REPORTS AND STUDIES No. 68

IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP
Joint Group of Experts on the
Scientific Aspects of Marine Environmental Protection
(GESAMP)

PLANNING AND MANAGEMENT

FOR

SUSTAINABLE COASTAL AQUACULTURE DEVELOPMENT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 2001

NOTES

1. GESAMP is an advisory body consisting of specialized experts nominated by the Sponsoring Agencies (IMO, FAO, UNESCO-IOC, WMO, WHO, IAEA, UN, UNEP). Its principal task is to provide scientific advice concerning the prevention, reduction and control of the degradation of the marine environment to the Sponsoring Agencies.

2. This study is available in English only from any of the Sponsoring Agencies.

3. The report contains views expressed by members of GESAMP who act in their individual capacities; their views may not necessarily correspond with those of the Sponsoring Agencies.

4. Permission may be granted by any one of the Sponsoring Agencies for the report to be wholly or partly reproduced in publications by any individual who is not a staff member of a Sponsoring Agency of GESAMP, or by any organization that is not a sponsor of GESAMP, provided that the source of the extract and the condition mentioned in 3 above are indicated.

5. Information about GESAMP and its reports and studies can be found at :

   http://gesamp.imo.org/
   http://gesamp.imo.org/publicat.htm
   http://www.fao.org/fi/publ/ficatpub/report/gesamp.asp

Cover photo : Shrimp aquaculture ponds in Mexico.
Courtesy of Mr José Aguilar-Manjarrez, Fisheries Department, FAO, Rome.

ISBN 92-5-104634-4
ISSN 1020-4873

For bibliographic purposes, this document should be cited as:

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 2001. Planning and management for sustainable coastal aquaculture development. Rep.Stud.GESAMP, (68): 90 p.

PREPARATION OF THIS STUDY

This report is based on a review of literature and experience relating to the integration of aquaculture into coastal area management. It is divided into two parts:

1. **Guidelines**, designed for both policy makers and technical specialists, which provides broad guidance on the principles and practice of more integrated planning to promote sustainable coastal aquaculture development;
2. **Tools**, designed primarily for scientists and technical specialists, or those closely associated with aquaculture development, which provides a more detailed scientific review of the tools and methods which can be used to facilitate and inform the planning process.

The Guidelines (Part 1) are “stand alone” and can be read by policy makers, planners and stakeholders without reference to Part 2. The guidance is necessarily general: the most effective approaches will vary significantly between locations. Our review of planning approaches world-wide revealed no models that were simple, effective and widely applicable. However, we were able to identify broadly agreed principles, and a common framework for more integrated approaches. The procedures and tools which can be used in support of better planning are also introduced in Part 1, with some discussion of their application, strengths and weaknesses.

Part 2 (Tools) should be read in conjunction with Part 1, since the latter provides the context and rationale for the former. The most important tools and methods that can be used to facilitate more integrated planning are reviewed, particularly as they relate to aquaculture. It was beyond the scope of this report to review all these tools in detail, and emphasis was therefore placed on those that have been applied in practice to aquaculture development planning. Where appropriate the reader is directed to other more comprehensive reviews and guidelines.

This report should not be considered a simple tool box. The complexity of the issues, and the variety of circumstances, precludes a standardised approach. Instead, the report provides realistic advice based on practical experience made in the field of planning of coastal aquaculture development and integrated coastal management throughout the world. Practitioners are encouraged to select, modify and continuously adapt their own approaches and tools to specific circumstances. The report calls for pragmatic, systematic and flexible planning and management efforts, which may need to be supported with patience, endurance and adequate funding, for the benefit of sustainable aquaculture development in coastal areas.

This document is an output from Working Group 31 of GESAMP, which met in Bangkok, Thailand, from 1-5 December 1997. Contributions to the work of the Working Group by the following experts are acknowledged with appreciation: John Hambrey (Chair), Piamsak Menasveta, Don Morrisey, Arthur Neiland, Ong Jin-Eong, Michael Phillips, John Radull, Marguerite Rasolofo, Peter Saenger, Siri Tookwinas, and Uwe Barg (Secretariat). The Working Group prepared the document “Integration of Aquaculture into Coastal Management" (GESAMP/XXVIII/5 and XXVIII/5.1). Valuable comments and suggestions on the draft study were received from Malcolm Beveridge, Dan Fegan, James Tobey and Rolf Willmann. The document was presented to the 28th Session of GESAMP in Geneva, 1998, and to the 29th Session in London, 1999, (as GESAMP/XXIX/5) for discussion and comments. The final version was endorsed at the 30th Session of GESAMP held in Monaco, 22-26 May 2000.

