. However, the latter may only be possible in catchments that are dominated by a single land-use. Another possibility is to use multivariate classification procedures for identifying groups of sites that form relatively homogenous areas (although this "black box" approach should be used with caution as there is no guarantee that the composition of the resulting groups will have a recognisable or obvious rationale). Whatever the method by which the water bodies are grouped, it is essential that sufficient water bodies are selected from each group to enable the specific objectives of the monitoring programme to be met with the required levels of precision and confidence.

The characterisation required by Annex II makes possible a characterisation of water bodies based on environmental variables. Water body characterisation as a function of pressures would be made possible through an assessment of pressures and impacts, in which optimisation of the monitoring programme could be achieved by a grouping of pressures.

Risk of failing environmental quality objectives

The Directive refers to the identification of water bodies at risk of failing environmental quality objectives as defined in Article 4. This identification will be partially based on existing monitoring data (initially) and then on data arising from surveillance monitoring for subsequent periods of RBMPs. Those water bodies identified as being at risk will then be subject to operational monitoring which will confirm or reject their status in terms of failure to meet the relevant objectives. By implication this means that operational monitoring may need to provide a more precise assessment of the status of those water bodies identified at-risk than that originally obtained from surveillance monitoring.

Not all the Environmental Objectives given in Article 4 will be applicable to all water bodies: they can be summarised as follows:

1) To achieve good groundwater status, good ecological status, good ecological potential or good chemical status;
2) To comply with any standards and objectives associated with Protected Areas;
3) To prevent deterioration in the status of a body of surface water or groundwater;
4) To progressively reduce pollution from priority substances, and cease or phase out emissions, discharges and losses of priority hazardous substances; and,
5) To reverse any significant and sustained upward trend in the concentration of any pollutant in groundwater.

Objectives 1 and 2 imply that assessments will have to be made as to whether status is better or worse than that which defines the threshold value between good and moderate status (or potential), or is in compliance with defined standards. Objectives 3 to 5 relate to assessing whether status is deteriorating with time or pollution is decreasing with time. In the latter cases, threshold levels or concentrations of substances against which risk of failure is judged will be specific to the water body of interest and will relate to levels or concentrations specified at a particular time.

As indicated above, the assessment of the risk of failure of a water body will make use (when possible) of data from monitoring stations within the body. The discrimination between good and moderate and hence the risk of failure could be determined based on comparison of the calculated "confidence of compliance" with the appropriate standard or threshold value.

As noted earlier, the assessment of failure would have to consider what would be acceptable Type I and Type II errors. A Type I error would occur when a water body that was truly satisfactory was failed on the evidence of the monitoring programme. Conversely, a Type II error would occur when a water body that was truly unsatisfactory was passed by the monitoring programme.

4.5.5 Transitional Waters

Aspects and features of the different quality elements to be monitored are set out below.

Biological Quality Elements

Phytoplankton

Particularly relevant is the identification of nuisance or potentially toxic species, if they are typical for the transitional water studied. The main difficulties in using phytoplankton as a quality element for transitional waters with pronounced tides are represented by the extremely high natural spatial and temporal variability of the planktonic communities which may make phytoplankton monitoring a useless exercise in some transitional waters. The use of size fraction and size spectra may overcome the problems of taxonomic identification and intercalibration, but still require a standardisation of methods In shallow environments, the structure of phytoplankton community can be influenced by the resuspension of benthic microalgae, mostly due to wave and wind.

Seasonal monitoring is suited for representing the phytoplankton community variability when seasonal patterns are predictable. However, the seasonal frequency applies only for taxonomic analyses. At least monthly samplings for phytoplankton chlorophyll-*a* should be considered during the vegetation period, weekly sampling would be optimal, fortnightly sampling recommended. Chlorophyll-*a* analyses give a coarse assessment of the phytoplankton biomass (expressed as $\mu g\ L^{-1}$), therefore parallel sampling for cell identification and counting should be collected and stored. In case of significant month-by-month changes of chlorophyll-*a* the stored samples might be used for taxonomical analyses. In addition to the chlorophyll-*a* analysis, the direct water colour can also give important information, namely the coloured waters are symptoms of typical blooms (e.g., red waters for dinoflagellates, etc.).

Macroalgae (seaweeds)

The main difficulties in using macroalgae as a quality element are represented by the ephemeral behaviour of these quality elements undergoing some spatial and temporal variability which bias monitoring, however, to a much lesser extent than in case of phytoplankton. Therefore in some transitional waters, macroalgae and other macrophytes such as angiosperms may be better suited for monitoring the ecological quality than phytoplankton.

The sampling frequency should be suited for representing changes in seaweed communities thus be selected on a region- and type-specific level. During the vegetation period, sampling should be carried out fortnightly to monthly.

Changes in community structure and specific biomasses may be rapid and unpredictable due to the ephemeral characteristics of some of the macroalgae, therefore seasonal samplings are not well suited.

The coverage (as a % of the total system area), changes of this area, the frequency of macroalgal blooms, their size together with the community variability are a good indicator of the state the macroalgae and their environment, and can be used as an early warning systems. Qualitative analyses of new species (new forms) can be also performed by site-trained personnel as an additional warning detection.

Angiosperms (seagrasses)

Optional parameters that countries may wish to use in addition are species abundance (as number of individuals per m^2) and biomass (as g dry weight m^{-2}) as well as depth distribution (lower limit of occurrence). Changes in coverage and composition as well as the occurrence of rare or sensitive species may be used as indicators of human, but also natural impact (e.g., storms, ice winters).

The sampling frequency suited for representing changes in seagrass communities in shallow transitional waters is monthly during the vegetation period. Depending on region and assemblage, it may be sufficient to sample twice during the vegetation period (extensive mapping at a time when species identification is most easy, e.g., during the bloom period, followed by a second survey at the end of the vegetation period).

Benthic invertebrate fauna

Optional parameters that countries may use in addition are biomass (usually expressed as g ash free dry weight m^{-2}) as well as fractionated biomass (size fractions or body size spectra). However, the reliable determination of macrozoobenthic biomass at a representative station requires a very large number of samples (e.g., 200 replicates per station). Apart from natural small-scale variability, the methodological bias is fairly high due to several steps involved (fresh/wet weight, dry weight, ash-free dry weight). A solution could be to use conversion factors derived from reliable time-series taken in the region/type concerned.

A standardisation of methods is still required and there is a lack of quality assurance protocols. On a temporal scale, the sampling frequency suited for representing changes in benthic invertebrate communities in shallow transitional waters should be selected on a regional/type-specific basis. Sampling should take place at least twice per year (spring and autumn) A recommendable approach for transitional waters in temperate areas (e.g., river Elbe) is fortnightly sampling during spring/early summer (April–June) followed by 2–-3 samplings in August/September. In other areas (e.g., Mediterranean), seasonal sampling might be preferable. Recent attempts to apply statistical analyses to the higher taxonomic levels or on species pooled into ecological or trophic guilds have been successful.

Fish fauna

For classifying the ecological status, the limnological classification scheme based on indicator fish species could be used. Sound abundance estimates require long time series due to high variability. In general, the species composition of transitional waters seems to be most appropriate for WFD purposes; abundance or biomass are not good in these waters because of high variability.

It should be noted that sampling for fish faunal composition and abundance should preferably be carried out at least twice per year (spring/autumn) and that for reliable estimates of fish abundance, long time series of at least 10 years are inevitable because of natural variability.

Hydromorphological Quality Elements

An Expertise's suggestion is to consider the hydrological budget a quality element more general than the freshwater flow, which is actually a component of the hydrological budget. Hydrological budget responds to variation of the freshwater flow but also to variation in the sand accumulation vs. sand erosion processes.

Morphological conditions

Refer to same paragraph for coastal waters.

Depth variations

Refer to same paragraph of Section coastal waters.

Structure and substrate of the transitional water bed

Refer to same paragraph of coastal waters.

Structure of the transitional zone

The structure of the transitional zone can be monitored in terms of structure of the vegetation occurring at the land-water interfaces, as affected by features of the substrate (mud, sand, rock, etc.), of the climatic and hydrologic regimes and of the anthropogenic pressures.

Vegetation coverage, vegetation type and floristic composition are the parameters that can be monitored.

A major problem is that the structure of vegetation is only an indirect indicator of the activity of the transitional zone as a buffering zone for the pressures of the anthropogenic activities in the watershed.

The structure of vegetation can be monitored each three years.

Hydrological budget

The hydrological budget characterises the different transitional waters, i.e., estuaries, deltas, lagoons, coastal lakes, ports or gulfs, determines the sediment distribution and affects the sensitivity and resilience of transitional water ecosystems. Consequently, the hydrological budget has a major influence on all the quality elements in transitional waters.

Hydrological relevant parameters for an estuary are: the volumes entering the estuary during high and low tide (tidal volume). The water flow (volume and velocity) is varying very locally. Subsequently erosion and sedimentation processes are sensitive to anthropogenic measures (LT-process) and extreme events like storm (ST-process). Special attention has to be given to the fish breeding areas between 0 to 5 m water depth and currents below 0,5 m. Monitoring these area's should be included in the programme.

Changes in the components of the hydrological budget, due to human activities, are expected to be relatively slow. Therefore, monitoring is recommended every three years. Monitoring should be performed with data collection on all the freshwater inputs and outputs arranged on a seasonal scale.

Chemical and Physico-chemical Quality Elements

For all the chemical and physicochemical quality elements refer to the same paragraphs of Section 1.4.3 (coastal waters).

A specific consideration for transitional waters is:

Salinity

It is fundamental to measure the salinity gradient horizontally as well as vertically, especially for the physical delimitation of the transitional zone.

4.5.6 Coastal Waters

Biological Quality Elements

A very important issue when using biological elements as QE is the need of expertise required for taxonomic identification at the species level and the *in-situ* taxonomic resolution limitation.

Appropriately scientifically qualified personnel are to carry out the surveys. They shall be able to document competence within their specialist field, and participate in ring-testing, when the appropriate routines are available. For investigations spanning several years, priority should be given to continuity in personnel carrying out the recordings.

Phytoplankton

Particularly relevant is the identification of nuisance or potentially toxic species as important assessment parameters. Bloom frequency and intensity is considered an indicative parameter for classification of ecological status.

High natural spatial and temporal variability of the planktonic communities requires frequent sampling to ensure meaningful data for classification or detection of events (blooms). Sampling frequency is determined by the variability, and it is recommended a minimum of monthly sampling with optional increased sampling frequency in seasons with main bloom events. Sampling should be performed together with measurements of chemical and physico-chemical parameters. Seasonal sampling is a minimum frequency.

The minimum sampling frequency required by the Directive is every six months; However, available expert knowledge and pilot studies on sampling frequencies could be helpful to set up the most appropriate sampling frequency, number and location of stations on a regional or type-specific level. A selection of region/area-specific phytoplankton indicator species could be useful.

New monitoring programmes for the WFD could build on the existing phytoplankton monitoring programmes for other purposes, as, for example, the Shellfish Hygiene Directive (Council Directive 91/492/EEC of 15 July 1991), to ensure best “value for money” in monitoring.

Macroalgae/Angiosperms (Phytobenthos)

It is important to monitor not only their composition and abundance (as requested in the Directive) but also their distributions, extension and variation in time and space (mapping at different needed scales), as it provides important information not only on the health status of the plants’ habitats, but also on the ecosystem stability, as variations may indicate long-term changes in the physical conditions at the site.

Macroalgae are an important region-specific parameter. Macroalgal communities often include a wide range of species/functional groups that may change upon eutrophication e.g., highly diverse algal species can be replaced by opportunistic and stress-resistant seaweeds.

For angiosperms, distribution is the most important parameter because changes are not occurring from month to month. It may therefore be sufficient to monitor angiosperms every six months (spring/autumn), once a year or even only once every 3 years, depending on the species.

Supplementary variables essential for interpretation of macrophytobenthos results include: substrate type, depth in relation to sea level or standard datum, slope and bearing, presence of loose sediment, degree of wave exposure, tidal range, Secchi disk depth, and salinity.

Benthic invertebrate fauna

The required parameters to be measured are composition and abundance. Important variables to be considered are also diversity of species and presence of sensitive or higher taxa as well as biomass, the latter being indicative of eutrophication phenomena.

Recent studies in taxonomic classification have shown that looping species into higher taxa (including morphological categories) does not necessarily limit the sensitivity of animal assemblages to detect impacts.

It should be noted that sometimes it is difficult to show a clear correlation between possible changes found in the benthos (e.g., long-term changes in zoobenthos species composition) and eutrophication. Biomass may be a better parameter though not mandatory for WFD monitoring. Therefore it is recommended to include biomass as optional monitoring parameter. Furthermore it should be noted that other factors, e.g., fisheries, may have an overriding effect compared with eutrophication effects. A distinction should be made between acute, direct effects on the benthos (e.g., directly related to dredging or oxygen deficiency and/or toxic blooms) and long-term changes. Both may need different sampling frequencies and spatial coverage.

Hydromorphological Quality Elements

Morphological conditions

The morphological characteristics of coastal areas are generally subjected to low variability due to natural large-scale bottom dynamics processes or changes in tidal regime and weather patterns.

Relevant for ecological status is the time scale of the changes resulting from human impact in the past. Time scale of 10 to 25 years means that relevant changes in hydro morphological conditions have impact on ecology. In addition sea level rise makes it necessary to adapt the monitoring frequency and spatial scale to analyse the processes and to find the sand budgets in coastal zone, sheltered seas and estuaries.

Monitoring the trends in depth gradients has to take into account water management measures like dredging and dumping activities and naturally induced variability, under particular weather conditions such as storm events and ice winters/ice coverage. Also natural coastal erosion and elevation of the land e.g., Baltic.

Depth variations

The topography of the area (shape, bathymetry, slope) influences the biological communities living in it. Depth variations could be important elements to be monitored in areas where disturbances are expected, anthropogenic changes will have relevance for the status classification of the water body.

Structure and substrate of the coastal bed

Changes in morphological conditions and/or nature of the substratum may exert severe detrimental effects on benthic organisms. Differences between communities in coastal zones and estuaries are linked to a coastal typology (see link with CIS WG 2.4):

Possible causes of anthropogenic alterations in structure, substrate and shape of the coastal bed are:

- coastal constructions (dredging, dumping, dams, artificial reefs, etc.);
- variations in riverine sediment inputs (solid transport regime) due to human impact.

For depth variation and structure and substrate of the coastal bed it may be sufficient to collect the required information once (e.g., a map of the coastal bed) and to record

- at each sampling carried out after first thorough survey: typical parameters (e.g., nature of substratum) and obvious changes (e.g., visible changes after big storm events);
- changes due to anthropogenic impact (e.g., dam construction).

A thorough survey should be repeated in regular, but longer intervals (e.g., once per management period or longer, depending on parameter).

Structure of the intertidal zone

As for the structure of the intertidal zone, it cannot be used as a quality element in the Mediterranean and the Baltic eco-regions, given the low amplitude of tides in the Mediterranean basin and in the Baltic Sea.

Thus it has been proposed to introduce the intertidal***/mediolittoral*** term as its ecological relevance is due to the fact that it comprises living assemblages that require or tolerate immersion but cannot survive permanent or semi-permanent immersion (same definition for the intertidal). Thus mediolittoral zone supports diverse and very productive assemblages of algae and invertebrates that can be considered analogues to those of intertidal habitats.

Possible causes of anthropogenic alterations in structure, substrate and shape of the intertidal are:

- coastal constructions (dredging, dumping, dams, artificial reefs, etc.);
- chemical inputs (nutrients) leading to a change in the composition of macroalgal communities;
- variations in coastal or riverine sediment movements (sediment transport regime) due to human impact.

Mediterranean experts' judgements suggest to focus particular attention on the structure and condition of the mediolittoral and upper infralittoral zones in tideless seas, at least in the Mediterranean, since several species and communities thriving in this area are very good biological indicators, as exposed to a wide range of anthropogenic impact due to their critical position at the interface between the sea and the land.

Tidal regime

Tidal regime in terms of direction of dominant currents and level of wave exposure can be seasonally predictable and are available from most of the National Hydrographic Services. Deviations from the natural pattern in tidal regime derive from direct anthropogenic intervention on the profile of the coastline and may have severe bearings on the stability of the biological assemblages, thus they need to be taken into consideration. Asymmetry in the tidal waves results in positive or negative yearly budgets of sediments.

Due to the low tidal range in the Mediterranean and Baltic Seas, tidal currents play a very minor role, if any. It is the case also in part of North Sea e.g., Skagerrak.

Direction of dominant currents

The direction and intensity (speed) of currents represent the main hydromorphological quality elements influencing the biological elements. They could be important elements to be monitored in areas where anthropogenic disturbance could be relevant for the status classification of the water body.

These parameters assume quite a relevant importance in those eco-regions and specific areas where the tidal range being very low poorly influences the coastal processes

Mainly changes in hydrodynamics induced by morphological changes will result in relevant ecological effects. Temporal changes (storms, anthropogenic activities) could be balanced in the time scale of 5–6 years. On local scales this could not be the case. Monitoring should take into account these short term-effects.

Wave exposure

Wave exposure (wave height, wind, Fetch-index) varies considerably according to coastal typology (from highly exposed to very sheltered) and meteorological conditions, in the different eco-regions. Parameters to be monitored in case of anthropogenic disturbances are e.g. frequencies of storms, directions, high/low tide surge levels.

Chemical and physico-chemical Quality Elements

In most of the EC countries, all these parameters (with the exception of specific pollutants) are routinely measured as part of their national monitoring programmes, with a variable frequency (weekly to monthly), using national guidelines or OSPAR/HELCOM standards.

Transparency

Transparency is mainly affected by mineral turbidity, organic pollution (e.g., urban discharges) and eutrophication; it can naturally vary due to local hydrodynamics, river discharge and seasonal plankton blooms.

The transparency parameter is necessary for the determination of the depth of the euphotic layer, where primary production exceeds respiration. Measurement is difficult in "troubled waters", e.g., the NE Atlantic Wadden Sea with high loads of resuspended sediments.

Thermal conditions

Temperature profiles along the water column can be easily obtained by means of *in situ* autographic instruments. The thermal structure of the water column is relevant information for assessing mixing/stratification conditions, which strongly influence primary production as well as possibly the development of oxygen deficiency.

Oxygenation conditions

Dissolved oxygen concentration is subjected to high natural variability since its solubility depends on temperature and salinity. Deviation, in absolute value, of % saturation from 100 % is indicative of intense primary production and/or organic pollution.

Salinity

Salinity in coastal waters can be subjected to high natural variability due to freshwater inputs and mixing of water masses, and due to tidal currents.

Salinity measures in coastal waters can be used to detect freshwater ingressions from the continent; the dilution rate of nearshore waters varies considerably in different areas and can be used, together with other quality elements to indicate potential pollution.

Nutrient conditions

The concentration of nutrients, together with the concentration of chlorophyll *a*, provide information on the general trophic conditions.

Natural variability of nutrient concentrations can be relevant on a seasonal basis; in coastal waters, high nutrient concentrations, mainly related to riverine inputs, are indicative of eutrophication and/or organic pollution.