The report complements previous Reports and Studies by GESAMP which focus on the environmental impacts of coastal aquaculture and coastal management issues. They include: **Environmental Capacity:** an Approach to Marine Pollution Prevention (1986); **Global Strategies for Marine Environmental Protection** (1991). **Reducing Environmental Impacts of Coastal Aquaculture** (1991); **Biological Indicators and their Use in the Measurement of the Condition of the Marine Environment** (1995); **Monitoring the Ecological Effects of Coastal Aquaculture Wastes** (1996); **The Contributions of Science to Integrated Coastal Management** (1996), and **Towards Safe and Effective Use of Chemicals in Coastal Aquaculture** (1997). The work of the Working Group was jointly sponsored by the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Educational, Scientific and Cultural Organization of the United Nations - Intergovernmental Oceanographic Commission (UNESCO-IOC), the World Health Organization (WHO) and the IUCN-The World Conservation Union. The Secretariat was provided by FAO.

ABSTRACT

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 2001. Planning and management for sustainable coastal aquaculture development. Rep.Stud.GESAMP, (68): 90 p.

The coastal zone is characterized by ambiguities of resource ownership, and complex interactions between resources, ecosystems and resource users. It has been widely recognised that to address these complexities, and to promote sustainable development in the coastal zone, a more integrated approach is needed, ideally within the framework of Integrated Coastal Management (ICM).

The rationale for more integrated approaches to aquaculture development is powerful: coastal aquaculture has brought significant economic and employment benefits to both national economies and coastal people throughout the world; aquaculture is highly vulnerable to pollution caused by other resource users; if poorly designed or managed it may cause pollution or the spread of disease; its impacts are often limited but incremental and cumulative; and it often takes place in areas where resource ownership or use rights are ill defined and ambiguous. Efforts to integrate aquaculture into coastal management can contribute to improvements in selection, protection and allocation of sites and other resources for existing and future aquaculture developments.

This report is based on a review of literature and experience relating to the planning and management of aquaculture development and its integration into coastal area management. It explores in detail how more planned and integrated approaches can be applied to aquaculture development. These approaches range from “enhanced sectoral” initiatives, to incorporation within comprehensive ICM programmes.

No simple, effective, and widely applicable models have been identified. The most appropriate approach will depend upon a wide range of local factors, including available skills and resources, the urgency of the problems or opportunities, and the nature of existing planning and development frameworks. The less comprehensive approaches may be the only realistic option in some situations, but should be seen as a starting point for, and stimulus to, more comprehensive ICM. These approaches should contribute to more systematic planning and improved management of individual aquaculture operations, as well as to the coastal aquaculture sector as a whole.

Key words: Aquaculture Development, Planning, Coastal Management, Sustainable Development

CONTENTS

EXECUTIVE SUMMARY

Background and rationale

1. Aquaculture production is growing at more than 10% per year, compared with 3% for terrestrial livestock and 1.5 % for capture fisheries. This growth is expected to continue. Asian aquaculture farmers continue to contribute about 90% of the world's aquaculture production, and more than 80% of total aquaculture yield is being produced in low-income food-deficit countries (LIFDCs).

2. Coastal aquaculture is dominated by the production of aquatic plants (seaweeds) and molluscs. However, a wide range of diverse coastal aquaculture systems has been developed in Asia, Europe, and the Americas, operating at different intensities and scales of production.

3. Aquaculture has great potential for the production of food, alleviation of poverty and generation of wealth for people living in coastal areas, many of whom are among the poorest in the world. The rapid growth of aquaculture in recent years has been consistent across sub-sectors, from low-input systems generating low value products of importance for subsistence and direct food security, to medium and high value products for national and international markets, which are important for improved living standards and foreign currency earning. The great diversity of the sector encompasses very small scale to very large-scale enterprise, implying that aquaculture can contribute significantly to a wide range of development needs.

4. However, significant problems can be associated with coastal aquaculture development. These include unsuccessful development, where the potential for development is not realised, especially among the poorer sectors of society; the vulnerability of aquaculture to poor water quality and aquatic pollution, caused by industrial, domestic, agricultural and aquacultural (i.e. its own) wastes; and over-rapid development, where the undoubted successes of the sector have been tarnished by environmental and resource use issues, social problems, disease, and in some cases, marketing problems.

5. Although some of the social and environmental problems may be addressed at the individual farm level, most are *cumulative* – insignificant when an individual farm is considered, but potentially highly significant in relation to the whole sector. They are also *additive* – in the sense that they may add to the many other development pressures in the coastal zone.

6. These cumulative and additive problems can only be addressed through better planning and management of the sector - by government, in collaboration with producer associations or industry organisations. A precondition for better and more effective planning is also better organisation and representation of the sector.