In order to enable discrimination of pollution sources, the following parameters should be analysed:

- Total Phosphorus (TP, $\mu g\ L^{-1}$)
- Soluble Reactive Orthophosphate (P-PO4, $\mu g\ L^{-1}$)
- Total Nitrogen (TN, $\mu g\ L^{-1}$)
- Nitrate+Nitrite (N-NO3 + N-NO2, $\mu g\ L^{-1}$)
- Ammonia (N-NH4, $\mu g\ L^{-1}$)
- An additional parameter is silicate (Si-SiO3, $\mu g\ L^{-1}$), which is a growth requirement for Diatoms.
- For a better understanding of nutrient cycling in coastal waters, the following supplementary parameters are recommended:
- Particulate Organic Carbon (POC-C, $\mu g\ L^{-1}$)
- Particulate Organic Nitrogen (PON-N, $\mu g\ L^{-1}$)
- Particulate Organic Phosphorous (POP-P, $\mu g\ L^{-1}$)

Nutrient ratios (N/P/Si) are useful for the interpretation of results and eutrophication status.

5 Discussion, and implications of WFD for mariculture

5.1 Definition of water bodies

At this time, national competent authorities are in the process of applying the CIS guidelines to dividing River Basin Districts into water bodies.

According to the Directive, water bodies are to be defined on a range of physico-chemical factors including location, tidal range, salinity, current velocity, exposure, temperature, mixing characteristics, etc. These factors will probably lead authorities to define quite large water bodies, probably on the scale of kilometres to low tens of kilometres. It is therefore likely that mariculture sites would be considered to be located within larger water bodies, and to act as pressures on the water quality within the wider water body.

However, the definition of water bodies has to take account of the particular pressures that may impact the ecological quality of surface waters in the area. Pollution control authorities will use the water body as the primary unit for pollution assessment, control and regulation in the future. From that point of view, arguments can be expressed calling for a one-to-one relationship between water bodies and potentially significant sources of pollution. Such arguments could lead to the definition of rather small water bodies, perhaps on the scale of single areas leased for mariculture.

The consequences for mariculture of the debate between the above two points of view are considerable. In the former case, in which larger water bodies are defined, the localised impact of mariculture can be viewed in the context of the wider environment of the water body. It would then be appropriate to assess the pressure from mariculture on the overall ecological quality of the water body.

In the latter case, attention is closely focused on the effect of the pressures on the ecological quality immediately surrounding the mariculture unit. Such close focus would increase to likelihood of these small water bodies failing to meet the target of good ecological quality. For example, the well-established localised enrichment of sea bed sediments arising from fish farming (and to a lesser degree shellfish cultivation) is known to commonly result in alterations to the benthic infaunal community.

It is our opinion that the former approach is more consistent with the general philosophy underlying the WFD. The debate is not confined to pressures arising from mariculture, but arises in the same way in relation to other activities operating within, and impacting on the coastal zone, such as domestic waste disposal, industrial effluent discharge, farming, forestry, etc.

It is clear that there are still significant uncertainties in the definition of water bodies and the subsequent classification process. It is not clear, however, what approach national authorities will take to the definition of water bodies, although this should become clearer over the next year as authorities progress through the assessment of pressures on water bodies and the consequential impacts.

5.2 Classification

The initial purpose of monitoring under WFD (after the definition of reference conditions) is to provide information on which to base the classification of water bodies. Monitoring in transitional and/or coastal waters will include biological, hydromorphological and physico-chemical elements.

The WFD contains definitions of the status of water bodies, based upon assessments under each of the elements of the monitoring programme. By way of example, these are reproduced below for transitional waters. It should be noted that the target in the Directive is that all water bodies should attain good status by 2015.

Phytoplankton

High status	***Good status***	***Moderate Status***
The composition and abundance of the phytoplanktonic taxa are consistent with undisturbed conditions. *The average phytoplankton biomass is consistent with the type-specific physico-chemical conditions and is not such as to significantly alter the type specific transparency conditions* *Planktonic blooms occur at a frequency and intensity which is consistent with the type specific physicochemical conditions.*	*There are slight changes in the composition and abundance of phytoplanktonic taxa.* *There are slight changes in biomass compared to the type-specific conditions. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbance to the balance of organisms present in the water body or to the physico-chemical quality of the water.* *A slight increase in the frequency and intensity of the type specific planktonic blooms may occur.*	*The composition and abundance of phytoplanktonic taxa differ moderately from type specific conditions.* *Biomass is moderately disturbed and may be such as to produce a significant undesirable disturbance in the condition of other biological quality elements.* *A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.*

Macroalgae

High status	***Good status***	***Moderate status***
Macroalgae:		
The composition of macroalgal taxa is consistent with undisturbed conditions. *There are no detectable changes in macroalgal cover due to anthropogenic activities.*	*There are slight changes in the composition and abundance of macroalgal taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of phytobenthos or higher forms of plant life resulting in undesirable disturbance to the balance of organisms present in the water body or to the physico-chemical quality of the water.*	*The composition of macroalgal taxa differs moderately from type-specific conditions and is significantly more distorted than at good quality.* *Moderate changes in the average macroalgal abundance are evident and may be such as to result in an undesirable disturbance to the balance of organisms present in the water body.*

Angiosperms

The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. *There are no detectable changes in angiosperm abundance due to anthropogenic activities.*	*There are slight changes in the composition of angiosperm taxa compared to the type-specific communities.* *Angiosperm abundance shows slight signs of disturbance.*	*The composition of the angiosperm taxa differs moderately from the type-specific communities and is significantly more distorted than at good quality.* *There are moderate distortions in the abundance of angiosperm taxa.*

Benthic invertebrate fauna

High status	***Good status***	***Moderate status***
The level of diversity and abundance of invertebrate taxa is within the range normally associated with undisturbed conditions. *All the disturbance-sensitive taxa associated with undisturbed conditions are present.*	*The level of diversity and abundance of invertebrate taxa is slightly outside the range associated with the type-specific conditions.* *Most of the sensitive taxa of the type-specific communities are present.*	*The level of diversity and abundance of invertebrate taxa is moderately outside the range associated with the type-specific conditions.* *Taxa indicative of pollution are present* *Many of the sensitive taxa of the type specific communities are absent.*

Fish

High status	***Good status***	***Moderate status***
Species composition and abundance is consistent with undisturbed conditions.	*The abundance of the disturbance-sensitive species shows slight signs of distortion from type specific conditions attributable to anthropogenic impacts on physico-chemical or hydromorphological quality elements.*	*A moderate proportion of the type-specific disturbance-sensitive species are absent as a result of anthropogenic impacts on physicochemical or hydromorphological quality elements.*

Hydromorphological elements

High status	***Good status***	***Moderate status***
Morphological conditions:		
Depth variations, substrate conditions, and both the structure and condition of the inter-tidal zones correspond totally or nearly totally to undisturbed conditions.	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*
Tidal regime:		
The freshwater flow regime corresponds totally or nearly totally to undisturbed conditions.	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*

Physico-chemical elements

High status	*Good status*	*Moderate status*
General conditions:		
The physico-chemical elements correspond totally or nearly totally to undisturbed conditions. *Nutrient concentrations remain within the range normally associated with undisturbed conditions.* *Temperature, oxygen balance and transparency do not show signs of anthropogenic disturbance and remain within the ranges normally associated with undisturbed conditions.*	*Temperature, oxygenation conditions and transparency do not reach levels outside the ranges established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.* *Nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified above for the biological quality elements.*	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*
Specific synthetic pollutants:		
Concentrations close to zero and at least below the limits of detection of the most advanced analytical techniques in general use.	*Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6 without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<environmental quality standard).*	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*
Specific non synthetic pollutants:		
Concentrations remain within the range normally associated with undisturbed conditions (background levels).	*Concentrations not in excess of the standards set in accordance with the procedure detailed in section 1.2.6. without prejudice to Directive 91/414/EC and Directive 98/8/EC. (<environmental quality standard).*	*Conditions consistent with the achievement of the values specified above for the biological quality elements.*

Table 3 below sets out below the various quality elements to be considered in Water Framework Directive and the predicted degree of interaction with mariculture activities. It is possible to make an assessment of these elements with respect to their potential to be affected by mariculture activities (see table below). In most cases where impact is likely (macroalgae, benthic invertebrates, nature of substrate, etc.,) the effects are also predicted to be rather local, in the area immediately surrounding the farm. In only a few cases there may be some potential for more widespread effects (e.g., increased phytoplankton growth as a consequence of nutrient concentrations, or toxic effects from specific pollutants). However, in some cases, the degree of impact may be quite strong; for example, the benthic invertebrate infauna below fish cages may strongly modified compared to conditions immediately outside the area of deposition of waste from the cages.

Elements of monitoring in Transitional and Coastal Waters	**Predicted degree of interaction with mariculture activities**
Biological elements	
• *Composition, abundance and biomass of phytoplankton*	• Unlikely except in areas of low water exchange and high exploitation
• *Composition and abundance of other aquatic flora*	• Possible local impact from nutrient release
• *Composition and abundance of benthic invertebrate fauna*	• Likely local impact
• *Composition and abundance of fish fauna*	• Unlikely
Hydromorphological elements supporting the biological elements:	
Morphological conditions:	
• *depth variation*	• Unlikely to be significant in most situations
• *quantity, structure and substrate of the bed*	• Local impacts are common
• *structure of the inter-tidal zone*	• Unlikely, except in intertidal areas used for mollusc cultivation (e.g. oyster trestles, mussel bouchots)
Tidal regime:	
• *freshwater flow*	• Nil
• *wave exposure*	• Local, and probably rarely significant

Chemical and physio-chemical elements supporting the biological elements:	
General:	
• *Transparency*	• Possible local impact
• *Thermal conditions*	• Nil
• *Salinity*	• Nil
• *Oxygenation conditions*	• Possible local impact
• *Nutrient conditions*	• Local or wider impacts on concentrations are likely
Specific Pollutants:	
• *Pollution by all priority substances identified as being discharged into the body of water*	• Probably insignificant impact from priority hazardous substances
• *Pollution of other substances identified as being discharged in significant quantities into the body of water.*	• Site specific pressure and risk assessments required for some substances such as antifoulants and sea lice treatments

The purpose of the classification process is to assess the ecological quality of each water body against the reference condition defined for that particular type. The reference condition is a description of the biological quality elements that exist, or would exist, at high status, that is, with no, or very minor disturbance from human activities. Reference condition standards are required to enable the assessment of ecological quality against these standards.

It is clear that reference conditions for water body types will need to be framed in such a way that the natural variability present in the environment at high or good status can be accommodated. Water body types will contain a sufficient range of environments (for example differences in substrate, degree of exposure, etc) that would lead to rather different communities of animals or plants being present. There is currently considerable work in progress to develop a coherent system of reference conditions for the water body types being proposed for transitional and marine waters.

In addition to the variability arising from natural factors, water bodies will also include some additional variability arising from anthropogenic factors, such as coastal works or waste discharges. As indicated above, the definitions of good ecological quality contain rather qualitative statements. For example, the description of good status for benthic fauna in transitional waters is described as:

"The level of diversity and abundance of invertebrate taxa is slightly outside the range associated with the type-specific conditions.
Most of the sensitive taxa of the type-specific communities are present."

National authorities are currently developing classification schemes based upon the principles defined in the Directive. The operation of the various schemes, and the conclusions to be drawn in terms of classification, will be the subject of inter-comparison exercises, primarily within eco-regions (as defined in the WFD).

It is not yet clear how the national schemes, and subsequently the inter-compared schemes, will accommodate differences in the values of biological or hydro-chemical elements within water bodies. How this is to be done is clearly of importance to mariculture activities, as mariculture sites will present pressures on the environment and some of the elements of the assessment will be at less than reference status at these sites. Again, this question is not confined to mariculture. Many other anthropogenic activities that result in waste discharges are subject to the same uncertainties.

The development of typology and classification systems for transitional and coastal waters, as well as the criteria for the assessment of water quality status for each water body type is likely to lead to a more harmonised and internationally comparable approach to monitoring.

5.3 Measures to improve ecological quality (mitigation measures)

The overall aim of the Water Framework Directive is the achievement of good water status in all waters by 2015. It is probable that the initial classification will result in some water bodies being classified as a having an ecological status below the target level. In such cases, Member States will then be required to take steps to improve the status of these water bodies.

"Member states should adopt measures to eliminate pollution of surface waters by the priority substances and progressively to reduce pollution by other substances which would otherwise prevent Member States from achieving the objectives for the bodies of surface water."

"…… specific measures for the progressive reduction of discharges, emissions and losses of priority substances …."

At this time it is not clear what measures/actions Member States may choose to take. It is apparent that rather little consideration has yet been given to this aspect of the Directive, with most attention being given to prior activities (such as the development of reference conditions, monitoring, and subsequent classification) with more pressing deadlines. However, it can be anticipated that additional management and mitigative actions may be required of aquaculture operations in some areas where good ecological status has not been achieved.

It is clear that the promotion of sustainable European aquaculture does not conflict with the requirements of the WFD. Aquaculture should therefore not seek "special treatment". Rather, aquaculture is to be viewed as a coastal zone activity in the same manner as other activities that can influence, and have requirements for, good coastal water quality, such as domestic waste disposal, agriculture, tourism and forestry. The contribution of aquaculture to ecological conditions assessed as less then good should be considered in the same manner as the contributions from other activities.

In developing mitigation schemes, however, it should be noted that aquaculture can also contribute to improving ecological status of surface water bodies. Such activities could include:

- macroalgal cultivation which can remove significant amounts of nutrients from the surrounding waters,
- bivalve mollusc cultivation which can extract both nutrients and contaminants from the water column through their filtering activity.
- Polyculture, e.g., finfish and macroalgae in which the inorganic nutrients from the finfish farms are taken up by the macroalgae and in which the both products can have an economic value.

In addition to the above other actions could be taken by the aquaculture industry that could lead to a reduction and minimisation of emissions of "specific pollutants" to the environment and a minimisation of impacts. These may include:

- improved feed formulations that could lead to an improved food conversion ratio (FCR) and hence a reduction in feed loss to the environment;
- improvement in feeding methods that could lead to a reduction in feed loss to the environment;
- improved sea-lice control strategies that could lead to a reduction in use of anti-lice chemical treatments and minimisation in emissions to the receiving environment;
- improvement in cage technology that could allow the siting of fishfarms in more exposed and better flushed area thus reducing the impact on both the sediments and receiving waters;
- Development of Artificial reefs in conjunction with fish farms which could enhance the development of epifauna filter-feeding community to act as biofilter and enlarge and allow rehabilitation of stressed natural habitats, and potentially quantitatively boost many marine species;
- Development of new methods for under cage collection of wastes.

6 Conclusions

It is clear that the implementation of the Water Framework Directive, within the climate created by the Commission policy for Sustainable Aquaculture, has the potential to have significant impacts on mariculture activities as they are currently undertaken. The above discussion has identified the importance of national (and international?) policies adopted on the definition of water bodies, the definition of reference conditions, and the interpretation of monitoring data. These will influence the likelihood of mariculturists being required to conform with any additional measures that may be instigated by Member States to ensure the achievement of high status in all surface water bodies. Mariculture also offers opportunities to regulators who wish to reduce the impacts of discharges from other activities.

It is recommended that WGEIM continue to monitor the progress of the implementation of the WFD and actions under the Commission policy for Sustainable Aquaculture, with a view to updating this review and advice to ACME.

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ANNEX 5: REVIEW OF THE POTENTIAL IMPACT OF ESCAPED NON-SALMONID AQUACULTURE CANDITATES ON LOCAL STOCKS

by Antoine Dosdat, Harald Rosenthal, Scott Campbell

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1.Term of reference

Attempts to culture the Japanese shrimp *Penaeus japonicus* have occurred in several Mediterranean countries, including Italy (Lumare and Palmegiano, 1980), Portugal (Arrobas *et al.,* 1993) and Egypt (Abdel Rahman *et al.,* 1993). Additionally, France tried to culture the species in ponds along the Atlantic coast (Blachier *et al.,* 1993) and the Mediterranean coast (Reymond and Lagardere, "Prepare a review of the potential impacts of escaped non-salmonid candidates for aquaculture on localized native stocks in order to develop, at an early stage, risk assessment and management strategies".

2. Introduction

This overview represents a first attempt to collate available published information on the subject. While initially not ignoring salmonids as source for background information, the vast experience available on stocking freshwater systems is also briefly addressed. Further, the introduction of related non-indigenous species is considered to some extent as it is believed that many similarities exist in relation to interactions at both the species and trophic levels. It is acknowledged that the present document has its shortcomings including being fragmentary in certain areas. It should, therefore, be considered more as a discussion paper and a first draft of a more comprehensive review on the subject to be elaborated more fully and finalised at the next WGEIM meeting.

The Working Group decided to not only discuss finfish species, but also aquaculture species belonging to other systematic categories such as molluscs and crustaceans. The report addresses in particular the following species groups:

- salmonids (principle differences and similarities to less migratory marine fish species)
- freshwater species (experiences from stocking estuaries, bays, rivers, and reservoirs including aspects of species interactions)
- Cod ranching trials in Europe
- Flatfish releases in Europe and overseas
- Mullet and threatfin ranching in Hawaii
- Haarder mullet introductions into the Black and Azov Seas (and interactions with local mullets)
- Seabass and sea bream culture and escapees in Europe
- Red Sea bream culture and ranching in Japan
- Shellfish, in particular oysters in the northern hemisphere-
- Ranching of *Penaeus japonicus* in Japan
- Escaped *P. japonicus* in the Mediterranean Sea

3. Principle differences and similarities with salmonid species

Although the ToRs explicitly requested the WG to deal with non-salmonid species in the marine aquacultural setting, there is a need to also draw heavily on the experience with salmonids. The reasons are:

- similarities in the interactions, and
- the extended background knowledge available.

A growing number of publications deals with salmonids. While salmonids form mainly migratory stocks with a specific homing capacity, their interaction with native con-specifics can be clearly demonstrable by monitoring the respective wild spawning stocks affected. The "far-field" effect (e.g., feeding pressure on trophic levels in the open ocean and feeding competition with native migratory conspecifics) are probably less pronounced or even non-existent and have so far not been studied. Even past and present enhancement programmes, which release millions of smolts, assume that the oceans capacity to support the population is vast and open ocean ecosystem and food web responses to an enlarged salmon population would not be demonstrable. Therefore, the interaction between wild and cultured salmon is primarily considered in the nearshore and freshwater reproductive and recruitment phase.

In contrast, the accidental release of non-migratory fish and shellfish species from culture sites will impact local populations by affecting all life-cycle stages and exposing the growing phase to feed competition and continuous exposure to behavioural stress conditions. In particular this would occur when territorial behaviour is a key component controlling population density in a given habitat.