7. Crucial elements in a more planned approach include:

   - improvements in siting, design, technology, and management at the farm level;
   - better location and spatial distribution of the sector as a whole;
   - better water supply for the sector as a whole;
   - better fish health management including disease and stock control at individual farm and sector levels;
   - improved communication and information exchange;
   - improved access to markets and trade opportunities;
   - more equitable distribution of the benefits derived from coastal aquaculture development.

8. In practice many of these are unlikely to be achieved without effective integration with planning and management of other sectors. The framework normally proposed to achieve this is integrated coastal management (ICM).

Review of experience

9. Some investors have responded to the problems associated with coastal aquaculture through more rigorous project appraisal. Governments have responded mainly with specific regulations relating to farm operation (such as effluent limits, design standards, best management practices,

and codes of conduct). In some cases they have responded with more rigorous requirements for social and environmental impact assessment.

10. These farm level measures have often been ineffective. Promotion of environmental assessment in particular has failed to address the problem of over-rapid and unplanned development of aquaculture in some countries. There are two reasons for this. Firstly, as noted above, the impacts associated with aquaculture are often insignificant when a farm is considered in isolation. Secondly, in the absence of any broadly agreed environmental quality standards, assessments of the significance of impacts have been highly subjective and inconsistent.

11. A range of more comprehensive approaches to coastal resources management have been proposed as frameworks for addressing the wider issues of sustainable coastal resource use, the minimisation of conflict, and the optimal allocation of resources including in particular land and water. These range from sector related environmental planning and management initiatives (enhanced sector planning) to more ambitious integrated coastal management (ICM) programmes.

12. There have been two main types of enhanced sectoral initiative for coastal aquaculture. The first has used geographic information systems (GIS) and remote sensing as the basis for defining suitable locations or zones for aquaculture. The second has focused on estimates of environmental capacity in order to define appropriate scale and location for sustainable aquaculture development. Both offer a useful practical focus for more integrated planning initiatives. Unfortunately, these initiatives have often failed to translate the findings into practical incentives and constraints to promote more sustainable development. This failure points to the need for broader and more integrated planning frameworks.

13. There are many examples of more integrated coastal zone management (CZM) or integrated coastal management (ICM) initiatives, some of which have encompassed aquaculture. The objectives of such initiatives typically include: the optimal allocation of resources to competing activities or functions; the resolution or minimisation of conflict; the minimisation of environmental impact; and the conservation of natural resources. Given the problems listed above, it is clear that they have great relevance to aquaculture.

14. Unfortunately the performance of regional or national level ICM initiatives has been disappointing in practice, particularly in relation to aquaculture. This is related to the complexity of the process, the difficulties associated with significant institutional and legal changes, and the time and cost involved. For example, the problems associated with shrimp farm development have arisen mainly when it has developed rapidly and uncontrollably in developing countries. Some major ICM initiatives have failed to respond with the rapidity required.

15. In these circumstances, more locally focused initiatives (e.g. relating to an estuary or lagoon system) may offer the most practical starting point, and are likely to lead to the identification of specific needs in terms of greater vertical integration (i.e. with higher level policy or legislation).

16. In other situations, where the nature of the resources or existing resource management systems precludes more locally based initiatives, enhanced sectoral approaches may be the most appropriate. However, the lack of effective mechanisms for implementation has often been a weakness of such approaches, and requires particular attention.

17. More comprehensive ICM may be effective as a starting point where coastal aquaculture is in the early stages of development, where institutions for resource management are flexible or un-developed, where appropriate legal and institutional frameworks are in place or can be developed rapidly, and where scientific and technical capacity is substantial.

Guiding principles

18. Despite this lack of a universal model, it is possible to present a set of widely agreed guiding principles which may be applied whatever the administrative level or scope of the planning initiative.

19. The first is the requirement for a clear planning objective. In broad terms, this would normally be *to promote or facilitate sustainable development*. Although there are many definitions and more interpretations, the most widely quoted and agreed, is: *"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (*Brundtland Report*; WCED, 1987). Ensuring that activities do not exceed the carrying capacity of the environment is one practical interpretation of this objective. Ensuring that the sum total of natural and economic capital is maintained or increased through time is another. Agreeing (at national or local level) on a practical interpretation of this in relation to aquaculture must be one of the first steps in any planning and management initiative.

20. Two principles were given emphasis at the Rio Summit and should be observed. ***The precautionary approach*** means that we should more carefully plan and rigorously evaluate developments that have uncertain and potentially damaging implications for the environment. The ***polluter pays principle*** is subject to a range of interpretation, from a requirement upon polluters to pay the costs of monitoring and management, through the requirement to pay the costs of clean-up, to the responsibility to pay for the cost of environmental damage as well as that of clean-up.

21. ***Integration or co-ordination*** with other sector activities or plans, with national sector plans, and with integrated coastal management plans (where these exist) is essential.