A further consideration with some marine species currently in cultivation or being considered for cultivation is that the eggs and larvae may be pelagic. This compares with salmon eggs which require the protection of the redd to ensure a reasonable survival rate. Even though cod eggs (for example) will naturally have high rates of mortality, the escape of fertilised eggs or larval fish from land-based hatcheries may therefore be a significant concern in some of the worst case circumstances referred to above. Likewise, some workers have expressed concern that if fish are allowed to mature in cages they may release significant amounts of self-fertilising gametes into the local environment.

4. Case examples from salmonids in the marine environment

One of the early reports pointing to the potential of large-scale genetic introgression appeared when Gausen and Moen (1991) reported on escaped farmed salmon in Norway which comprised a substantial proportion of the mature salmon present on the spawning grounds in autumn. Hansen *et al.* (1987) reported on the direct evidence that salmon that had escaped from Norwegian farms were caught in the long-line salmon fishery north of the Faroes, thereby documenting a far-field effects on fisheries (Hislop and Webb, 1992). Hansen *et al.* (1994) as well as McEvoy, *et al.* (1994) also showed that salmon which had escaped from cages in one jurisdiction were actively feeding in a coastal habitat of another jurisdiction A review on possible genetic effects of escaped cultured fish on natural fish populations has been provided by Hindar *et al*. (1991), addressing the genetic consequences of aquaculture on natural fish populations. The study is motivated by rapidly increasing numbers of intentionally and accidentally released fish and is based on empirical observations reported in the literature. A wide variety of results, ranging from no detectable effect to complete introgression or displacement, have been observed following releases of cultured fish into natural settings. Where genetic effects on performance traits have been documented, they always appear to be negative in comparison with the unaffected native populations. A case example has been provided by Clifford *et al.* (1997) using microsatellite markers to identify interbreeding in two Irish river systems, showing the proportion of juvenile.

Other recent relevant references on salmonids to be considered as useful readings can be listed as follows:

Clifford *et al.* (1997) (addressing large accidental releases in Ireland in 1992, using mitochondrial DNA and microsatellite markers to estimate the number of successfully reproducing escapees).
Fleming and Einum (1997) (determining the divergence of farmed from wild salmon due to domestication).
Hansen, *et al.* (1997) (identifying the origin of escaped salmon in West Greenland) Youngson, *et al*. (1993) (discussing potential hybridisation of escaped salmon with brown trout).
Fleming *et al.* (1996) (looking at reproductive behaviour and success of farmed and wild Atlantic salmon).

For further reading, the reader is referred to the respective NASCO documents and those of the respective ICES Working Group on Genetics in Mariculture.

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5. Deliberate releases for stock enhancement and fisheries

Vast amounts of information are available from long-term research and management practices in the stocking of freshwater systems. Although most of these releases were deliberate, the data accumulated provide a wealth of background information that should be contextually utilized to discuss future management strategies to reduce the risks of negative interactions between escaped non-salmonid (mainly non-migratory) species in the marine environment and natural stocks of the same species (Holcik ,1990).

The stocking of hatchery-produced fish (including cyprinids, pike perches (Percidae), trout (Salmonidae) into rivers, lakes and reservoirs has been a common practice with the sole purpose to enhance recreational fisheries. Early attempts to evaluate the effects of such practices on wild populations have been made by Butler (1974). Effects of introducing brown *trout (Salmo trutta)* into rivers of New Zealand were studied in terms of feeding competition to common river galaxias, *Gaiwdas vulgaris,* upland bully, *Gobiomorphus breviceps,* long-finned eel, *Anguilla dieffenbachii,* short-finned eel, and *A. australis schzmittii* (Cadwallader, 1975). Since trout (< 200 mm long) and galaxids occupy the same microhabitat and feed in the same manner, similarity in their diets can be regarded as giving rise to direct competition. Such direct competition for food, combined with interspecific aggression and similar microhabitat requirements, were seen as reasons for the reduction in abundance of other galaxiids in areas where trout had been introduced.

The release of exotic fish species into freshwater can serve as model cases to evaluate the ecosystem effects as the situation is usually not complicated by the prior interaction with con-specifics. It has been reported that the use of several Chinese carp species, all of them thriving low in the food web and occupying a different ecological niche (e.g., feeding on shore vegetation, zooplankton and/or benthic fauna) is an effective measure to cope with eutrophication issues (mainly weed control in confined water bodies (e.g., Balon, 1968) Addor and Theriot (1977) addressed early on large-scale plans and their potential effects on ecosystems. Bain (1993) discussed the potential impacts of grass carp in open freshwater systems by reviewing grass carp biology relative to an impact assessment checklist prepared by the author.

Kubecka (1993) identified the fish communities of 84 Central and Eastern European reservoirs and divided these according to their species composition into six fish faunal types that are identical with the successional stages of the reservoir ichthyocoenoses. Stocking ratios of various predators and prey species often determined the level of productivity. Stocking of freshwater fish have been extensive historically. For example, a review of the Annual Report of the United States Bureau of Fisheries (U.S. Department of Commerce and Labor) (Anonymous, 1909) reports on nation-wide transfers and introductions in 1908, ranging in the millions just for this one year. Among the most important species were: American shad, *Stizostedion vitrium*, *Pseudopleuronectes americana,, Perca flavescens*, cod, *Morone americana, Oncorhynchus tshawytscha,* and *Homarus americanus*. The export of eggs amounted to a total of 3.997 million.

Grass carp *(Ctenopharvngodon idella)* stocking is one example of world-wide importance where interactions with other cultured native and introduced fish species are deliberate. For example, Hanlon et al. (2000) reports on thirty-eight lakes in Florida with aquatic plant problems. These lakes were stocked with varying levels (range *<1-59/ha)* of grass carp, *Ctenopharvngodon idella,* for 3–10 years. The long-term effects on the aquatic macrophyte community showed that complete control of excessive vegetation can be achieved by stocking carp at levels of 25 to 30 fish per hectare of vegetation. Interaction of grass carp stocking with waterfowl in reservoirs has been reported by McNight and Hepp (1995) as the food of grass carp and waterfowl overlap. Krzywosz (1997) reported that destruction of vegetation by grass carp increased the trophic level of the lakes.

Skaala *et al.* (1990) reviewed the literature on the potential interactions between wild and farm escapees, and between wild and stocked fish populations. Examples of the application of genetic markers in studies concerning survival and reproduction of stocked fish, and genetic and ecological interactions between stocks, are given for brook trout, *Salvelinus fontinalis,* brown trout, *Salmo trutta,* rainbow trout, *Oncorhynchus gardneri,* cod, *Gadus morhua,* Guadelupe bass, *Micropterus treculi,* walleye, *Stizostedion vitreum* and chum salmon, *Oncorhynchus keta.* Various studies produced different results. Evidence for successful reproduction and genetic interactions between released and wild stocks have been found in a few cases. Stocked genetic material sometimes had a lower reproductive success than wild material. In one case the transplanted genetic material failed to acclimatise, and was apparently lost from the gene pool in two generations. Investigations on the genetic and ecological interactions between wild and farmed populations are of great importance to the preservation of wild populations and their genetic resources.

These few examples out of a vast literature of over 1000 papers published during the past decade indicate that a full reflection of the freshwater experience would be useful to better understand overall ecosystem responses and species interactions.

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6. Overviews on experiences with non-salmonid cultivated and ranched species and their interactions with wild stocks

There is some information available on intentional release of marine finfish species for ranching and stock enhancement, however, almost no data are available on accidental releases (escapees). While intentional releases are meant to have a pronounced or at least a noticeable (positive) effect on natural populations of con-specifics by increasing stock size and abundance, effects of accidental releases by species or number are considered to have negative (or at least unwanted) effects. It should be pointed out that this is not necessarily true in all cases.

The most recent review on enhancement of marine stocks, including pelagic and bottom-dwelling finfish and crustacean species, has been prepared by Blaxter (2000), addressing the rational for enhancement, and giving an account on historic approaches in plaice (in Scotland 1894-1920), Cod and plaice (in Norway, 1882–1969), Baltic plaice (in Denmark, Limijord 1893–1990) and the UK (plaice and sole, 1957–1967).

More recent studies are also highlighted by Blaxter (2000), mentioning the Danish trials to release of tagged turbot *(Scophthalmus maximus),* the flounder *(Pleuronectes flesus)* and red sea bream *(Pagrus major)* in Japan, the red drum *(Sciaenops ocellatus)* and spotted seatrout *(Cynoscion nebulosus)* along the Gulf of Mexico, the striped bass *(Morone saxatilis)* in Chesapeake Bay, and the mullet *(Mugil cephalus)* and threadfin *(Polydactylus sefilis)* on Hawaii.

Problems discussed by Blaxter include (a) the viability of released fry (quality of seed), (b) survival after release and releasing strategy, (c) carrying capacity in relation to the size of released stock and interactions with the receiving ecosystem, and (d) the impact on wild stocks. Although the chapter on the last item is relatively short, indicating that little information is available, the case examples presented are worth discussing here in greater detail.

Table 1 provides insights on interactions of wild and culture-released conspecifics of several marine species that had after release co-existed with natural populations for extended time periods.

Table 1 Estimates of percentages of recaptured stock (through fisheries) of hatchery produced releases (%A) and percentages of survival of released individuals (%B) (modified from Data of Munro and Bell, 1997; and Blaxter 2000).

Species	Size at release (mm)	Duration of release	% A	% B
Cod	110–210	14 months		4
Cod	160–400	To 2 years		12–32
Cod	*150*	To 6years		1–11
Japanese flounder	100	To 3 years		15
Red sea bream	70	1–11 years		14
Red drum	35	??	20- 46	
Striped mullet	45–130	To *5* years	14	
Striped mullet	60–130	11 months		50
White sea bass	80–120	To 4 + years		12
Threadfin	**65**–150	10 months		65
Turbot	150g	l year	*9.5*	
Barramundi	30–60	To *2.5* years	17	

An overview of stocking and enhancement programmes performed along the coasts of North America has been compiled by Richards and Edwards (1986). The long history of stocking marine fishes for enhancement of natural populations shows that recent efforts have been stigmatised by the many failures of early endeavours. Mention is made of stocking 250,000 hatched Spanish mackerel in Chesapeake Bay in 1880 from a floating hatchery. The Woods Hole Laboratory hatched and released 25,000 Atlantic cod larvae in 1885, and over 6 million eggs were fertilised the following year and several million stocked, including 500,000 transplanted to a site in the Gulf of Mexico, 25 miles off Pensacola, Florida. In 1926, the U.S. marine hatchery at Gloucester, Massachusetts, stocked a total of almost 3.5 billion fry of cod, haddock, pollock, winter flounder and other species; this activity continued with varying degrees of intensity up to the 1950s. All efforts were without noticeable effect on populations. However, a modern understanding of biology and ecology of marine fish larvae, juveniles, and adults, coupled with recent advances in marine fish culture techniques, have revived interest in marine stocking projects. An analysis of recent marine efforts shows that most are based on a synthesis of fish culture, fish biology, ecology, and fisheries management concepts. The potential for future enhancement of marine fish populations through stocking is discussed. No considerations are given in this review to the potential impact of these releases on natural ecosystems

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7. Marine species by species considerations (non-salmonids)

Plaice *(Pleuronectes platessa)*

Transplantation of young plaice *(Pleuronectes platessa)* in Denmark started back in the late 19th century with the first published data being available in 1891 (Anonymous, 1908; Blegvad, 1935). Experiments were initiated by local fishermen and sponsored by the Danish government. Large quantities of small plaice (16–19 cm) were caught, either in the western part of the estuarine fjord Limfjorden close to the North Sea or in the coastal waters of the North Sea, and transplanted to the inner parts of the fjord and to water bodies between the Danish islands in the southern Kattegat. In a few cases, transplantations of plaice to the central North Sea (Dogger Bank) were also carried out (Garstang, 1905; Borley, 1909). The expectation was to enhance either the local stocks or just the commercial catch. The latter was the case for the Limfjord area, where the great majority of the transplantations occurred. The work started in 1891 and continued for more than sixty years, during which time about 6,000 tonnes were stocked. The work stopped in 1958 due to the lack of financial support from the government. Up to then the transplantations had been the topic of long economic and political discussion (Bagge, 1957; Bagge and Bertelsen, 1957). The overall conclusion concerning the economics of the matter indicated that no net gain was actually being obtained by the transplantations except in certain areas in Limfjord. In 1984, some minor experiments initiated by the Fishermen's Association were again started in the Limfjord. The findings of this work showed that the plaice stayed in the fjord and that the growth was adequate. In 1988, a semi-commercial transplantation programme was initiated and 14,000 plaice were transplanted to the Limfjord. In 1989, the programme was expanded, 132,000 being transferred to the Limijord and 30,000 to other water bodies in Denmark. This new work also included the transplantation of turbot *(Scophthalmus maximus).* eels *(Anguilla anguilla),* whitefish *(Coregonus* sp.) rainbow trout *(Oncorhynchus mykiss),* reared in captivity, and cod *(Gadus morhua)* caught in the wild. The government provided 1 million DKr. for this work in 1990. A review of the entire Danish experience with plaice transplantations has been provided by Hoffmanm (1991).

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Sea bass *(Dicentrarchus labrax)*

There is evidence that there are three endemic populations of sea bass *(Dicentrarchus labrax)* in the Atlantic and the Sea of Alboran, the western and the eastern Mediterranean (Patarnello *et al.,* 1993; Cesaroni *et al.,* 1997). This differentiation has been described using allele frequency on six microsatellite loci. It is suspected that the passive retention of larvae on either side Gibraltar strait is not a sufficient explanation for the persistence of this divide. Significant genetic divergence between the eastern and western Mediterranean (Bahri-Sfar *et al.,* 2000), as well as differentiation seems to exist within the eastern population. Such a differentiation seems to occur in the eastern stock between "groups" of fish that grow in lagoon environments and those that live in the open sea, although both groups appear to share the same breeding areas (Allegrucci *et al.,* 1997; Lemaire *et al.,* 2000). Thirteen enzymatic loci exhibited moderate to high values compared with microsatellites. This was interpreted as evidence that these allozymes are non-neutral. However, only six loci seemed to be implicated in differentiation between marine and lagoon samples, the causes of selection being unknown for the others. A possible scenario of population dynamics of the sea bass between the marine and lagoon habitat is suggested (Lemaire *et al.,* 2000). Sea bass are known to migrate between coastal and off-shore grounds, and a homing behaviour is suspected due to local genetic differentiation over small areas (Allegrucci *et al.,* 1997).

These genetic variations have not been correlated to phenotypic variations as yet. Another species *(Dicentrarchus punctatus)* living in the same geographic area is thought not to interbreed naturally, but artificial breeding has been reported and hybrids have been produced (Ky, IFREMER, personal communication). The fertility of the hybrids has not yet been confirmed. A genetic distance tree inferred from the polymorphism at six microsatellite loci shows a distinct pattern for the two species. *D. labrax* samples appear to be genetically more homogeneous than *D. punctatus,* indicating a lesser level of gene flow in the latter species (Bonhomme *et al.,* 2002). While appearing more differentiated, *D. punctatus* presents no clear geographical organisation of its genetic variability in contrast to *D. labrax* samples.

Transfer of eggs and breeders from Western populations of seabass to the Eastern Mediterranean have occurred, particularly to Greece and Turkey from France and Italy. Studies on genetic structure of sea bass in the farms demonstrate a high level of genetic variation in aquaculture stocks. This is due to the continuous replacement of broodstock by individuals originating from the wild, but selective breeding programmes are underway that will inevitably make those stocks genetically distinct from the wild populations.

No information is available on possible interactions between escaped and wild sea bass. This would require more studies on the patterns of genetic structuring among the wild fish. Nevertheless, the use of western Mediterranean stocks in the eastern Mediterranean is likely to alter local gene frequencies, and individuals from the eastern stocks seem hardly to concentrate in some Greek locations (Divanach, personal communication). Wild Egyptian specimens collected in the study by Bahri-Sfar *et al.* (2000) were consistent with the western group, supposedly attributable to the introduction of aquaculture broodstock. Sea bass are reported to mature in the sea cages, but no containment structure is provided to avoid dispersion of eggs and mill, eventually leading to some uncontrolled release of fry into the environment. However, aquaculture facilities (whether they are land-based units with their effluents or cage systems placed in coastal waters) may be situated in locations where conditions are unfavourable to support survival of larvae and the escape of cultured specimens to the wild may be irregular and insignificant in numbers to interfere with natural stocks. The behaviour of escaped sea bass has not yet been adequately documented, and it is not known whether these fish would have the fitness to survive under highly competitive conditions. Also it is not known whether they are capable of migrating to suitable breeding areas, whether maturity cycles are synchronous with local fish, and whether interbreeding might occur.

Triploid sea bass have been produced to evaluate their growth potential (as has been shown for rainbow trout). The results so far do not seem satisfactory to employ this technique commercially. Indeed, susceptibility to diseases and skeletal deformations are higher in triploids than in diploid fish, and growth rates were not substantially improved to compensate noticeable for the losses.

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Seabream *(Sparus aurata)*

Allozyme and microsatellite variation and variation in mitochondrial DNA have been examined in seabream. The fish from six different origins from Portugal to Greece were not distinguishable, indicating substantial gene flow from the Eastern Mediterranean to the Azores (Zouros *et al.,* 1998). The comparison with aquaculture stocks demonstrates very low loss of variability among stocks. Nevertheless, effect of domestication, determined by a measure of the heterozygosity, was apparent in aquaculture stocks. Genetic drift, probably caused by propagation practices, is most likely responsible for the decrease in genetic variation (Palma *et al.,* 2001).

Although farmed stocks outnumber wild fish, the presence of an apparently undifferentiated, single stock of seabream extending throughout the Mediterranean Sea greatly reduces the potential for adverse genetic interactions. The present practice of using wild stock to maintain the artificial broodstock in the hatcheries would lower the possible effects of domestication and inhibit the divergence of aquaculture fish from wild stocks. This would be increase by the maintenance of strains to implement selective breeding programmes.

Wild seabream reproduce in coastal lagoon areas. These are relatively rare environments, and behaviour of reared fish that could escape is not known. In contrast to sea bass, the risk link to fry production in the wild from spawning fish in the aquaculture facilities is not likely to occur, because sea bream are protandrous hermaphrodites and become females at the age of 3 years, which is after they are harvested, so only males are reared. Any male contact with females would require (i) that males would have to disperse over large distance to the breeding areas or (ii) that mature females would have to be in the vicinity of the cages at the critical time.

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Cod *(Gadus morhua)*

There is now evidence that there are least three reproductively isolated populations of cod in the North Sea and that there may be further isolated populations in the northwest Atlantic and Norway. However the amount of information is limited and FRS has just begun a FP5 project - MET ACOD to investigate this issue. From evidence of NW Atlantic stocks we might expect that the different reproductive units may intermix to some extent during the summer. However FRS tagging data show that there is little exchange between Firth of Clyde cod and those in the Minch, particularly in the North Minch, north of Skye. Cod from the Minch have been caught north of Scotland but there is little apparent exchange between Minch cod and cod in the Moray Firth.

Whether there will be an impact from escapes from fish farms will depend on the exact nature of the population structure in the wild stock and the genetic nature of the farmed stock of the same species. For instance, it could be envisaged that the impact of escapes would be minimal if farming involved the rearing of wild-caught juveniles from a local stock which was widespread and abundant, and showed a regional rather than local population structure. This would be true even if escapes involved relatively large numbers of fish. On the other hand, a significant impact could occur if the farmed stock were a variety of non-local origin with a narrow genetic base (i.e., a high degree of inbreeding) and it escaped and mixed with a highly structured stock with a local population restricted, say, to the fjord with the farm in question. Since cod are now very scarce in some inshore waters (e.g., in Scotland) this may increase the impact of escapes of large numbers of non-native farmed stocks.

Otterlind (1985) has reviewed the literature and reported on the occurrence and migratory habits of Baltic cod based on experiences since the 1950s, with results from extensive tagging trials combined with information on changes in allele frequency for haemoglobin types, meristic characters and otolith types. About 15 transplantation experiments with tagged cod assessed the potential homing ability of the fish. Waters west of Bomholm constitute an area of hydrographic instability with varying cod migrations and passive transport by currents of fry. Migration east of Bornholm refers—except for local stocks and a varying contribution from the west—mainly to fish raised in the central Baltic and northern areas. Fish in the latter group migrate primarily southward for spawning; as adults they usually stay east and north of Bornholm. Results of the transplantation experiments support a strong direct linkage of cod migration and hydrographic factors. Cod tagged and transplanted to a new area behaved and moved in the same way as the local stock. Indications of "homing" can be found in areas with suitable hydrographic gradients, such as changes in salinity, for example, in Øresund. This information is useful to assess potential risks of impacts of escapes within each of the identified separate Baltic cod stock components.

Jørstad and Nævdal (1992) and Jørstad (1994) reported on an extensive investigation of the effects of mass rearing and release of 0-group cod in fjords and coastal areas of Norway. Each year since 1987, pond-produced cod have been liberated in Masfjorden, a small fjord north of Bergen. The released cod as well as the wild fish and those recaptured in the fjord system have been genetically characterised by electrophoretic analyses of haemoglobin and several enzymes. In 1990 and 1991 about half of the released cod consisted of offspring of broodstock homozygous for a rare allele (Pgi-1(30). This broodstock was produced by crossing pre-selected heterozygotes for this allele, the homozygotes among the offspring were sorted out on the basis of biopsy sampling of muscle tissue, and when matured, used as parents. Genetic tagging seems to be a useful method both for studying factors controlling survival, growth rate and dispersal of released cod (Jørstad, 1994), and also for more long-term studies on hybridization and gene introgression between natural and reared populations.

Svasand (1993) looked at behavioural differences between reared and released and wild juvenile cod, using Floy anchor tags and oxytetracycline markers. While differences in individual behaviour patterns occur, no difference in migration patterns between wild and reared specimens have been demonstrated.

Nordeide and Salvanes (1991) compared the stomach contents and liver weights of reared newly released cod and wild cod; the stomach contents and abundance of potential predators were also described. During the first three days after release, the reared cod fed mainly on non-evasive prey of Gastropoda, Bivalves, and Actinaria. This is in contrast to wild juvenile cod, which mainly fed on Gobidae, Brachyura, and Mysidacea. Large cod, pollock, and ling preyed upon the released cod immediately after their release whereas during the months following release the stomach contents of large predators were dominated by Labridae and Salmonidae. The abundance of predators did not seem to increase within the area of release.

Further references relating to cultured and wild cod interactions include Jørstad et al (1994a; 1994b) and Kitada *et al.,* (1992). The latter theoretically studied the effectiveness of fish stock enhancement programmes using a two-stage random sampling survey of commercial landings for cod and flounder.

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Introduction of haarder *(Mugil so-iuy)* into the Black and Azov Seas

In response to the rapidly diminishing stocks of the three local species of mullets in the Black Sea and the Sea of Azov, the first juvenile Far-Eastern mullet haarder *(Mugil so-iuy)* were transferred into the brackish ponds at the Sea of Azov in the late 1960s (Starushenko, L.I., Kazansky, A.B. 1996). This was followed by more transfers during 1972–1980 and releases of fish into lagoons of the Black Sea. Much of the transferred stocks were kept at a research station on a Black Sea lagoon to produce brood stock. Starting in 1978, several batches of haarder were released into the Sea of Azov. Haarder is a highly adaptable fish that tolerates a wide range of salinity and water temperatures, and unlike the local mullet species, it winters in lagoons. It proved to be an ideal fish for the increasingly more extreme conditions in the Sea of Azov, which have resulted from the greatly reduced river discharges into this sea as a consequence of irrigation and other demands for water. The production of stocking material in a Black Sea lagoon removed the need for further transfers from the Far East. In addition, self-reproducing fish stocks of haarder were established in the Black Sea. Haarder is now commercially fished along the northern shores of the Black Sea and in the Sea of Azov. It is gradually expanding its range and it has been recorded from Romania, Bulgaria, Georgia and Turkey, and is expected to enter the Mediterranean. The mass occurrence of the ctenophore *Mnemiopsis leidyi* in the Black Sea and the Sea of Azov since 1989 has not interfered with haarder stocks, which continue to produce strong cohorts. The introduction of haarder is of considerable importance for the local fisheries which have been negatively impacted by the decline of many commercial fish species. Between 1992 and 1994, an extended study revealed the relationship between changing environmental conditions and spawning behaviour of this introduced fish species. Reproduction occurs in spring, mainly in the central part of the sea. The grey mullet may reach a size of about 62 cm TL, and a weight of 4.1 kg. Average size is about 1.9 kg. Age classes up to 6+ were observed with a dominance of 3+ to 4+. In 1994, landings amounted to about 11 000 tonnes, which represents a valuable commercial contribution to fisheries (Izergin and Yanovsky, 1997).

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White Sea bass *(Atractoscion nobilis),* California halibut *(Paralichthys californicus),* and Asiatic flounder *(Parlichthys olivaceus)*

The Ocean Resources Enhancement and Hatchery Programme (OREHP) (Kent *et al.,* 1993) has been evaluating both the biological and economic feasibility of culturing, tagging and releasing juvenile marine fish into southern California embayments since 1984. This programme has focussed on two species whose populations have declined greatly in recent years, the white seabass *(Atractoscion nobilis)* and the California halibut *(Paralichthys californicus).* Benefit-cost analyses suggest that a release at larger size is recommended. This problem was overcome by expanding the culture program to include pen rearing trials. Various aspects to optimise procedures and costs are discussed. Protocols for the enhancement of white sea bass in the Southern California Bight region were established (Bartley and Kent, 1993) with regard to conserving the genetic diversity of both the wild and hatchery populations. Surveys of allozyme variation of the natural population from southern California and of progeny produced at the Hubbs-Sea World Research Institute revealed that the natural population of white seabass appears to be characterised by little population subdivision with rare alleles, of frequency of around 2 %, contributing to the differences between sampling locations. Therefore, it is suggested that an enhancement effort should attempt to conserve these rare alleles in the hatchery population.

A Japanese attempt to improve the stock size of the Japanese flounder *Paralichthys olevaceous* has been reported by Koshiisi *et al.* (1991).

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Striped Bass *(Morone saxatilis)* and Red Snapper *(Luthianus campechanus)*

Striped bass, *Morone saxatilis,* were reared and stocked into Barataria Bay, an estuarine system along the south-east coast of Louisiana (Hem, 1979). Over a five-year period (1975–1979), 160,000 fingerling bass were introduced into the system. Commercial fishermen reported capturing striped bass, but only one was seen and positively identified by biologists.

Stocking trials were also performed along the Alabama Coast (Minton, 1979). During the reporting period, 2,192,962 fingerlings were reared and released into Alabama coastal waters. Total striped bass stocked during this period was 2,865,907. Stocking evaluation produced 89 fish during the period and over 372 striped bass catches were caught.

A total of 64 experimental stockings were carried out by Minton (1979) including striped bass among other species. These took place in 55 freshwater reservoirs. Survival was monitored for the first 24 hours after release. Survival of striped bass varied from 0 to 100 % and differed between size-groups; all striped bass fry died. Logistic regression showed relationships between survival of striped bass fingerlings and hauling time, pH and conductivity of water in the reservoirs, and cumulative changes in temperature and conductivity to which fry were exposed during stocking.

Striped bass have also been cultured in cages along the Mediterranean coast of Israel. Several specimens were recorded as caught by experimental beach seine fishing (Golani, 1997). The specimen was deposited in the Hebrew University Fish Collection (HUJ 18299). The specimen was dissected; the stomach was found to be empty and the gonad undeveloped.

More recently, attempts are under way to enhance American red snapper, *Luthanus campechanus* stocks (Leber *et al.,* 2002). It has long been an important commercial and sport fish throughout the eastern United States. In response to declining red snapper stocks, the Gulf of Mexico Stock Enhancement Consortium was formed to develop protocols necessary for responsible stock enhancement of the species. This programme was implemented to determine the feasibility of large- scale enhancement of red snapper populations in the Gulf of Mexico. During the fall of 2000, 851 hatchery-reared red snapper were released off the coast of Florida. Fish were released on two replicate reef complexes, each composed of three reef types: oyster shell, concrete rubble and concrete block pyramids (150 fish type), located within 200 metres of a natural reef. Initial fish loss within the first 24 hours was estimated to be 50 % *(*225 fish complex) of release totals. Seven days following the release, totals were reduced a further 50 % to 125 fish complex, which remained constant for 120 days. Observations made after 150 days revealed a downward trend in total counts, possibly due to the increased foraging range of the fish. This preliminary release operation shows potential, but ultimately true success can only be determined when released fish replenish the threatened fishery stocks.

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Penaeus japonicus in Europe

Attempts to culture the Japanese shrimp *Penaeus japonicus* have occurred in several Mediterranean countries, including Italy (Lumare and Palmegiano, 1980), Portugal (Arrobas *et al.,* 1993) and Egypt (Abdel Rahman *et al.,* 1993). Additionally, France tried to culture the species in ponds along the Atlantic coast (Blachier *et al.,* 1993) and the Mediterranean coast (Reymond and Lagardere, 990). These attempts were done because the growth rate of the native species, *Peneaus kerathurus* was seen as too slow to support an economic viable operation. No environmental risk assessment in relation to ecosystem effects of potential escapes from coastal pond farms was ever undertaken.

In Italy, there have been attempts to develop a ranching strategy for the species (Lumare and Palmegiano, 1980). About three hundred specimens of *P. japonicus* were reared in net cages and released into the brackish water of a local lagoon. The performance of these specimens was compared with a control group raised in laboratory tanks. About 1,000 post larvae of the control group escaped into the lagoon and were subsequently fished as adults. It is suggested that this species can be utilized in extensive polyculture in central and southern Italy. *P. japonicus* seems to be more resistant to low temperatures that the local species *(P. kerathurus)* and showed also faster growth rates. However, *P. japonicus* has shown substantial range extension in coastal Mediterranean waters and the impacts (positive in terms of fishery enhancement, or negative in terms of inter-species competition with the native species) have so far not been addressed.

The first acclimatisations of *P. japonicus* in French Mediterranean lagoons were attempted in the early 1980s (Reymond and Lagardere, 1990). Several semi-extensive rearing projects were set up along the west coast of France as well. Yields appeared to be very similar to those obtained in other parts of the world (30–100 g m^{-2}). The feeding habits of *P. japonicus* were studied in salt marsh ponds of the French Atlantic Coast. A bi-monthly sampling programme was carried out over 3 months. A shift from continuous to nocturnal feeding occurred during the second month of the rearing period. Shrimps appeared to be opportunistic carnivores since they fed on all salt marsh fauna, with a preference for halophilic insects, especially chironomids. However, a selection of prey, related to their size, was observed over the rearing period. There seems to be no follow up study on the environmental interactions with native competing crustacean species. A similar study was performed by Kevrekidis *et al.* (1996) in the Lagos lagoon in the Aegean Sea.

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Peneaus japonicus ranching in Japan

Ocean ranching programmes for *Penaus japonicus* have been undertaken in Japan for over two decades. (Harnada *et al.,* 1983), using various elaborate releasing techniques, including the specific construction of releasing habitats (Hamamura, 1979) and temporary elimination of predators during the benthic seeding period (Hamada *et al.,* 1983). Hamamura (1979) took a very opportunistic approach in stating that "Culture-based marine fisheries may be defined as production systems in which man undertakes commercial fishery production through a series of raising, nursing and catching marine products in the sea using natural or artificial biotic productivity." Since then, culture-based fisheries studies have been undertaken in Japan using commercially important marine organisms that have been established in Japan for decades. Generally, these activities have involved the capture of cultured seed stock and their artificial propagation to the juvenile stage before being released into the natural environment. Species farmed for release include ayu *(Plecoglossus),* kuruma shrimp *(Penaeusjaponicus),* blue crab *(Portunus* sp.), red seabream *(Pagrus major)* and abalone *(Haliotis).* In general, one of the basic problems facing development of culture-based fisheries is the jurisdiction or latent ownership of the culture-based fishery resources. Additionally, no concern was expressed at the time on potential ecological implications of such activities.

The economic effect on fishing yield by releasing kuruma-prawn juveniles was investigated as early as 1973 by Hasegawa (1973) as an example of a farming fishery at the pilot farm of Saijo, Ehime Prefecture, in the Hiuchi-nada. The natural mortality of the prawn was about 3–4 % per five days. The growth period to commercial size was very short. Seedlings released in June grew to commercial size by September and were recaptured by gillnets and small trawlers on the fishing ground near and off the releasing points in the tidal area. The actual cost of the seedlings with the same survival ability as natural juveniles in the sea would be more than the cost of 0.3 Yen of hatchery production, and estimated to be between 1 to 2 Yen in the case of the pilot farm in 1971.

Rosenthal (1984) reviewed the ranching activities of *Peneaus japonicus* and *Chiysophys major* in the Seto Inland Sea, Japan, using Japanese reports which have so far not been translated into English (translation was assisted by 0. Fukuhara, Nansei Station, Hiroshima).

Releasing programmes at the time included a step-by-step adaptation process from hatcheries via coastal ponds and/or enclosures to open sea areas such as artificial and natural reefs and/or mud flats and sublitoral habitats. The most advanced method includes preparation of artificial tidelands in which predators are largely excluded. Survival, growth, competition and migration were studied in relation to the releasing technique, and studies on the effects of ranching on the fishery are outlined. The presently released post-larvae of *Penaeus japonicus* amount to approximately 340 million individuals, providing a net income of 2.74 yen per effective recapture.

A review of the recent developments compared to the situation at the turn of the century is missing and/or was at least not accessible to the Working group during the 2003 meeting.

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Miscellaneous species

Halibut

There do not seem to have been any significant escape issues with respect to halibut. However, since there are no populations of wild halibut in areas where they are currently being commercially farmed, the issue of introduction of an "alien" species rather than potential for an impact on the fitness of local populations via genetic interactions is more likely.

Sparids

A population genetics survey on seven commercially valuable species theta fish belonging to the family Sparidae, namely *Dentex dentex, Pagrus pagrus, Pagellus bogaraveo, Lithognathus mormyrus, Diplodus sargus, Diplodus puntazzo,* and *Spondylosoma cantharus* has been carried out (Penzo *et al.,* 1999). The populations investigated cover a wide geographic range including the Atlantic coast of Portugal, Eastern Spain, the Adriatic coast of Italy and Greece. The genetic analysis included both mitochondrial and nuclear markers. The statistical analysis consistently showed significant genetic differentiation between the Atlantic populations as compared to the Mediterranean ones in the majority of the species investigated with a further population structuring within the Mediterranean area only in some cases. The most striking Atlantic-Mediterranean separation was shown by *D. dentex* and *L. mormyrus* where the Atlantic populations did not share any allele with the Mediterranean ones, indicating for both species a complete absence of gene flow between the two areas.

Oysters

During the last 20 years, oyster culture, principally based upon natural spat in Europe, also developed through hatchery-propagated spat. Nowadays, this hatchery production reaches about 15 % of the spat production in France and tends to increase. This is especially true for the cupped oyster, *Crassostrea gigas* that has been introduced in Europe, where no wild stock of the species were resident, from British Columbia in 1979. However, the European flat oyster, *Ostrea edulis,* may also be concerned as some resistant and or tolerant strains to Bonamiosis have been developed and will be proposed to producers. The use of these strains for replenishment of the flat oyster stocks has to be questioned because of underlying genetic concerns.

To quantify the risk of "genetic pollution" by these stocks, an estimate of the numbers of wild parents contributing to the overall oyster population is needed, in both the hatchery and in the wild. At the individual level, females can be fertilised by a limited (down to one) number of males. Comparisons between obtained data using nuclear and mitochondrial markers clearly suggest that female effective population sizes are smaller than male ones. This seems to be particularly the case on the Atlantic coast. At the within-population level, data on spat genetic variability suggest that the dynamics of recruitment might also vary between the Atlantic Ocean and the Mediterranean Sea. At the species level, markers consistently show a clear pattern of isolation by distance. In any case, significant values are found, even at a rather small scale. At the same scale, gene diversities were also quite variable, showing that populations with different diversities may coexist in close proximity (for review see Boudry *et al.,* 2002).

Recently, tetraploid strains of *C. gigas* have been produced in hatcheries. Breeding tetraploids with diploids leads to sterile triploids. This enables oyster commercialization all the year long by maintaining a high grade quality on the market. This raises two possible interactions:

- triploids are not 100 % sterile and a high level of aneuploids have been reported in their offspring. Observations that chromosome loss in somatic cells of juveniles of the Pacific oyster *C. gigas* is associated with reduced growth rate have been reported (Garnier-Gere *et al.*, 2002). This consistent effect appears to be unrelated with the commonly, but not consistently, observed correlation between degree of allozyme heterozygosity and growth. The inverse relationship between aneuploidy and growth is due to the unmasking of deleterious recessive genes caused by "progressive haploidization"of somatic cells. Because unmasking of deleterious recessive genes by random chromosome loss is unlikely in polyploid cells, this hypothesis may also provide an explanation for the observation that artificially produced polyploid shellfish usually grow at faster rates than normal diploid ones. Their higher growth rate is to be taken in consideration when releasing them in the natural environment.

- gametes from tetraploids could "escape" from the hatchery, and meeting diploids gametes in the wild, leading to the production of large number of sterile triploids. A preliminary study has been undertaken to model the effect of releases of tetraploids gametes on the capacity of natural stocks to reproduce. The first results indicate that the risk was very low given the low reproductive success sustained by tetraploids in the hatcheries and the standing natural stocks of diploids in the environment.

General considerations on potential interactions

Competition and trophic interactions

Available food in the natural environment is structured within the trophic chain as a whole, it is limited in quality and quantity. Releases of large quantities of aquaculture individuals may disrupt the trophic chain, unbalance the available food and consequently deplete the food available to wild conspecifics. Of course a decrease in available energy through food impairs a number of physiological functions, including the reproduction, thereby altering growth rates and reproductive success. It can also modify the behaviour (feeding behaviour, aggressiveness) of the individuals. In nature, competition between individuals for limited resources (food, feeding sites, hiding places, spawning habitat, etc.) often results in the development of altered dominance hierarchies. This is a common feature in fish and it leads to disparity in food intakes, growth rates and survival. Thus, it is very favourable to hold a high social position and behaviour is strongly related to fitness. In that way, not only growth of the wild stock individuals may be impaired, but also their reproductive success and their susceptibility to diseases (nutritional and non-nutritional ones).