22. Wide ranging ***public involvement*** is important, meaning not only consultation and information exchange, but also direct involvement or *participation* of stakeholders in the decision making process, especially in relation to defining overall objectives and associated targets and standards. Related to this, particular attention should be paid to the promotion of ***effective representative organisation*****s**.

23. Thorough ***assessment of costs and benefits*** (financial, economic, social, environmental) of aquaculture in a specific area (e.g. estuarine or lagoon system) should be undertaken; as should *comparative* assessment of costs and benefits of aquaculture relative to other resource uses.

24. Some assessment of ***environmental capacity*** is desirable. The scope and accuracy of this assessment will depend critically on resources and time available.

25. ***Regulation*** is difficult, especially with respect to large numbers of small-scale developments, and offers limited incentive for improved environmental performance. It may be made more effective if responsibility for design, implementation and enforcement is located at the proper administrative level, and full use is made of self-management and self-enforcement capacity by industry and farmers' associations.

26. ***Incentives*** (financial, market, infrastructure) can be designed to stimulate innovation and improvements in environmental management, and should be used wherever possible. However, incentives may need to be underpinned or reinforced through complimentary regulation.

27. Emphasis should be on the control of ***effects***, rather than the scale of activity. This allows for economic growth at the same time as providing an incentive for improved environmental performance.

28. More integrated planning and management is extremely complex, and the outcomes from each stage of the process are likely to be flawed or inadequate in some way. If the planning process is not to fail, it must learn and adapt. This requires an ***iterative*** approach of *action-monitor-evaluate-adapt-action-monitor-…* and so on. This applies to all forms of action associated with the planning process: research, setting objectives and targets, specific planning interventions, and designing new institutional structures and procedures.

29. Many integrated planning initiatives have foundered through lack of appropriate institutional structures or capacity for developing or implementing the plan. ***Institutions*** and capacity must be considered at all stages, but especially in relation to implementation.

Legal and institutional frameworks

30. The importance of legal, procedural and institutional frameworks designed to facilitate sustainable aquaculture development is emphasised in the FAO Code of Conduct for Responsible Fisheries. Again, there are no universally applicable models. The nature of any improvements will depend on existing laws, traditions, and institutional structures. The key point is to develop or adapt a system that allows for the comprehensive application of the principles set out above.

31. Where the introduction of new legislation is difficult, or will cause excessive delay, *guidelines* for developing new initiatives may be introduced prior to specific legislation, as a means of testing out different approaches.

32. The ideal framework would allow for vertically (national to local) and horizontally (across sectors) integrated policy-making and planning with a significant role for strategic, sector or regional (integrated) environmental assessment as an input to the planning process. Such a framework should allow for adaptation in both directions, i.e. national policy should inform local planning; local planning and public involvement should inform the development or adaptation of policy at higher levels.

The planning process

33. The planning process is broadly similar, irrespective of the degree to which it is integrated (enhanced sectoral planning or ICM), and whether it takes place at local, district, regional or national level:

   I. *Stage setting and planning* involves the identification and analysis of issues; the definition of provisional (working) goals and objectives; the selection of strategies and specific instruments to meet the objectives; and the selection or design of implementing structures.
   II. *Formalisation* involves the agreement and formal adoption of the plan or program, and securing of implementation funding.
   III. *Implementation* involves deployment of specific planning instruments and development actions, the promotion, facilitation, and if necessary enforcement of policies and regulations, and monitoring of the effects of the plan.
   IV. *Evaluation* involves analysis of progress against targets and objectives, and problems encountered

34. In practice stage I. can be further broken down into a set of operational components:

- Identifying the means/mechanism and level of planning;
- Initiation;
- Gaining the trust, involvement and commitment of key stakeholders;
- Understanding the development context (natural and human resources and economy);
- Understanding the development options;
- Defining goals and objectives, and identifying corresponding performance criteria, including environmental quality standards;
- Identifying development priorities and acceptable practices;
- Defining broad development strategies (strategic planning) to promote development priorities and practices;
- Designing/agreeing specific planning and management instruments (incentives and constraints) to promote development priorities and practices;
- Designing and agreeing monitoring, reporting, evaluation and response procedures;
- Building necessary institutional capacity, and if necessary new institutions.

A variety of tools and methods are available to help inform and facilitate each of these components.

35. Initiation must be done with great care. The “who and how” of planning is likely to have a significant impact on support for the plan and compliance with its provisions. A variety of tools may be used in this first exploratory phase, including stakeholder and institutional analysis. Public involvement and participation from the outset is crucial.

36. Understanding the development context can be extremely complex and great care should be taken to avoid data collection for its own sake. There are several examples of very detailed resource assessment for aquaculture development planning, which have fallen into this trap. The collection of information and research about human and natural resources should be undertaken in parallel with broad public involvement and issues identification, so that the research and information collection can be focussed and steadily refined. Logically, this should be done within a broader ICM, or locally integrated initiative, rather than within a sectoral planning framework.

37. The estimation of environmental capacity is of particular relevance to aquaculture, to the problem of cumulative impact, and to promoting sustainable development in general. It is therefore discussed in detail in part 2 of this report. An assessment of environmental capacity should be undertaken, even if only at the most elementary level, if promoting sustainable development is to have any practical meaning. Given its complexity however, and its relevance to other activities in the coastal zone, it is better done within a broader ICM rather than sectoral planning framework.

38. Again it is important not to be too ambitious. A very rough estimation of environmental capacity, followed by monitoring of key indicators so that the estimate can be steadily refined, may be much more rapid and cost effective than a major research initiative.

39. Describing development options is rarely done thoroughly or objectively, despite the fact that this is relatively straightforward. Financial analysis is essential, and if quantities as well as value of inputs and outputs are included in financial models or projections, important indicators of resource use efficiency and socio-economic benefit can be generated. This information, along with more qualitative descriptions of site/location requirements, markets, risk, access and equity issues, can be used to generate an analysis of comparative economic advantage and an overall “sustainability profile”. This can be done at the sector level, but the information generated will also be invaluable for broader ICM initiatives.

40. Defining goals and objectives again requires stakeholder participation. Agreement on goals and objectives (before specific development cases are addressed) can be a significant factor in conflict avoidance and resolution. It is also important to agree on specific targets and standards relating to these objectives. These may then serve as the basis for more consistent social and environmental assessment, as the rationale for specific planning interventions, and as a baseline against which progress (in terms of improved performance of the sector) can be measured. Once again, this is costly and difficult to do at the sector level.

41. Identifying development priorities and acceptable practices can be done using a range of formal and informal tools including social and environmental assessment; cost benefit analysis; and participatory/multi-criteria decision making. The success of these approaches, especially for comparing economic and environmental costs and benefits, will depend critically on the thoroughness of the issues identification; the quality of the technical-economic assessment; and the existence of agreed objectives and targets/standards. It will also depend on effective communication and exchange of information so that all those involved in the decision making process are well informed.

42. The foregoing should provide the basis for a planning and management strategy, which might include, for example:

- zones with development and environmental objectives specifically related to aquaculture and other compatible activities;
- environmental quality standards associated with these zones;
- allocation of environmental capacity, in terms of waste production/emission limits, for aquaculture and other activities within these zones; and
- production targets related to development potential, and social-economic objectives.

43. A set of planning interventions in the form of incentives and constraints (planning instruments) will be required to implement the strategy and ensure that objectives are met, standards are not breached, and environmental capacity is not exceeded. Incentives and constraints might apply to :

- location and siting of aquaculture development;
- waste emissions;

- the quantity or quality of inputs used (e.g. food, chemicals);
- design, technology and management practices;
- stock movement and disease management; and
- the level of activity or production.

44. The incentives and constraints may take the form of:

- rules and regulations, and associated enforcement measures;
- economic instruments (e.g. grants, subsidies, tax breaks, taxes, bonds, price intervention, product labelling);
- infrastructure provision (such as water supply, effluent treatment); and
- services (such as disease certification; marketing; training; advice; extension).

45. It is important that these are agreed with all stakeholders if compliance is to be maximised. Particular attention is paid to economic and market instruments in the report, since these are more likely to take the form of incentives rather than constraints (which are often difficult to enforce).

46. Monitoring and evaluation are of paramount importance with such a complex process. This should be straightforward if clear planning objectives have been set, and associated performance criteria (e.g. standards) agreed. However it is also important to monitor and evaluate these criteria, especially environmental standards, since the link between them and people's perception of the quality of the environment may be weak. For example, water quality standards in receiving waters are often based on national guidelines or international precedent, and rarely relate directly to local environmental quality values and objectives. It may be useful to develop "state of the environment" reporting in order to examine overall effects of development activities on the wider environment, the relevance of particular standards, and the utility of indicators.

47. Monitoring should also apply at a more immediate level to the planning and implementation process. There will be many indicators relating to the success of specific procedures or interventions, and these should be set out in the monitoring programme. In addition, it is vital to agree on the nature of the response if standards are breached, procedures fail, or targets are not met.

48. The plan must be flexible. Procedures must be established for communicating the results of monitoring and evaluation to stakeholders, and adapting and modifying the plan in the light of experience. At minimum this may involve slight adjustments to planning interventions. In the extreme it may involve developing completely new policy, laws and institutions.

49. The report presents policy guidelines for all the stages described above, describes and discusses specific tools which can be used in support of the planning process, with emphasis on those of particular relevance to coastal aquaculture development, and provides examples and case studies relating to both the planning approaches and the application of specific tools. It has not been possible to cover all areas in detail, and in this case the reader is referred to other guidelines or reviews for further information.