Although the knowledge of dominance hierarchies and their effect on population structures in the nature is quite high, very little is known of the behaviour of aquaculture fish when returning to the wild. It can be assumed that fish, in terms of social behaviour, try to act in a similar way independently if they live in a stream or in a tank. Generally, aggression, food intakes, growth rates and energy reserves are known to increase with higher social rank (dominant fish), whereas stress, metabolic costs and fin damages are known to increase with lower social rank (subordinate fish).

Webster and Hixon (2000) made observations on coral fish that could be a model for released aquaculture population. This applies particularly for competition between size classes of the same species of *Gramma loreto.* In a removal experiment, when larger fish were removed, smaller individuals quickly occupied these prime feeding positions and were the recipients of less aggression compared to controls. As a result, the average feeding rates of smaller fish were more than 60 % higher in aggregations in which larger fish had been removed. This competition is expected to affect demographic rates and ultimately contribute to local population regulation.

Laboratory studies suggest that dominance and aggression increase fitness, but this hypothesis has rarely been tested under natural conditions. Hoejesjoe *et al.* (2002) designed a combined laboratory-field experiment on brown trout to detect how social status and aggression relate to growth rate, movement and habitat choice in a natural stream. Juvenile brown trout were caught in the wild and relative dominance rank was determined in tanks. All tested fish were released back into the stream and recaptured after 3 and 8 weeks. Dominant fish grew faster than subordinates, but non-aggressive fish grew as fast as dominants. Social status had no significant effect on recapture rates. Movement was not significantly related to status, but smaller individuals were more mobile and preferred faster-flowing habitats closer to the shore than larger fish. The utilisation of pool and riffle habitats varied among status categories, but this relationship was not consistent between years. These results support the hypothesis that dominance increases fitness in the wild. However, the findings also indicate that less aggressive individuals can be successful in heterogeneous natural habitats.

These considerations take an increasing importance when individuals are released in regions where natural stocks are depleted, and call for additional attention (e.g., cod in Canada).

Youngson *et al.* (1993) have identified what is likely a behavioural deficiency in escaped farmed salmon that has led to increased levels of hybridization with brown trout. Such hybridization was found to be ten times more frequent among escaped farmed than wild Atlantic salmon females. Concern was raised regarding the negative effects this may have not only upon Atlantic salmon populations, but also upon brown trout populations. No studies are yet available on the subject dealing with other aquaculture candidates such as sea bass, seabream, cod, and shrimps as well as shellfish such as oysters and mussels.

Breeding and genetic interactions

Cultured marine fish are still genetically and phenotypically close to their wild originating conspecifics. So they can interbreed, which is not the case for the majority of terrestrial species being cultivated. Concerning genetics in aquaculture and the likely environmental interactions that may occur, two areas are to be taken into consideration: (a) the use of genetic knowledge and methods in breeding programmes to improve the production properties that have great influence on the economic success of the operation; and (b) the description of the natural population genetic structure to analyse the influence the cultivation may have on the wild strains of the cultivated species.

(a) The genetic improvements and/or drifts, and their correlative potential impacts can be described in three different aspects

(i) The intentional selective breeding for culture operations.

Selection is mainly based on socio-economic criteria (growth rates, disease resistance, maturation period, food efficiency...). These criteria are correlated to the production systems, and selection procedures integrate the husbandry (i.e., the environment and genetic interactions in the estimation of the genetic traits). In these conditions, it can be predicted that the pressure of selection in the aquaculture process will divert from the one in the natural environment. In addition to these, the selective breeding often relies on a limited genetic resource (i.e., a limited number of parents) that may decrease the genetic diversity of farmed strains. This issue is to be combined with the initial choice of wild breeders for the implementation of breeding programmes. In the absence of sufficient knowledge about the phenotypic variability of the natural populations of a given species (if these populations exist), the supply of the breeders is often being done randomly. The genetic difference between local natural stocks and aquaculture strains may be then important in case of these breeders or their gametes/fry being transferred in areas where the genotype structure of the population is different.

It is well documented in all farmed species, including terrestrial ones, that selecting on a limited number of criteria (usually 1–3) leads to losses of fitness on other criteria, the genes of which may be far away in the genome structure (i.e., no co-selection), particularly when the genetic basis is restricted and the intra-family genetic variability is low. So selected fish may present losses of fitness on those criteria not submitted to selection pressure when compared to their parents, and of course to their natural conspecifics.

Where adaptive differences exist between native and cultured salmon, interbreeding may lead to an overall reduction in survival and recruitment in the native population (Verspoor, 1997). Genetic changes can also occur indirectly through competition, which may cause a reduction in the effective population size, resulting in inbreeding and loss of genetic variability (Hindar *et al.,* 1991). As an example, it is known that a higher growth rate is determinant in competition. Consequently, these individuals may have a higher ability to reach the reproduction period. Since aggressiveness is known to be a heritable trait in salmonids, selection for rapid growth may indirectly select for aggressive behaviour rather than for physiological growth rate. The implication of this is so far unknown.

(ii) Unintentional drifts from husbandry practices

The domestication of strains is a complex process in which the initial population loses genes generation after generation. In that sense, the resulting strains are, at family levels, better adapted to the particular set of environmental criteria describing a particular aquaculture system. For example, the artificial breeding (including artificial insemination) may decrease the reproductive fitness of the cultured populations. Even if their reproduction success is generally lower than their wild conspecifics in the natural environment, these individuals have been reported to breed (Fleming *et al.,* 2000). One can expect they could transfer the deleterious genes responsible, which would have the same depression effect when naturally breeding with wild conspecifics. Native population may be even more weakened by exclusion of wild fish by aquaculture fish that could have a low reproductive fitness.

(iii) Genetically Modified Fish

This section applies mainly to the gene transfer from alien species (transgenic). Even if they not are GMO, we include cytogenetic manipulations to produce polyploids and interspecific breeding to produce hybrids.

Genetic modifications are now technically feasible on aquaculture commercial scale. However, even if some experiments have proved some commercial advantages (mainly in salmonids, see Youngston *et al.,* 2001) for some species, there are no reports on their utilisation in marine species. WGEIM has asked the WGAGFM to utilise their recommendations on some particular topic. Concerning GMOs, despite some studies on the safety evaluation of transgenic fish (e.g., Duham *et al.,* 1999; Guillén *et al.,* l999), there is clearly still insufficient knowledge about the possible impact of GMOs on wild populations and ecosystems, calling for use of the precautionary principle. Recent papers by Muir and Howard (1999, 2001) and Hedrick (2001) demonstrate the complexity of the problems. They found that if a transgene decreases the viability of an organism, but at the same time has a positive effect on some fitness components (for instance, transgenic males with an inserted growth hormone gene causing faster growth/larger size may be superior in spawning competition relative to unmanipulated wild conspecifics), then the transgene could spread in wild populations despite the lowered viability, provided it is fixed in the offsprings. This would lead to a decreased mean fitness of the wild populations and could eventually cause their extirpation (the "Trojan gene hypothesis"). Conceptually, gene transfer acts as a speeding up of the selection process and qualitative consequences on the environment are similar to those of the classical selective breeding. The matter addresses mainly the size of the effect rather than its nature.

Very fast growing transgenic Atlantic salmon have recently been developed, which stresses the actuality of the "Trojan gene hypothesis" (Reichhart, 2000).

Triploids of many marine species have been successfully produced at the experimental and industrial level (sea bass, sea bream, turbot, Japanese shrimp, Japanese oyster,...). They are produced using heat or pressure shocks on the developing eggs. These triploids have been produced mainly to allow the diversion of the energy dedicated to gonad production into meat production. In many cases this has been linked to increased growth rates. Being sterile, triploids strains have been recommended to protect the genetic improvements obtained by the industry through selective breeding, and to avoid any reproduction of those strains when escaping.

In a study by Cotter *et al.* (2000), the migration behaviour of groups of triploid salmon was investigated. The return of triploid salmon from the release groups was significantly reduced compared to diploid salmon. The return of a small number of hormonally deficient, sterile triploid female fish suggests that migration to fresh water is not inextricably linked with reproduction. The substantially reduced return of hormonally competent triploid males to the coast and to fresh water, indicates that other factors may have an effect on their marine survival. The reduced return of triploid salmon to the coast and to fresh water, together with their inability to produce viable offspring, demonstrates the potential for triploidy as a means of eliminating genetic interactions between cultured and wild populations, and of reducing the ecological impact of escaped farmed fish.

Nevertheless, triploids may have reproductive success and rarely 100 % of the individuals from any batches are sterile. Triploids of pacific oyster have been produced using tetraploids (see that section). These tetraploids, if not well isolated, may interfere with wild diploids to produce sterile triploids, which could lead to a depletion of recruitment.

(b) In many fish, the genetic diversity is partitioned at the geographical population level, because of spatial distance, or behavioural or temporal isolations. Phenotypic variations among various populations of marine species are well documented in some species. Genetic analyses have much to offer fisheries managers, especially in the provision of tools enabling unequivocal specimen identification and assessment of stock structure. The three commonly used genetic tools—allozymes, mitochondrial DNA and microsatellites—differ in their properties. These differences must be borne in mind, especially when interpreting gene frequency data collected for stock structure research for the estimation of genetic introgression from cultured populations. These may partly be a result of the environmental conditions, but may also be caused by genetic factors.

The degree of risk for a population adapted to the local environment to lose its fitness when breeding with a cultured population is correlated to the genetic distance between the populations that comes from the divergence of the selection pressures. At least two cases can be considered depending on the migratory or non-migratory features of the concerned species. In case of non-migratory species (that means that reproduction occurs in the local environment), when the populations are highly structured, the local impact of releases may be very high. On the opposite, in case of migratory species, e.g., for reproduction purposes, represented by a unique population, the spreading of the genes carried can be higher and the dilution of genes in the population as well.

Pathogenic interactions

Aquaculture facilities lead to increased density of fish, which increases the random spreading of diseases (virus, bacteria or parasites) into the facility, either coming from the transfer of pathogens from hatcheries, or from contamination from the wild in case of facilities not isolated from the natural environment. Thus, the infected stock carries an increased risk of dissemination of the pathogens, acting as reservoir pathogens relative to the species. It is recognised that aquaculture facilities, particularly sea cages, act as FAD (fish aggregation devices), concentrating wild fish around the cages. This leads to an increase proximity, and contact when these fish enter the cages. By the way, it increases the risk of disease transfer from the cultured fish to the wild. This risk is increased when the parasite is carried by more than one species (e.g., *Diplectanum,* an ecto-parasite of sea bass and grey mullet, or *Vibrio* sp. that is carried by a great number of fish (sea bass, turbot, seabream, halibut, flounder, mullet)

The trade of fry from more and more distant geographical areas is increasing. Live animals are crossing borders that were not naturally accessible to them, carrying a series of pathogens, not all described (e.g., the *Nodavirus* has been only described in the 1980s, many years after transfers of fry began). Regulations, even if they are well implemented at national level, will not avoid this increased risk. The further spreading of these pathogens is increased in case of migrating species. The case of the commercial trade of oyster in France is a very interesting example. The fertility of hybrids *C. angulata* (Japanese oyster) and *C. gigas* (Pacific oyster) was demonstrated, which is further evidence that they are the same species. In the 1970s, strains of *C. gigas* were introduced in France from British Columbia (Grizel and Heral, 1991). A few years later, the French stocks of *C. angulata* were eradicated by an iridovirus. It is suspected that the transfer of *C. gigas* was accompanied with the transfer of this iridovirus. *C. gigas* from B.C. acted as an healthy carrier, tolerant to the virus, and impacted heavily *C. angulata* which were not resistant to it.

In the same way, it is suspected that *Bonamia,* a parasite of the flat oyster *Ostrea edulis,* has been imported through the same transfer of *C. gigas* and further dissemination of *O. edulis* in all the French and European production basins, from Portugal to the Netherlands and the British Isles. In America, the haplosporideans *(Haplosporidium nelsoni* and *H. costalis)* that have infested the local oyster population of *Crassostrea virginica* in the Chesapeake bay are suspected of being introduced through spat from Japan. This has also been the case for nodavirus on sea bass. The Nodavirus is the causative agent of the viral encephalopathy in sea bass and many other fish species. Sea bass is one of the most sensitive species to this virus, while seabream is an healthy carrier (Aranguren *et al.,* 2002). Two main strains have been reported, one from the Atlantic and one from the Mediterranean. Increasing occurrence of the Atlantic strains of Nodavirus in the wild have been reported in the Mediterranean (Richards, Stirling University, personal communication), which is suspected to be caused by increasing aquaculture stocks and living fish transfer from Atlantic hatcheries.

Another issue is the indirect effect from genetic selection to increase the resistance to diseases, the use of resistant hybrids, the choice of resistant natural strains, and the use of vaccination. Very often, the selection process leads to increased tolerance of reared fish to pathogens. The vaccination may not eradicate the pathogens. In all cases, these interventions make the individuals healthy carriers for increased duration, which subsequently increases the risk of pathogen dissemination.

Recombinant DNA vaccines are under development. The most frequently used method consists in introducing a gene, usually fixed in a plasmid, in the fish by intraperitoneal or intramuscular injection, bathing, cutaneous particle bombardment using a gene gun. It is then expected than the gene will produce the viral protein to induce the specific immunological response by the fish. The plasmid is often produced using recombinant technology in bacterial vectors. This technique has been tested at the experimental level against sea lice and some viruses (IHNV, VHS, Nodavirus,...). The environmental impacts refer to both genetically modified fish and resistance issues developed above. Nevertheless, the risk of transferring the plasmids to wild populations appears minimal, given the low probability to see a plasmid transferred to eggs or sperm.

Mitigation strategies and recommendations for research programme

To counteract the possible negative effects that escapees (gametes, eggs, juveniles, breeders) from aquaculture operations may have, there is a need to further document numbers of the potential impacts reviewed above. Blaxter (2000) concluded in his review that “unless a small wild population is swamped by large-scale releases (or stocking) of reared fish, it seems unlikely that the reared fish will out-compete the wild fish”. Nevertheless there seems to be reasonable scientific evidence to take a precautionary approach and to put in place a legislative framework for monitoring fish farm escapes of non-salmonid species, at least until the potential for problems is better understood. Some of the operational strategies that could help decrease these impacts are listed below.

Measures that are not specific to a particular risk

One of the key points for the research development is to evaluate the number and the origin of the fish being released. A great deal of research has been undertaken to distinguish between wild and reared salmonid fish (e.g., Lund *et al.,* 1989; Lura and Sagrov, 1991; Lura and Økland, 1994; Fleming, 2000). There has not yet been an attempt to look into distinguishing wild and cultured fish from other species. Similarly, there are no easy methods to readily identify the origin of shellfish (e.g., oysters, mussels) in areas where cultured and wild populations may co-exist.

A major issue is to improve the physical characteristics of the containment facilities for fry, ongrowing stocks, and breeders (particularly in the case of GMOs). This applies to both floating cages (mooring, net quality, resistance of the raft to waves, avoidance of predators’ effects on the nets, choice of locations) and to land based facilities (sieving of the out-flowing water). Development of closed systems, on land or floating, must be encouraged in these objectives. These technical issues have necessarily to be accompanied by the education and training of aquaculture personnel. They will limit the accidental releases coming from storm or hard weather conditions that are more often predictable. This should be extended to include accidental releases of eggs and gametes from self-spawning broodfish.

It has been reported that a high percentage of the escapees are due to releases of ongrowing fish during usual husbandry operations (sorting, local cage transfer, bathing for vaccination or chemical treatments). Through the expanded use of Code of Conducts and Code of Practice, the husbandry standards have to be improved in order to decrease the risk.

In case all these precautionary methods would fail, measures for the recovery of escaped stocks should be developed and applied. Bridger *et al.* (2001) reported a case of site fidelity in intentional releases of steelhead trout adults in Newfoundland. The same case has been reported in cultured Atlantic salmon by Rosenthal (personal communication) in New Brunswick and in sea bass in the French Mediterranean (Dosdat, personal communication). Effective recovery protocols can be based on this behaviour. Additionally, it may prove possible to facilitate recovery further by strengthening or manipulating the site cues to fish response. These developments have to be extended to small fish. And again, site selection should integrate that type of constraint.

These principles rely on a precautionary approach and there is a crucial need for implementing long lasting monitoring programmes to evaluate the anticipated effects in the long term Due to their costs these programmes have not been developed in the marine environment.

There is a urgent need to better regulate the intentional transfers of living animals for commercial purposes. These have impacts on the genetic and pathogenic issues that call for specific application and must include specific regulation to be addressed to GMOs.

Measures that are specific to competition and trophic interactions

The behaviour of marine wild fish for which conspecifics have been cultured has not been intensively investigated. There is an urgent need to better understand not only the behaviour of those wild individuals, but the behaviour of released culture fish when returning to the wild. This would give an assessment of the degree of risk.

The maintenance of sufficient wild populations (managing fisheries pressure, enhancement,...) is an efficient tool to mitigate the effects of increasing quantities of released aquaculture individuals. Many fish populations have suffered a substantial reduction in number during the last century, due to anthropogenic disturbance such as habitat degradation and overexploitation. Loss of genetic variation can, on a short time scale, lead to inbreeding and associated inbreeding depression. On a long time scale, it is expected that the loss of genetic variation will impair the adaptability of the population. In that situation they would be dominated by aquaculture strains. The maintenance of high numbers of wild fish at all life stages, especially in populations that are at risk, and the conservation of natural genetic variation within and among populations will maximise their robustness to the effect of genetic interactions. However, very little empirical evidence on changes in levels of genetic variation can be found for fishes submitted to overfishing in the natural environment.

Modelling the risk of genetic mixing will help the decision makers and managers. Lacroix *et al.* (1998) show modelling approaches to estimate genetic introgression into the genome of wild stocks for salmonids and such approaches should be considered to be employed in studies of non-salmonids as well. This has also been utilized to evaluate the risk from accidental release of tetraploids oyster gametes (Chevassus, 2000).

The use of reproductively sterile fish is recommended. Currently, triploidy is the only practical large scale option, given that hormonal treatment is to be forbidden in many countries. In some species, because of their impaired commercial performance (e.g., sea bass), high priority should be given to devising alternative means of sterilisation that could be achieved at low cost. Nevertheless, sterile fish do not solve of the problem, given that some sterile individuals have been reported to mimic the reproductive features, thus impairing the natural reproduction of their conspecifics.

The use of local, unselected stock will decrease the risk of potential genetic interaction. In practice, this approach is not likely to be sustainable in the future, given the industry need for improved strains. This recommendation is to be implemented in new species development, and the local resource can be used as founding stock, before any selective breeding programmes become effective. Besides, the maintenance of a large genetic diversity in the hatcheries may limit the decrease of natural genetic variability.