PART 1

GUIDELINES FOR PLANNING AND MANAGEMENT FOR SUSTAINABLE COASTAL AQUACULTURE DEVELOPMENT

Part 1 of this document contains guidelines designed to help policy makers, planners and stakeholders in the coastal zone promote sustainable aquaculture development, and facilitate its integration into broader coastal management initiatives.

The first part of the guidelines provides a background and rationale for improved planning of aquaculture development, and integration of such planning as far as possible with other sectors. The second part offers a brief review of the theory and practice of more integrated approaches to aquaculture development planning, and coastal management more generally. The third part summarises the main guiding principles that should be applied to any coastal aquaculture planning initiative, irrespective of its scope, or the administrative level at which it takes place. The fourth part deals with the need (and the obligation now resting on producer countries) for enhanced legal and institutional frameworks to promote better-planned and more sustainable coastal aquaculture development. The final part takes the reader through the various operational components of a more planned and integrated approach to promoting sustainable coastal aquaculture development, and introduces the various tools that may be used to facilitate or support these components. Brief case studies are presented throughout the text to illustrate worldwide experience in the use of different approaches and planning tools. Where appropriate the reader is referred to the more detailed discussion of supporting tools and methods in Part 2.

Our review of actual planning approaches worldwide revealed no models that were simple, effective and widely applicable. Nor did our review of the application of the various planning tools yield simple general conclusions about how and when they should be used. Their suitability and utility will depend on local circumstances and the type of aquaculture being considered. We have therefore identified as far as possible the strengths and weakness of different planning approaches, and the tools which may be used to facilitate them, so that practitioners can make a critical appraisal of these approaches, and make informed choices in relation to their own circumstances.

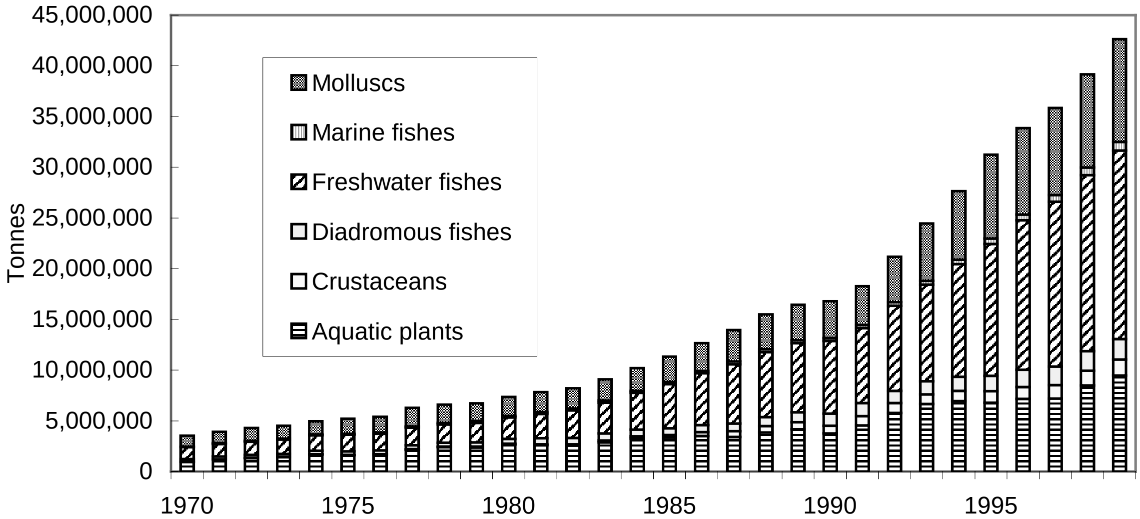
1 GUIDELINES

1.1 Background and rationale

1.1.1 The status of aquaculture development

Aquaculture is the farming of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants (FAO, 2000; FAO Fisheries Department, 1997; FAO/FIRI, 1997). Aquaculture has been the world's fastest growing food production system for the past decade (Muir, 1995; Tacon, 1997).

Figure 1. Global aquaculture production trends by major species groups 1970-1999 (Source: FAO, 2001)



Aquaculture production increased from 7,4 million tonnes in 1980 and 16,8 million tonnes in 1990 to more than 42 million tonnes in 1999 (Fig. 1), valued at over US$ 53 thousand million. The sector's production is growing at an average rate of more than 10% per year, as compared with a growth of about 3% for terrestrial livestock meat production, and 1,5% for capture fisheries production. The contribution of aquaculture to world food fish landings has more than doubled since 1984. In 1997, over 30% of food fish consumed by humans, from a total average per caput food fish supply of 16.1 kg, was provided by aquaculture. Global projections for future supplies from aquaculture production include, for example, 47 million tonnes for the year 2010 (Pedini and Shehadeh, 1997).

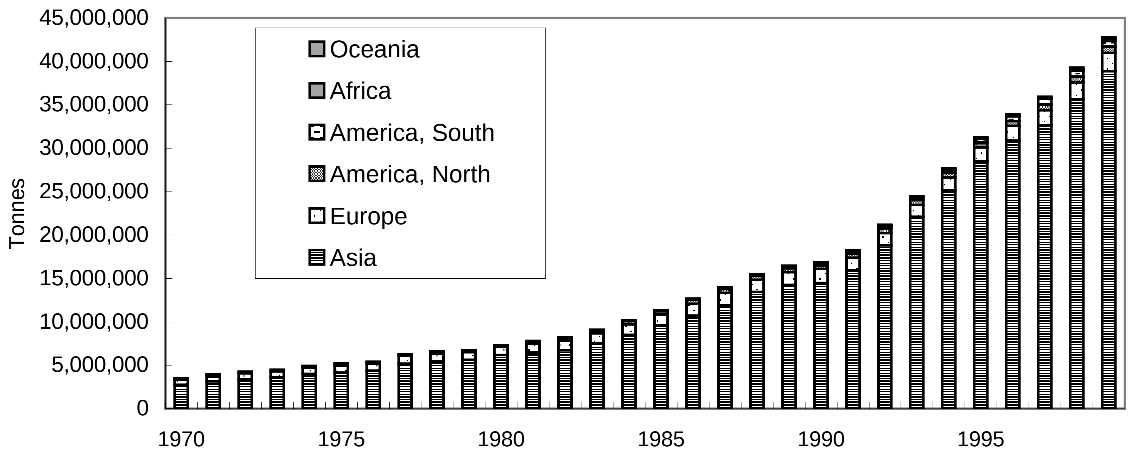
Asian aquaculture farmers continue to contribute about 90% of the world's aquaculture production (Fig. 2), and in 1999 more than 82% of total aquaculture yield was produced in low-income food-deficit countries (LIFDCs). The growth rate of the aquaculture sector in LIFDCs between 1984 and 1995 was six times faster than that for non-LIFDCs (Rana, 1997; Tacon, 1996).

The vast majority of finfish produced by aquaculture is based on extensive and semi-intensive freshwater culture systems producing predominantly Chinese and Indian carps, and contributing more than 44% of global total aquaculture production by weight in 1999. In contrast, marine and brackishwater aquaculture systems employed in coastal areas inf 1999 yielded 23,4 million tonnes, valued at US$ 30,3 thousand million, representing 55% of total volume and 56% of total value of global aquaculture production (Fig. 3).

Coastal aquaculture is dominated by production of aquatic plants (seaweed) and molluscs. For 1999, their shares of total coastal aquaculture production in terms of quantity and value are 40% and 19% (seaweed) and 43% and 30% (molluscs). The production share of crustaceans (6%) and finfish (11%)

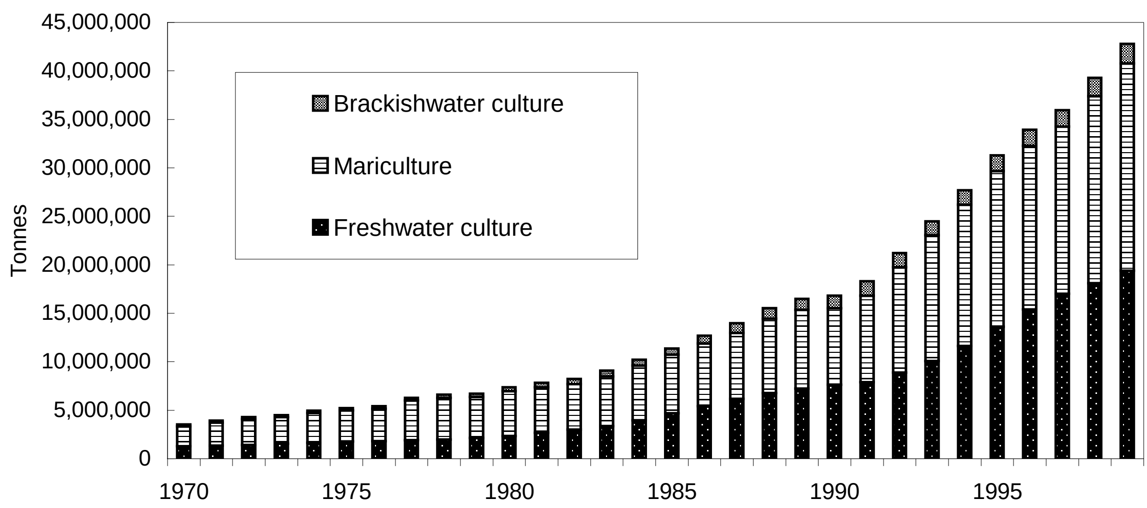
is comparatively low, but their relative contributions to the value of total coastal aquaculture production is significant, i.e. 24% (crustaceans) and 27% (finfish).