Measures that are specific to pathogenic interactions

When it is proved feasible (i.e., in land based systems for both hatcheries and ongrowing purposes), water treatment on both inflowing and outflowing water is recommended. In particular, closed recirculating systems are recommended as a powerful tool to handle this particular issue.

The susceptibility of fish reared in an artificial environment to diseases is a matter of great concern. Research programmes should be developed to assess and increase the natural resistance of fry in order to limit the propagation of the disease when returning in open water conditions (i.e., in sea cages).

To decide if those are to be maintained or not, other issues proximal to those:

- impact on other species that have the same feeding habits, the same habitat, that are sensible to the same pathogens

- Catching wild juveniles in some species fry production is not mastered. The production relies on natural production. In some case, the catches may be high compared to the standing natural stocks. Case of Bluefin tuna in Spain: collecting juveniles out of the quotas could lead to overfishing. In some cases, catching of maturing females. Case of cod in Canada? Case of eel in Europe

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ANNEX 6: STRATEGY TO PROTECT MARICULTURE AGAINST THE HARMFUL EFFECTS OF EXTERNAL INFLUENCES

INTRODUCTION

The mariculture sector provides many benefits to rural and coastal communities, but is often vulnerable to harmful effects from other activities in these areas. These activities are for the most part traditional and can be both land and aquatic based. In this environment, the mariculture sector is often at a disadvantage to resolve conflicts arising from these other activities and seldom has the legal mechanism to protect itself from their harmful effects. To overcome this imbalance, the use of Integrated Coastal Zone Management (ICZM) strategies is showing potential, at least for the implementation of mariculture activities in coastal systems. The protection of mariculture against the harmful effects of external influences, however, is often omitted in such ICZM strategies and therefore the legal basis and the public support to ensure the equal right of mariculture in the coastal zone are not firmly established. This concept has been discussed extensively in previous reports of the Working Group on Environmental Interaction with Mariculture (1, 2, 3). The main objective of this section will be to discuss new strategies that could be incorporated to ICZM to protect mariculture against the harmful effects of external influences from other activities.

Coastal zone planning in most parts of the world is mainly conducted to evaluate the possibility of adding new activities and limiting conflicts with existing ones. The new activities, including mariculture in the coastal waters, are also subjected to environmental assessments and monitoring that are not equally applied to existing activities. More specifically, the potential harmful effects from external influences on mariculture are commonly overlooked. This can be seen in the new EU Strategy For the Sustainable Development of European Aquaculture; "*It is critical, in considering the location of aquaculture sites, to proceed to a systematic, integrated assessment of both the positive and negative impacts of new aquaculture developments*." (EU COM 2002, 511).

This decision process tends to create an order of importance and responsibility (liability) based on traditional values rather than economic, social and ecological values across all stakeholder interests. The integration of mariculture in the Coastal Zone requires longer-term perspectives. Planning, therefore, is often done on an experimental/temporary basis and avoids making the required commitments and compromises in mariculture, that is commonly done for other activities, particularly for land based activities.

The competition for space is obvious in the coastal zone: "*Many complaints against aquaculture development reflect competition for space; the recent growth of aquaculture, particularly on the coastline where there is already a high concentration of activities, put it in the place of the newcomer disrupting the long-established status quo between existing users..*" (EU COM 2002, 511). This could lead to an increased risk for mariculture to establish in the coastal zone without proper management of harmful effects from external activities.

Mariculture needs similar protection from the harmful influences of external activities as the others in the coastal zone. Such an integration of mariculture has been better assimilated in some parts of the world where the use of aquatic resources has always been a major source of income (e.g., South-eastern Asia, Norway) and its social value is high in local communities. It is vital that mariculture promotes its potential contribution to the coastal economical and ecological value, and pursues a cross-sectoral approach.

The proposed zoning strategy in this document is consistent with some suggestions from the EU document; "*The Commission's Demonstration Programme on integrated coastal zone management has shown that the best response to such complex situations is an integrated territorial approach that addresses concurrently the many different problems an area faces and involves all the stakeholders*" (EU COM 2002, 511). This would imply that the integration of mariculture should not be treated in isolation from the rest of the existing activities in the coastal zone. In doing so, the harmful effects of other activities have to be considered in the planning process, including the interaction among different mariculture operations within a zone.

One of the starting points would be that mariculture has to be treated as an equal rights resource user with other activities in the coastal zone. Mariculture benefits the local community by increasing the socio-economical diversity and sustainability of a coastal area. The multiple-use concept provides a hedge against any failure of any one of the resources and resource users in face of the uncertainty of natural resources (e.g., Climate change) or uncertainties in the market place (e.g., Shift in the global economy). These planning exercises must take into consideration the different categories of influences, such as natural and anthropogenic influences (indirect and direct). The goal of this discussion paper is to promote the importance of evaluating the impacts of harmful effects from external influences within an Integrated Coastal Zone Strategy and Management Plan, to ensure the sustainability of mariculture in coastal areas. Unfortunately, mariculture can be a weak partner in the coastal zone, despite the important investment required for its establishment and its many benefits.

The coastal zone is a complex ecosystem with high interaction, both from land and aquatic areas, and few natural borders. Ecological disturbances at a local site can have significant effects to a variety of natural processes, leading to impact on other activities in the coastal zone. The first objective should be to establish the ecological, economic and social goals at the international, national, regional and community levels. For each level, an education process for the stakeholders has to take place to ensure that the best-informed decisions can be made. It is important to seek a balance between the community's needs, from a socio-economical basis, and the ecological capacity to support the activities permitted. From these planning principles, the integration of mariculture activities in a coastal zone would be assessed on an equal footing with all other activities and the interaction with other users could be evaluated both in terms of potential benefits and costs (harmful effects). The result from this exercise could lead to the establishment of aquatic activity zones similar to those existing for land based activities (e.g., agricultural, industrial, residential, natural, commercial) with environmental, economic and legal standards. One of the main benefit of the zoning approach is that some of the effort to control harmful effects from external influences could be avoided through good planning or become generic to the zone and therefore, less onerous on individual mariculture enterprise.

The establishment of a mariculture zone could be shared or be part of a more generic zone with activities of similar needs, concerns and interests. For example, it is becoming very clear that the co-existence of the fishing industry and mariculture industry have similar concerns in terms of invasive species that can be introduced by the commercial shipping industry. Planning strategies could therefore consider the establishment of a food production zone with strict control or limited contact with the navigational zone. The zonal concept could be either geographically based or activity based. For instance, based on a socio-economic and ecological assessment, an estuary could be declared as a predominantly food producing zone. Here, the onus of reducing the harmful effect of navigation activity would be on the navigation industry. The reverse would also be true for a system declared as a navigational zone, whereby the mariculture would have to manage the risk of operating in that zone.

STRATEGIC PLANNING FOR MARICULTURE

The development of mariculture in the coastal zone needs a holistic approach taking into account the environmental aspect as well as the potential conflict between users of the same resources (Figure 1). In this part of the document solely the effect of external factors on mariculture development and operations is discussed, although it is obvious that mariculture itself has an environmental effect on the coastal ecosystems. For this reason it can be assumed that at the very end mariculture will operate in a way that the basic living conditions are maintained in its zone. The external factors (Table 1) which can influence mariculture can be divided into three large areas which have to be tackled. In relation to the environment, the starting point for zoning or planning might be:

(1) natural influences in the forthcoming site selection in a mariculture zone;

(2) anthropogenic influences that must be controlled, reduced or avoided; and

(3) unacceptable intentional anthropogenic influences in a mariculture zone.

From the systematic point of view, one can distinguish between land-based and aquatic-based factors. In this section we prefer to talk specifically about the environment, although there are many other factors which influence the choice for site selection. In general terms integrated coastal zone management may be the prime start for coastal aquaculture today but that is dealt with in another section of this document.

Site selection factors must be considered during planning and construction of a new mariculture facility. All existing external factors, which can have an effect, must be balanced (Figure 1). Only if it can be made sure that the conditions are adequate and limitations can be excluded at the planned location, is it meaningful to advance the process of the establishment of a new mariculture facility. The site specific factors determine in the first phase whether a settlement of a mariculture is meaningful at all and whether a viable operation can be expected. The establishment of zones for mariculture is one possible way which is particularly preferred here.

Tabel 1: Some potential external factors impacting mariculture operations (in part adopted from the 1997 Working Group Report (WGEIM).

Type of Mariculture **External Factors on Mariculture**	**Cage Culture**	**Seaweed Culture**	**Mollusc Raft Culture**	**Mollusc Bottom Culture**
Cage Culture	Eutrophication, Disease transfer, Contamination with Chemicals	Contamination with Antifoulants	Excessive Nutrient Release, Suspended Solid Load	Excessive Nutrient Release, Suspended Solid Load
Seaweed Culture	Habitat for Intermediate Hosts for Parasites, Pathogens	Disease Transfer	Spatial Competition	Spatial Competition
Mollusc Raft Culture	Habitat for Intermediate Hosts for Parasites, Pathogens	Spatial Competition	Disease Transfer	Suspended Solid Load (Pseudofaeces)
Mollusc Bottom Culture	Deterioration of bottom Fauna and Flora, Habitat for Intermediate Hosts of Parasites, Pathogens	Spatial Competition	Deterioration of bottom Fauna and Flora. Habitat for Pathogens	Spatial Competition, Disease Transfer
Commercial Fishing	Damages to Structures, Spatial Competition	Spatial Competition	Damages to Structures, Spatial Competition	Spatial Competition
Agriculture	Nutrient release, Suspended Solids, Chemical Contaminants and Pesticides	Nutrient release, Suspended Solids, Chemical Contaminants	Nutrient release, Suspended Solids, Chemical Contaminants and Pesticides	Nutrient release, Suspended Solids, Chemical Contaminants and Pesticides
Recreation	Spatial Competition	Spatial Competition	Spatial Competition	Spatial Competition
Industry	Toxic Wastes, Oxygen depletion, Temperature Changes Suspended Solids	Toxic Wastes, Temperature Changes Suspended Solid	Toxic Wastes, Oxygen depletion, Temperature Changes Suspended Solids	Toxic Wastes, Oxygen depletion, Temperature Changes Suspended Solids

Critical issues which are discussed below are chemical, biological and physical factors influencing the site selection and those factors in particular which might be stressed for the different type of mariculture operations, not taking into account the various available methods for different types of establishments. Land and water based operations, except those which use closed system methods, are heavily dependent on the kind of water resources which are available.

In mariculture the water quality is of utmost importance. In many cases the water has to be treated before entering the mariculture system which means an extra cost for the farmer.

With regard to chemical factors, diffuse sources of nutrients from agriculture, forestry and industries, must be considered and how much the surrounding commercial activities will influence the quality of water used. The farmer must also take into account the influences from atmospheric deposition of various kinds of chemicals, e.g., the downfall of acid substances such as sulphuric acid originally created from the traffic and industries.

The supporting water sources available might also be influenced by biological organisms. Microbial organisms from urban sewage and livestock rearing can contaminate the available water sources. Other factors might be water fowl, terrestrial birds or mammals. They can bring noxious or other microbes or seeds to an aquaculture operation which might interfere with the biological life in the systems. In addition, mammals and birds can act as predator in production units.

Open cultures near the coast are for example heavily influenced by run-off from land. This means that water might be slightly polluted when it comes into the operation area. In shallow-based units the bottom is of great importance for the water quality. The sea floor might also be influenced by the water flow from land. In a worst case scenario anoxic conditions may develop at the bottom followed by the release of hydrogen sulphide. For this reason it may be important to get a site with bottom currents; you might choose an erosion bottom type instead of a deposition bottom type.

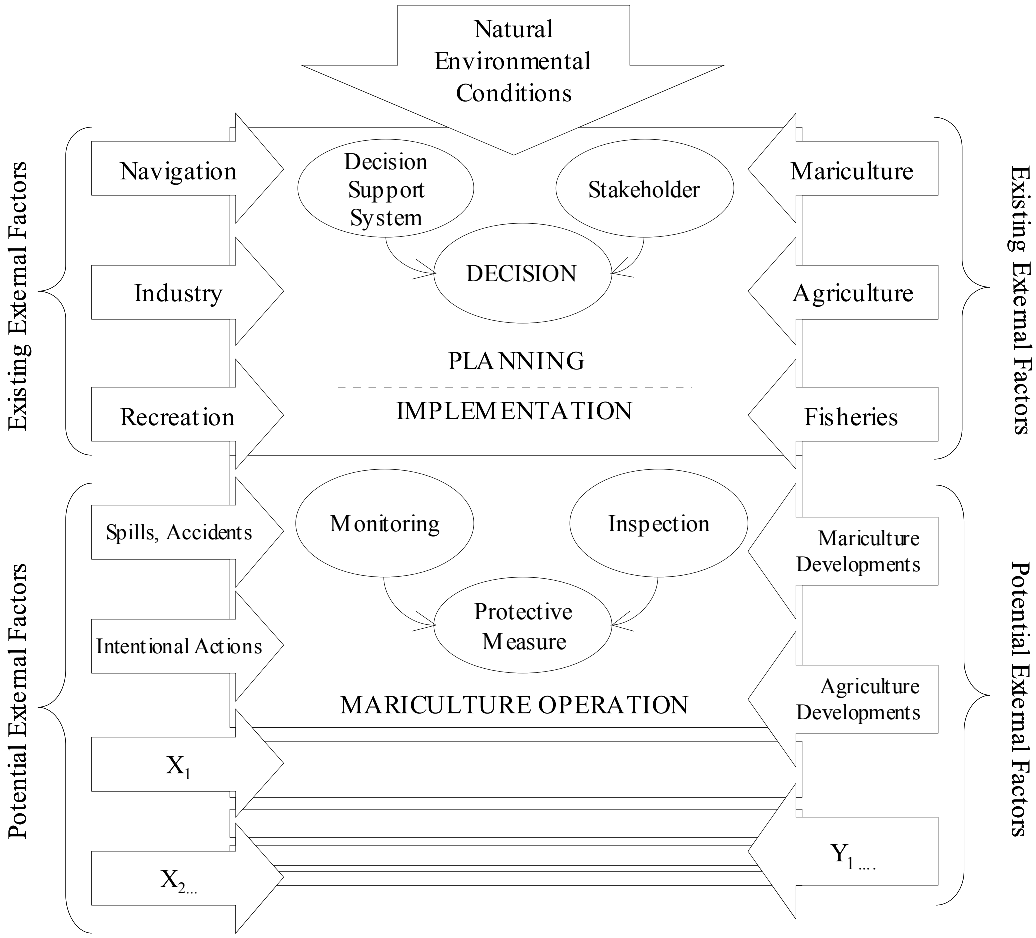

Figure 1: External factors impacting mariculture development and its operation.

Other physical factors influencing the water source and the operation unit are sediment deposition, turbidity, humic substances and flooding. Also factors such as wave action and temperature are critical to farming operations. In exposed areas wave action can be hazardous to the whole operation with escaped fish as a result. Depending on the species in culture the temperature is a key factor often related to the salinity conditions. In areas with not full marine salinity one may face the problems with chilled surface water (supercooled waters), which is known to be lethal for salmonid fish.

A strategy for the mitigation of the impact of potential external factors on mariculture during the first phase (developmental phase) must include the assessment of baseline monitoring data in the vicinity of the selected site (shoreline survey, resource inventory). This must for example also include a watershed survey to describe the catchment area (area of potential harmful effects). An investigative sampling in order to locate sources of pollution should also be carried out in relevant areas. However, there is obviously a need to use so-called decision support systems (DSS, see Section in this document) to better assess the interactions, including the environmental and economic consequences. In doing so comprehensive information and descriptions of the potential risks can be provided to any resource user in the zone and the responsible authorities.

After implementation of a mariculture operation it must be guaranteed that new activities of other users (Figure 1) in the zone do not interfere with this operation. It must be protected by adequate regulations. This must apply to already existing as well as new operations in the vicinity of a mariculture facility either land based or water based. Under the assumption that mariculture activities have a positive effect on the local economic development it is inevitable to guarantee adequate operating conditions and a permanent license. Supporting decisions of the local authorities are one of the prerequisites to ensure a viable operation of mariculture.

There are several potential chemical pollution sources in an industrial society such as point and diffuse sources of nutrients from municipalities, animals farms, forestry and industries. Contamination from chemicals and oil sources are most significant. They might be controlled and avoided, but accidental discharges are always a risk for a mariculture operation. Other potential pollution sources are microbial contamination of the water from sewage, stockbreeding, or industries.

A mariculture zone might receive hazardous substances from ship use. This includes discharges from fuel and other sources on board as well accidental discharges of oil. Antifoulants on ship hulls may also influence the quality of your products, e.g., mussels.

The introduction of alien species from released ballast water in the area is a risk for the farmers. That is also true for organisms which have been transferred from one part of the world to another on ships' hulls. Lots of bird species can be a nuisance for farmers. This can also be said about various mammals.

Waves and water movements from various activities as ship traffic and boating are other risks which might be minimised by regulating such activities.

A strategy of zoning for mariculture must take into account that in such an area mariculture has to coexist with other users. Every single user will possibly interact with the others in the zone and the totality of all activities determines the risk for each individual user in the zone. This means that the coexistence will depend on everyone and an attitude that every one does his best to prevent negative effects on others by a responsible management.

The third area concerns all the external factors which have their origin in accidental or deliberate events of third parties. These external influences can be controlled through inspection. Precautionary measures can be meaningful such as protected areas. The avoidance of perturbations in the nearby area of an operating mariculture is also of great importance.

Chemical pollution may be caused by unregulated use of fertilisers and pesticides as well as various industrial discharges. This is true for aquaculture farms linked to natural habitats (excluding indoor closed systems). Microbial contamination from sewage, stockbreeding and industries exceeding standard values set by relevant authorities is not acceptable. Restricted approaches to farm operation are important in order to prevent transfer of bacteria etc. from one area to another.

All kind of dumping activities in the mariculture zone as well as oils and chemical discharges are unacceptable. The release of ballast water is unacceptable as well as other pollution activities from cattle rearing and leaking sewage holding facilities etc. nearby. Shipping activities must also be regulated in the mariculture zone. This also includes the use of leisure boats including diving activities.

Uncertainties arise from unexpected occurrences that are due to stochastic processes (accidents) in the highly variable coastal environment. However the risk can be assessed from past experiences and at the same time standard supervisory systems and biological early warning systems can help to identify critical situations and to take the appropriate measures in order to protect the mariculture operation.

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ANNEX 7: DECISION SUPPORT, GIS AND OTHER EXPERT SYSTEMS

Introduction

Implementation of scientific advice requires good communication between the scientific community and stakeholders, including managers, fish farmers, NGOs and the general public. As our understanding of the complexities of mariculture interactions within the coastal zone improves, it becomes harder to convey the necessary information to individuals without scientific training, and an increasing amount of attention needs to be placed on how this information is presented and how the results of scientific investigations are conveyed to the various client groups.

A related issue is that the scope of individuals who are considered stakeholders is increasing with growing awareness of the social responsibilities associated with the exploitation of natural resources. As use of the coastal zone undergoes rapid changes, old activities associated with, for example, fisheries and agriculture, may disappear, while others like recreation, nature conservation and transportation claim greater allocation of resources. The mariculture industry is also experiencing rapid diversification and development. This offers new options for new and normally more environmentally acceptable activity, but also emphasises the need for flexible and frequently reviewed regulations. Mariculture is no longer the concern only of fish farmers and managers; it involves all other users of the coastal zone as well as consumers and environmentalists. The circle is expanding, with animal rights activists and other groups not obviously connected to mariculture becoming involved. Yet while the number of people who need to receive and understand scientific advice increases, the size of the research community is not growing proportionately to the work load.

As a result of these changes, mariculture can no longer be considered an isolated activity, but must rather be considered in the general context of Integrated Coastal Zone Management (ICZM), and in fact, especially given the growing crisis in wild fisheries, it has become an increasingly important component of the global food production system.

This has led to increased interest in the development of expert systems and related tools for the evaluation, presentation and communication of scientific as well as socio-economic information. These tools include Geographical Information Systems (GIS) to store spatial information in a way that can easily be accessed, displayed, and represented, and Decision Support Systems (DSS) to provide scientific advice in a form that can readily be understood and evaluated by managers and stakeholders without a scientific background. This report elaborates on ways in which these tools can be used, both within the sphere of mariculture proper and in the broader context of coastal zone management.

Terminology

The following definitions describe terms used in this report in a relevant context, and do not agree exactly with the standard dictionary entries.

An Expert System is an interactive tool, usually but not always computer-based, that makes scientific expertise available to the user.

A Decision Support System (DSS) is an Expert System that is designed particularly to assist the decision-making process, for example, a means to provide scientific input to the site licensing process.

A Geographical Information System (GIS) is a database system to store and display geographical data. Usually the data can be accessed at varying degrees of detail through superposed layers. Each layer can incorporate particular features such as fish farms, piers, temperature profiles, bathymetry, current patterns or transportation channels. By selecting appropriate layers one can, for example, see how mussel rafts are distributed relative to sewage outlets. A GIS display is similar to what one sees if one superposes several transparencies on an overhead projector, a technique that was in fact used before the advent of desktop computers.

The Decision-Making Process

Development of decisions about coastal zone planning, including mariculture, involves several steps and requires a framework for ensuring adequate input from all concerned parties, including not only traditional stakeholders with an evident direct interest but also environmental groups, local residents, and consumers. First of all, there must be agreement on a set of environmental quality objectives, which is a key starting point for all aspects of ICZM. These objectives must be implemented through the definition of standards. Based on these standards, a management system must be developed which involves monitoring to see that the standards are followed, and includes steps to avoid violating them. Finally, this should occur within a regulatory framework that gives all stakeholders a voice and a chance to see that their interests are protected.

There are several different mechanisms through which mariculture interacts with the environment, on different spatial and temporal scales, and in ways that are likely to be of concern to different groups of stakeholders. The most obvious of these, and the one that has probably attracted the most attention, is through the release of effluents including nutrients, particulate matter, and chemicals which include antibiotics and other pharmaceuticals. Fish farms also consume oxygen and generate other forms of BOD. These are usually considered to be negative impacts, although it should be recognised that some effects can actually be seen as positive from the viewpoint of some stakeholders—local enrichment of the seabed by mariculture often attracts crustaceans of commercial value, and in some regions the zones around fish farms are exploited by crab and lobster fishermen. The release of nutrients into oligotrophic waters can enhance primary production, and this, as well as particulate effluents, can increase mollusc production. In fact, some fish farmers are investigating polyculture - this involves growing shellfish or algae in the effluent from a finfish farm, where particulate wastes can provide food for shellfish or dissolved nutrients can enhance primary production, and since the wastes are removed by the secondary stock the effluent impacts are reduced. In general, well-managed mariculture can increase natural biodiversity, biomass and productivity, although at increased production levels these variables can also be reduced.

These effluents affect several different groups of stakeholders; they can lead to self-effects, namely impacts on the farm itself, and they can affect other farms in the same area as well as wild species in the locality. There is also the possibility of disease and parasite transmission to both farmed and wild species, and risks of release of cultured organisms into the wild.

It can be difficult to distinguish self-effects from impacts on nearby mariculture sites, which creates confusion about who the stakeholders are — a farmer whose poor husbandry practices lead to outgassing (the release of toxic gasses like hydrogen sulphide) under his pens is also likely to have negative impacts on his neighbours. Thus the interests of individual firms (or individuals) may be different from those of groups of stakeholders, and a decision process where any individual or group can participate may function differently from one in which groups participate through the mediation of representatives.

There are also environmental interactions which act on mariculture, such as the release of waste products from other coastal zone users, physical disturbance due to ship traffic, dredging and construction activities. Most of these effects are due to other human uses of the coastal zone, although the possibility of effects due to storms, sea level rise and climate change must be considered. This is discussed in detail in Section 6 of the WGEIM report which deals with strategy to protect mariculture against the harmful effects of external influences.

In addition to these environmental interactions, a DSS must incorporate other types of possible conflict or concern such as competition with other coastal zone users (conflicts with other fisheries, with recreational areas or transportation channels, and zones that are reserved for factory or sewage discharges), animal welfare issues, and possible degradation of scenic, historical, tourist, or property values. Spatial conflicts in the coastal zone are increasing due to population pressures coupled with growing awareness of the need to conserve natural environments, which makes it essential that a DSS incorporate geographic information (to be discussed in detail later in this section).

While these are formidable challenges, it is important that the decision-making process be transparent and understandable by those affected, which means that while it may be very complex, both the results and process which produce them must be presented in a way that can be reviewed and interpreted by people with a wide range of skills, training, and education. It also needs to be accessible to the stakeholders, which in practice means a degree of accessibility to the general public. If it is maintained under strict government or industry control, then it is unlikely to earn the trust of other stakeholders. For this reason it is important to design these systems with public accessibility in mind, similar to the practice of releasing official documents to libraries rather than restricting them to government offices.

This can lead to problems with proprietary data, such as confidential farm production figures and financial statistics. Access to databases containing such data must contain safeguards against improper use. There are mechanisms to deal with this, and many countries have online statistical databases where the data that a user can see depends on passwords and access codes. This type of approach offers a good model for access to mariculture data.

Conflict Resolution

An important point to keep in mind when designing a DSS for mariculture planning (or any other aspect of ICZM) is that the objectives represent a compromise, and there will almost never be complete consensus among all the stakeholders. Because of this there must be a reporting facility that includes comprehensive details on the nature of the analysis and describes the different factors that enter into the decision.

Conflicts can arise between fish farming and other coastal zone uses, including capture fisheries, and between different fish farms. The circle of stakeholders is so large that conflict is inevitable, and one of the major functions of an Expert System is to provide information that can be used in resolving these conflicts. It is not realistic to expect a DSS by itself to resolve conflicts — that ultimately has to be settled by human beings. It can however play a useful role in clarifying the scientific and technical issues.

Economic factors certainly play a major role in mariculture, although to some extent these involve business decisions by fish farmers that are not always the concern of regulatory agencies. Even so, it is important to realise that there can be incompatibilities between the short-term concerns of a small-scale farmer with a family to feed, the medium-term interests of an industrial operation which is looking for a good return on its capital investment, and the long-term views of conservation groups.

Social and political factors are also important, especially since fish farming is often developed as an alternative to failing capture fisheries. These are often overlooked because they are difficult not only to quantify, but even to identify. Even so, they are a key part of the decision-making process and must be included.

Unfortunately it is not always clear what the objectives of the stakeholders are, since they often involve value judgements about which there is a degree of dissimulation. For example, politicians may profess a strong commitment to conservation, but as elections approach they tend to focus on immediate job creation and security for their constituents, to say nothing of financial support by industries which favour their re-election. Local residents similarly may support a "green" position primarily out of concern for their personal recreation and preservation of their property values. Expert systems need to be sufficiently robust to allow for these considerations, and ultimately a high degree of human intervention is required to interpret the results meaningfully.

Risk and Uncertainty

Any planning process involves risk and uncertainty, and this is definitely true of fish farming. Fish farming is a risky business, and to some extent the companies involved manage risk by size and diversification so that localised catastrophes, such as heavy losses caused by an epizootic disease or bad weather, do not wipe out the firm. Fortunately these risks are declining with maturation of the industry and better procedures for dealing with known risk factors, but they are still present. Since fish farmers and mariculture firms are independent businessmen, how they handle risk is their choice, and while external agencies such as governments may be able to provide advice, the final decisions about internal operations are up to the industry. However, the impacts that mariculture might have on the environment are a matter of public concern and need to be addressed in the design of Expert Systems.

There are several sources of uncertainty in the complex models used in assessing and predicting the environmental interactions associated with mariculture. Uncertainty in scientifically measured parameter values should be the easiest to deal with, since responsible researchers should assign confidence regions to all measurements, and Expert Systems should be designed to accept ranges (rather than point estimates) as inputs and to carry out propagation of error analyses so that their outputs also are expressed in terms of confidence intervals. Unfortunately this attention to proper measurement protocol is not always followed, but developers and users of Expert Systems should make it clear to the scientists who provide the underlying data that they need to provide information on how uncertain their data are.

There are further uncertainties that arise from stochastic processes in the environment which are more difficult to deal with, although they can usually be estimated from historical data. Such processes include weather (storms, temperature fluctuations) as well as less predictable events associated with disease and the occurrence of parasites. These kinds of uncertainties add to the risk and are difficult to avoid.

There are however additional uncertainties that may reflect bias in the data, and these uncertainties — whether real or perceived — can be a cause of distrust and dissension. Some stakeholders may question information provided by other stakeholders and may want to have the flexibility to adjust the inputs to fit their own estimates. This can happen if, for example, coastal residents or an NGO suspect that a fish farmer is exceeding his licensed production capacity or using prohibited pharmaceuticals, and they may want to see what the effects would be if this is the case. In such a situation it is important that users of the Expert System have a high degree of flexibility in how they treat the data, including freedom to change any input values that they consider questionable.

An important initiative is the work of GESAMP WG 31 on Environmental Risk Assessment and Communication in Coastal Aquaculture. GESAMP Working Group 31 on Environmental Impacts of Coastal Aquaculture has been charged with the task of producing a review report and guidelines for risk assessment of coastal aquaculture, aimed at promoting harmonisation and consistency in the treatment of risk and uncertainty, and improved risk communication (Hambrey and Southall, 2002). This will have major implications for the future work of WGEIM.

The 3-M Strategy

Management of mariculture can be thought of in terms of three M words — Modelling, Monitoring and Mitigation. Modelling is essential to the planning process and implies prediction of the probable environmental interactions of any proposed development before implementation. These predictions must be confirmed by ongoing Monitoring once the project is under way, and there must be a Mitigation plan in place to deal with the risk of adverse unforeseen consequences.

It is important to stress the importance of good data in mariculture management. Not only is it vital to base the modelling on the best possible data, but it is often difficult to carry out meaningful monitoring unless there are good baseline data on conditions before the site is developed and a good time series that can be used to diagnose impact values that exceed reasonable thresholds. Furthermore it is essential that data be kept up-to-date.

However, one must also recognise that in many cases the data are not as good as could be desired, and there must be a strategy in place to deal with this. For example, there are many farms already in existence for which baseline data do not exist. In these cases one must try to find surrogate data, such as measurements at control sites or the use of transects showing the dispersion of effluents.

Environmental Impact Assessment

In many countries any major mariculture development requires both licensing from the relevant regulatory agency (usually the Department of Fisheries) and an Environmental Impact Assessment (EIA) for the Department of the Environment. This double hurdle adds to the start-up expense and increases the risk that after a lengthy and expensive submission, the application may be rejected. One important way in which a DSS can be used is for preparation of license applications in conjunction with EIA submissions. Since the applicant has access to the same programs that will be used in the evaluation of the application, it is possible to obtain an unofficial preliminary evaluation that can be used in planning. For example, if the Estimated Site Potential (ESP) calculated for the site is less than what the applicant intends, he can re-evaluate the proposal and either investigate a different site or consider reducing the size of the proposed farm.

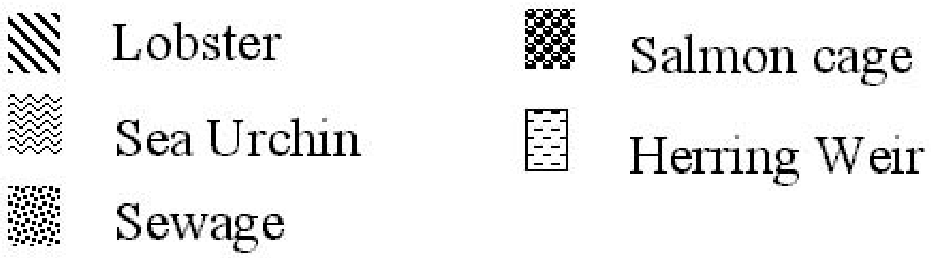
Geographical Information Systems

Geographical Information Systems (GIS) can be a powerful, versatile and comprehensive visual tool in any decision support system for Integrated Coastal Zone Management (ICZM). The following discussion focuses on the utility of GIS in a DSS for mariculture in the context of ICZM.

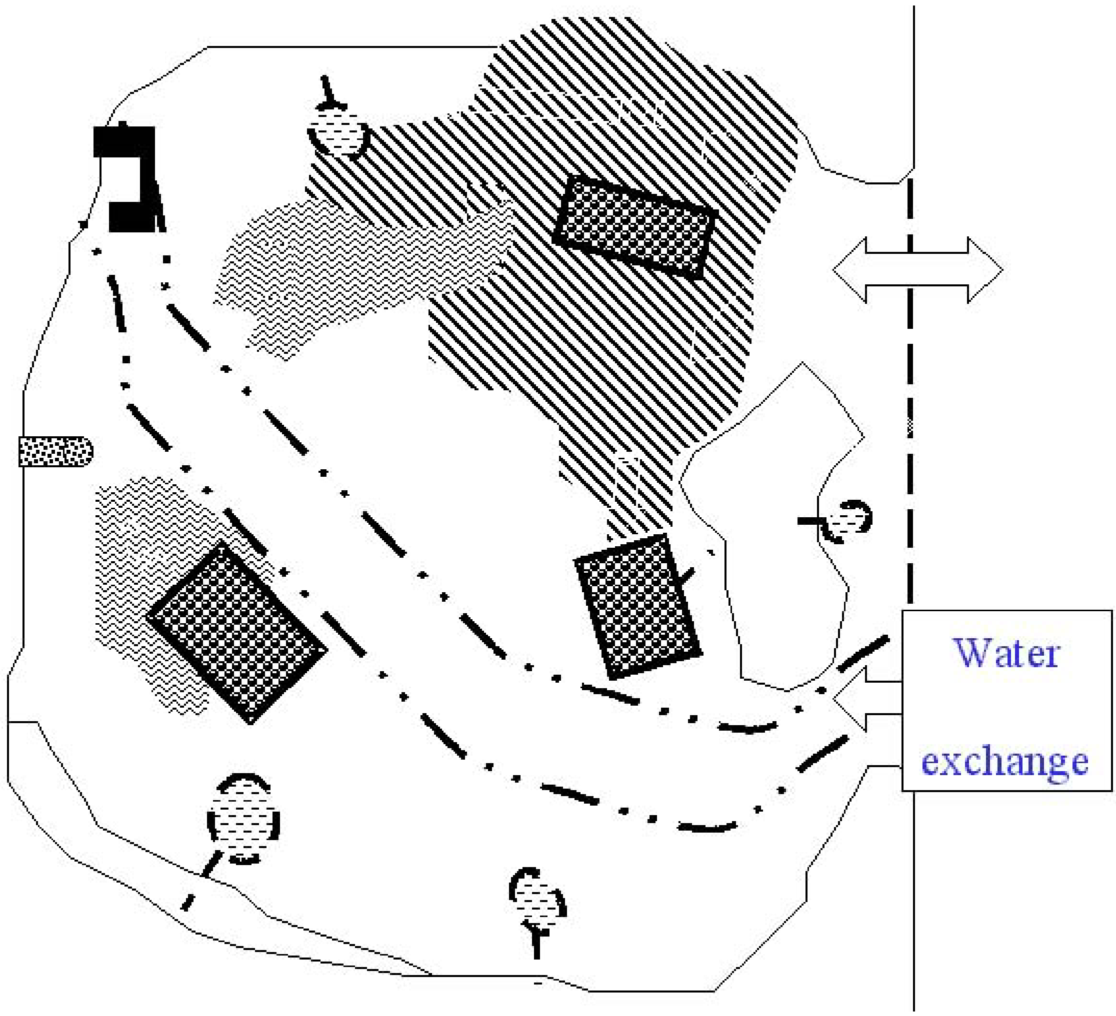
These geographical databases consist of digital maps that are made up of layers, where each layer represents different levels of detail or different kinds of features. Existing databases generally have large amount of physical geographical information such as maps and survey data that are geo-referenced. For example, the GIS databases of Scotland, Norway and the province of New Brunswick, Canada, are extensive and available to registered users. The complete database can exist in one central location (server) or it can be installed on a network of different systems.

The information can be retrieved, analysed and modified by software of varying capabilities and ease of use. Generally the more powerful the software the more training is required to use it, which means that more effort must go into developing a user-friendly interface. MapInfo is frequently used but requires extensive training. Other programmes such as STEM™ and CARIS™ are more "user friendly" but have lower resolution.

After preparing a map of the study area, other information can be incorporated into the display by superposing additional layers. For example, the spatial and temporal extent of human activities, chemical and water quality criteria, and natural resources (spawning grounds, herring weirs, fish migration pathways, lobster grounds, sewage effluent, dispersal plumes, etc.) can be represented in any combination. Thus the presence and magnitude of spatial and temporal overlaps in combinations of activities and/or resources can be displayed as in the figure below for a Potential Bay Scale Operational Plan and can be used to indicate whether a site is likely to be acceptable or contraindicated for mariculture. There is a set of layers indicating various activities as follows:



which can be superposed on a base diagram of the Bay to generate a figure like the following:



While it is clear that GIS can be a valuable tool for management of mariculture, especially in the context of ICZM, there is a need for guidelines to ensure proper use.

- The quality and permanence of data must be identified by the use of metadata (data about data) which specify the provenance of data along with information about their reliability.
- Proprietary data must be securely maintained so that access to it and also modification of the metadata are restricted.
- Maintenance of GIS databases is mandatory and is a significant task — for example, subsequent dredging or siltation may compromise old data on bathymetry, and tidal flows can be affected by construction.
- Since most GIS programs involve expensive software and powerful computers, providing good public access to the information is difficult. Web-based readers may be the best solution, and some GIS packages now support this approach (although often at a loss of resolution). This method has the advantage that layers that contain proprietary data can be omitted from the web version and can be accessed only on secure computers. Alternatively, confidential data can be protected by password-based access methods.

Data, Metadata and Knowledge

Ultimately any Expert System is based on scientific information, which may be of different kinds. Often we think of science as producing simply data, numbers which are interpreted as the ultimate truth. It is increasingly appreciated that there can be problems with data — it may be old, it may be incomplete, it may be unreliable. A ship that is navigated by an outdated chart may be stranded on an undocumented wreck. Therefore it is essential that the database on which an Expert System is based must be reliable and fully documented.

The concept of "metadata" addresses this need — metadata are data about data, meaning information about the provenance, reliability, age, and other relevant factors about data. The concept is actually quite old, although the term is relatively new. For example, nautical charts are annotated with this sort of information, and a sailor who is navigating with one of Captain Cook's 18th century Admiralty charts knows that it may not be as reliable as a new one. The inclusion of metadata in an Expert System also improves the transparency of the methodology, as users who question the validity of the results can review not only the analytical process but also the quality of the data that go into it.

Knowledge is another concept that is gaining respect in a scientific community which is increasingly recognising that not everything can be expressed in numbers. The field called "Knowledge Engineering" is relatively new, but is gradually gaining recognition. It is likely that it will play a role in the future development of Expert Systems. For example, in some regions it has been observed that the productivity of fish farms in some areas decreases over time, even though it is not possible to ascribe this to any documented causes. Fish farmers in these regions use this knowledge and follow a practice of rotating sites every few years. There is no reason why this knowledge cannot be incorporated in an Expert System. A methodology for doing this, namely the use of rule-based systems, is described in the next section.

Rule-Based Systems

While this report is not intended to go into the details of Expert System design, it should be noted that many of these are *rule-based*, meaning that they are formulated in terms of IF…THEN sets of rules.

Often the rules are simply expressions of existing regulatory policy. For example, a legal requirement that new farms must be at least 2 km from existing sites could be expressed as the rule, "IF distance to nearest site < 2 km THEN reject application." This can greatly simplify the development of Expert Systems, although of course many rules are far more complicated than this.

There is growing interest in the development of fuzzy rule-based systems, which permit the introduction of factors which are difficult or impossible to quantify, but which in practice are often taken into account. Some of these fuzzy factors are technical ones for which there are no clear-cut definitions, such as depositional vs. erosional sites on the seabed, while others represent subjective assessments about recreational potential and natural beauty (Angel *et al.* 1998; Silvert, 2000). Fuzzy rules are similar to precise rules, and often a fuzzy rule such as "IF the risk of super-chill is high THEN …" is much clearer and really no less informative than a rule which sounds more objective like "IF the frequency of temperatures less than -1.7° for more than 30 min. is greater than once every 5 years THEN …".

SimCoast™ (McGlade, 1997) is a fuzzy logic rule-based expert system in which a methodology called issue analysis has been incorporated to produce a soft intelligence system for multi-objective decision-making, and it has been applied to several aspects of ICZM. Several similar programs and approaches have been described by Rosenthal (2001). Expert System design is a rapidly developing field, and there is a wide choice of programs available for implementation.

One of the main advantages of rule-based systems is that they easily avoid the linear assumptions that are implicit in many other approaches, especially those based on multi-variate statistical methods. A rule can express a non-linear condition such as "IF ammonia output is excessive THEN …" much more easily than a more mathematical formulation based on assigning a cost function to the ammonia level.

Perhaps the greatest advantage of rule-based systems is their transparency, since each rule can be expressed in comprehensible language that can be understood and discussed by the stakeholders.

Traffic Light Methods

Some of the reports reviewed by WGEIM deal with ways of representing the results of complex decision support systems in ways that can easily be understood by managers, fish farmers, the general public and other non-scientists. Several projects have investigated the use of "traffic lights", colour-coded displays which use some variant of the traditional red-yellow-green traffic light coding to provide *yes*, *no* or *maybe* answers to management queries. The major objection to the use of traffic lights is that they are too coarse for practical use, so various variants have been developed to provide more subtle shades of meaning, such as the use of more than three colours or different types of "fuzzy" traffic lights (Hargrave, 2002).

Traffic lights can often be used in conjunction with more complex displays as an aid to understanding (Halliday *et al.,* 2001). For example, in one prototype system it is possible to adjust the production level of a site with a slider and read the calculated benthic carbon loading (BCL) under the cages, while simultaneously an indicator changes colour to show whether the BCL is acceptable, borderline, or excessive.

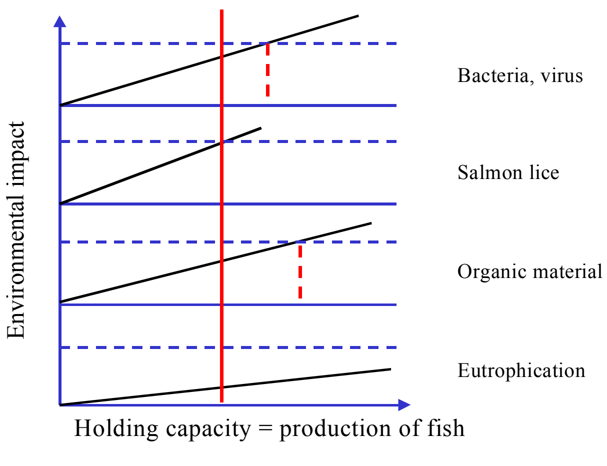
A General Approach to Site-Specific Monitoring and Management

One of the challenges in developing a general strategy for management of the environmental interactions of mariculture is that each area is unique and may have its own set of potential environmental limitations. In some cases, such as at parts of the seabed where sediment accumulates, the most important effects are due to benthic deposition, while in others, such as the Baltic, eutrophication is the major concern—in other cases it may be turbidity and other consequences of the release of fine particulates.

Disease transmission is usually an important concern, but may not be an issue if a farm is in an isolated location. Genetic interactions with wild stocks due to the escape of farmed fish are a major problem, as such impact is deemed irreversible.

However, the cumulative effect of potentially important impacts from multiple mariculture operations within one area must be included in Area-Specific Management. This leads to problems of scale, as relating the environmental interactions of individual farms to the overall impact on an entire bay or estuary can be complex. One way to deal with this is by using a comprehensive list of all potential impacts and ranking them by how serious each is at any particular site. This could be achieved with traffic lights, but an alternative more comprehensive approach is to represent the degree of risk associated with each interaction in a graphical manner that reflects both the actual effect level and its sensitivity to changes in the strength of the interaction.

This figure shows a sample set of plots representing the degree of environmental impact as a function of fish production in a hypothetical area (Ervik *et al.,* 2003). The horizontal dashed lines represent the threshold for acceptable impacts, and the vertical dashed lines indicate the production level at which the relevant threshold is reached. From this we see



that the factor which limits fish production at this site is salmon lice. The threshold level for microbes is slightly higher, release of organic material is a bit above that, and eutrophication would not be an issue unless production were much higher than the limits imposed by the other factors. To increase the holding capacity of the area, more efficient delousing would have to be undertaken to lower the slope of the line relating fish production to the environmental significance of salmon lice. The graphical representation is easily understood, and since it can easily be generated by a computer program it is a reasonable kind of output for an Expert System. However, it requires that the variables be quantifiable, and in many cases must be supplemented by other indicators such as traffic lights.

Scale Issues

There are important issues of scale involved with consideration of mariculture interactions. Some concerns, such as the self-effects of a farm on itself, can be evaluated on a very small spatial scale. Others, such as the possibility of eutrophication of an entire inlet, involve larger spatial scales (Silvert, 1994).

Similarly there are factors that operate on very different temporal scales. Some of these are environmental in nature, ranging from the possibility of oxygen stress during a short period of stagnant water at low tide to the years that it can take for the seabed to recover from excessive carbon deposition (Sowles *et al.,* 1994). Many of the stakeholders have economic concerns that can be characterised by their "discount rate", which is the term used by economists to reflect how different stakeholders view future costs and benefits. For a small-scale farmer with a family to feed and consequently a short-term outlook, the discount rate is high, meaning that promises of financial rewards several years down the road mean little and are heavily discounted. A well-financed industrial operation which is looking for a good return on its capital investment can afford to take a more long-term view with a discount rate that reflects the costs of borrowing money, while conservation groups and other NGOs tend to take the long view and think of the indefinite future, with a "social discount rate" approaching zero.

An example of a management scheme which has recently been developed is the Bay Management Scheme in the Bay of Fundy which was introduced to combat the spread of disease and mitigate the effects of sea lice treatment with pesticides by using the bath methodology. Each Bay Management Area (BMA) is intended to hold only one year class of stock. Treatments for sea lice are to be conducted simultaneously at all sites within each BMA. Based on evaluation of physical oceanographic characteristics, the division of the main salmon mariculture areas in south-west New Brunswick, Canada, into four was recommended, each of which would be approximately 3 km in radius. However, after consideration of management implications of this policy, this area was divided into 21 Bay Management Areas.

The Limits of Decision Support

Decision Support tools are attractive, and in some cases it appears that they may even be too attractive — there are cases where prototype systems based on hypothetical data have been misunderstood and implemented prematurely by hard-pressed bureaucrats. There are limitations to their use, and these need to be understood.

The most important single point to raise is that Decisions Support is not the same thing as Decision-Making. The human element cannot be removed from the Decision Making process, and any attempts to do so will almost certainly fail.

There are several reasons for this. The main reason is that human decisions inevitably include parameters that no one will enter into a computer program. For example, no politician will ever admit that one of his chief concerns is re-election, but this will inevitably affect his decisions. Even though decisions about mariculture need to be made in the broader context of ICZM, this does not ensure that all interactions are included, and it is not possible to circumscribe the scope of considerations that might ultimately arise.

The scope of Decisions Support is limited, and pragmatic solutions to environmental problems often go far beyond what can reasonably be included in a DSS. For example, some major environmental crises have ultimately been resolved by drastic measures such as compensation and even relocation of affected individuals — such extreme cases cannot be built into the structure of a DSS. If DSS are to prove useful, it must be possible to use them as a starting point rather than a final answer. The part of the process that a DSS encompasses must be transparent and dynamic so that whatever advice it generates can be extended and applied. A "black box" whose workings are hidden and whose output is cryptic will ultimately never be accepted.

Acronyms used

The following list identifies the acronyms used in this report:

BMA Bay Management Area

BOD Biological Oxygen Demand

DSS Decision Support System

EIA Environmental Impact Assessment

ESP Estimated Site Potential

GIS Geographical Information System

ICZM Integrated Coastal Zone Management

NGO Non-Governmental Organisation

WG Working Group

WGEIM Working Group on Environmental Interactions on Mariculture

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ANNEX 8: RECOMMENDATIONS

1. The WG approved the draft technical report on "Chemicals used in Mariculture" and recommends that the report be passed to ACME for publication in the *ICES Cooperative Research Report* series.

Justification:

The use of chemicals as therapeutants, disinfectants, etc., in mariculture remains of significant concern to the industry, regulators, and the public. This second edition of *ICES Cooperative Research Report* No. 202 brings the report up to date, and should prove to be a valuable reference work. The update was overdue as chemicals and regulations have drastically changed during the past few years and requests for current information on the use of chemicals have been from industry, regulatory agencies, and NGOs. The report includes detailed technical information concerning the chemicals used, their specific purposes, and references to environmental implications of their use. In particular, the report discusses in detail the significance to the environment of the use of antibiotics, and makes observations on changes in the pattern of use of antibiotics and sea lice control treatments as national fish cultivation industries mature.

2. WGEIM requests that the ACME seeks the advice of the Mariculture Committee in proposing to the Council a theme session at the 2004 Annual Science Conference on the integration of "Mariculture in Integrated Coastal Zone Management Systems", to be co-chaired by Edward Black (Chair WGEIM) and (Chair Josianne Støttrup, Study Group on Integrated Coastal Zone Management).

Justification:

In response to increasing pressure on the environment by coastal populations, the Water Framework Directive in Europe and policies promoting integrated ecosystem management in North America will put an enhanced emphasis on water quality standards in marine and transitional waters. With increased and new types of activity, the mix of coastal resource use is expanding. Aquaculture activities not only act as a contributor to these changes but also are affected by those changes. As a continuous biological monitor of environmental quality, aquaculture can play an important role in the development of integrated coastal zone management plans. The WGEIM has extended expertise on board on the subject since it organised at an early date (1995) the first ICES Workshop on Integrated Coastal Zone Management. This theme session will explore some of the needs of aquaculture that must be incorporated into developing schemes for integrated coastal zone management.

3. That MARC advises ACME of the proposal from WGEIM to work towards the preparation of an *ICES Cooperative Research Report* on "**risk assessment and management strategies for controlling the impacts of escaped non-salmonid species on native stocks**", and seek approval for the publication after finalising the document at the WGEIM meeting in 2004.

Justification:

The Working Group is generating a unique and comprehensive summary of the available literature on the subject that would benefit a wider audience than the ICES community. There is a need to prepare a critical review of information on the effects and management of escaped and released mariculture species on wild populations. While sporadic events of escapement are carefully monitored in a few cases, much can be learned from long-term experience of deliberate stocking not only with salmonids but also from other fishery enhancement practices. Incorporation of information from a broader range of marine species and a comprehensive consideration of the finding of extensive work undertaken by EIFAC on stock enhancement and release in large water bodies would provide substantial insights in concepts and principles of interactions with conspecifics and with species at various trophic levels. The comparative analysis represents a significant new opportunity for conceptualising criteria towards a better understanding of risk assessment methodologies for potential species and trophic interactions.

4. That MARC advises ACME of the proposal from WGEIM to hold a joint workshop with CSIEM to share the Mediterranean experience on methods to monitor the interactions between non-salmonid finfish aquaculture and natural stocks of con+specifics.

Justification:

There is need to develop simple and cost-effective tools to discriminate between cultured and wild stocks of the same species (e.g., seabass, seabream, lobster, shellfish) in order to enable better assessments of the true interactions.

Techniques to be discussed might include Sr/Ca ratio in studies as a potential tool to discriminate cultured specimens which have been raised in brackish/freshwater environments and released to seawater habitats while con-specific natural specimens have been exposed all their life to seawater. Also, genetic tools (microsatellites, mitochondrial DNA) might be discussed in terms of effective use as these methods are at present very costly and need substantial improvement to be more widely used.

5. That the parent committee request ACME to contact the European Environment Directorate (EED) to invite participation of a delegate to this Working Group.

Justification:

The Working Group feels that it would benefit from the expertise available in the EED and that the recommendations from the Working Group would be better informed and more pertinent to the rapidly evolving European Regulatory Environment policies if the EED had direct input to the WG's activities.

6. That MARC/ACME recommend that the **Working Group on Environmental Interactions of Mariculture** [WGEIM] (Chair: E. Black, Canada) meet in late March 2004 in Galway, Ireland, to:

a) receive, and prepare comments on, a report of a Workshop to be organised jointly by the Xunta de Galicia and the Instituto Español de Oceanografia in 2003 on stock enhancement in the Galician rias;
b) continue to monitor and review the progress of the implementation of the Water Framework Directive, and activities arising from the European Commission policy on sustainable aquaculture, and to report on developments;
c) continue preparation of a review of the potential impacts of escaped non-salmonid candidates for aquaculture on localized native stocks in order to develop, at an early stage, risk assessment and management strategies;
d) continue formulation of a strategy to protect aquaculture against the harmful effects of external influences (e.g., contaminants, habitat alterations) arising from other resource users and their environmental impacts, with the aim of gaining better cooperation in developing modern tools to prevent or mitigate negative interactions;
e) continue preparation of a report on an evaluation of existing Decision Support System (DSS) tools, GIS and other expert systems in order to derive strategic advice on the content of a DSS for mariculture, and also to identify potential linkages to existing tools presently being developed, tested or already used in coastal management schemes;
f) hold a joint session with GESAMP WG 31, to discuss risk assessment methods in relation to mariculture.

Justifications:

Priority:	WGEIM is of fundamental importance to ICES.
Scientific Justification:	a) The rias of Galicia are the most important area for the production of farmed shellfish in western Europe. However, the very heavy reliance on mollusc (mussel, oyster, etc.) cultivation has resulted in large numbers of small businesses, which comprise the bulk of the industry, being vulnerable to external factors such as harmful algal blooms, climate change, market forces, etc., which are outside their control. There is therefore considerable interest in Galicia in both diversification and expansion of the industry. Similar pressures applying elsewhere in European aquaculture, for example the heavy reliance on salmon in Scotland and Norway, have similarly led to moves towards diversification. The purpose of the review is to assess the approach taken to resource allocation and prioritisation of species/techniques for development, which must balance environmental, technological, social, and economic factors. The workshop report will also contribute to the continuing WGEIM task to report on the potential impact of escaped (stocked) organisms on localized native stocks. b) The EC policy on Sustainable Aquaculture sets a new context for the aquaculture industry in the EU. It holds out the possibility, among other things,

	that Integrated Coastal Zone Management will become the normal approach to the management of the aquaculture development, and that new tools and processes will arise from the new policy. The Water Framework Directive will determine the direction of water quality regulation and improvement in the EU over the next 10–20 years. The coincidence of major new policy initiatives in both industrial development strategy and environmental quality presents European aquaculture with a unique set of opportunities and risks. c) In order to foster a sustainable development of coastal and marine aquaculture, there is a need to diversify production and to cultivate new species. A pro-active approach is required to avoid mistakes made previously when salmonid farming was developing. Mitigation strategies based on sound scientific criteria in relation to the species under consideration need to be prepared at an early stage of development. Studies would have to consider the status of the natural stocks in the area, the potential genetic, trophic and behavioural interactions, and, foremost and specifically, the development of methods for recovery of escaped fish in the event of large-scale escapements. This subject seems to be of particular importance for non-migratory fish stocks with small, localized populations (e.g., sea bass and seabream), or migratory species with different migratory patterns than salmonids (e.g., cod, halibut, turbot, and wolffish and other species). *d)* External influences are increasingly recognised as risk vectors for aquaculture. For example, with the continued globalisation of markets, shipping is gaining importance worldwide and already today transports about 80 % of the world's cargo. Ships are becoming larger and so are ballast water volumes. There are increasing reports of the transport of viable, and potentially harmful, species in ballast waters, and also documented instances of the establishment of populations of harmful exotic organisms and pathogens. The participation of stakeholders permits timely input of practice-oriented views on the strategies proposed for the finalisation of the draft discussion report in order to edit the document for potential publication in the *ICES Cooperative Research Report Series* e) A number of technologies and support systems are presently under development, some of which have been outlined in the WGEIM 2002 Report. These should be evaluated and compared, with the aim to prepare a review publication on the requirements for a DSS system tailored to the needs of mariculture. The review should take account of the call in the EC policy on sustainable aquaculture for more widespread use of ICZM processes in relation to aquaculture developments. f) The ICES WGEIM would greatly benefit from inputs of the GESAMP WG31 because risk assessment methodologies have not yet been addressed in its previous meetings. A critical factor in the evaluation of risks and the definition of risk management options for member states to control the potential interactions between wild and cultured aquatic organisms is an understanding of the structure of population units of evolutionary significance. With the development of culture activities for these species, there now is a need to invest in studies on stock discrimination for sea bass and seabream in coastal habitats of ICES member countries. This will enable better management of existing resources and allow integration of aquaculture into the existing mix of coastal resource users for member states.