Figure 2. Global aquaculture production trends by continents 1970-1999 (Source: FAO, 2001)



A wide range of very diverse coastal aquaculture systems has been developed in Asia, Europe, and the Americas, operating with different intensities and scales of production. The potential for additional growth and future expansion of coastal aquaculture is being recognised by many government authorities, private sector (investors, aquaculturists and ancillary activities), financial institutions, such as development banks, as well as aid agencies, at national and international levels.

Figure 3. Global aquaculture production by environments, 1970-1999 (Source: FAO, 2001)



1.1.2 Sustainable Development

During the last decade there have been increasing efforts, at national and international levels, to address opportunities and needs for more sustainable aquaculture development[1]. Sustainability issues associated with coastal aquaculture developments, in particular aquaculture of salmonids and shrimp, have attracted the attention of government authorities, the private sector, environmental NGOs, the academic community, international agencies, the media and the public in general[2].

There have been many definitions of sustainable development. One of the most widely quoted and agreed, is:

> *"Development that meets the needs of the present without compromising the ability of future generations to meet their own need"* (WCED, 1987)

Rather more specifically, and in relation to agriculture and fisheries, it has been defined by FAO as follows:

> *Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable* (FAO Fisheries Department, 1997).

Other definitions have been developed by economists, which allow (in theory) for the actual measurement or quantification of sustainability. These generally require that the sum total of different resources and/or capital (natural capital; human capital; physical plant (equipment, machinery, buildings) and infrastructure; financial capital; and other forms of capital valued by particular societies) does not decrease over time (Hartwick, 1977; Solow, 1986).

The practical meaning of sustainable development will rarely be agreed in relation to particular development decisions, because:

- its component ideas may be contradictory, or interpreted in different ways by different interests;
- the values or weights assigned to its various components by different interests may differ; and
- it may conflict with short term financial viability[3]

The idea is nonetheless a powerful and constructive one, since it forces people to assess, research, and discuss development opportunities from a broad range of perspectives. It also encourages specific discussion of the trade-offs between different development and conservation objectives and their associated activities.

---

[1] ADB/NACA, 1996; Bagarinao and Flores 1995; Bailey, 1988, 1989, 1997; Bailey and Skladany, 1991; Barg, 1992; Chua, 1997; Chua *et al.*, 1989; FAO, 1995a; FAO/FIRI, 1997; FAO/NACA, 1995; GESAMP, 1991a; GESAMP, 1996a; GESAMP, 1997; ICES, 1997; Makinen, *et al.* 1991; Mires, 1995; Muir, 1996; Munday *et al.*, 1992; NACA, 1996; Barg and Phillips, 1997; Phillips and Macintosh, 1997; Pillay, 1997; Pullin, 1993; Rosenthal, 1997; Saenger, 1993; Stewart, 1997; Videau and Merceron, 1992; Wu, 1995.

[2] Bardach, 1997; Barg *et al.*, 1997; Beveridge *et al.*, 1997; Chamberlain and Rosenthal, 1995; Clay, 1997; Nambiar and Singh, 1997; Naylor *et al.*, 1998; Phillips and Barg, 1999; Phillips, 1995a; 1995b; Pillay, 1996; Reinertsen and Haaland, 1995; Rosenthal and Burbridge, 1995; Tobey *et al.*, 1998.

[3] It is for this reason that some development specialists include financial viability as part of any practical definition of sustainable development

1.1.3 The costs and benefits of coastal aquaculture development

Planning for sustainable development and improved natural resource management implies a thorough examination of different development options in terms of their financial, economic, social, and environmental costs and benefits, and the distribution of these costs and benefits through time and space, and between different groups in society. This implies some form of valuation – either qualitative or quantitative.

Despite the rapid growth of aquaculture and the growing awareness of environmental issues, few studies have been made which address these issues objectively. In many cases the debate has polarised between those who emphasise the economic benefits, and those who emphasise negative environmental impact. The debate has also tended to generalise from specific examples, although the sector is enormously diverse. For example, four major species groups are farmed in coastal areas, including seaweed, molluscs, crustaceans and finfish, with a range of significant differences within and between each of these groups.

A major purpose of this document is to help those involved in development decisions make a more rational assessment of these issues in relation to particular circumstances.

1.1.4 The need for planning and management of the aquaculture sector

Experience has shown repeatedly that without some form of intervention, short term financial perspectives will tend to dominate development decisions to the detriment of environmental and social objectives. In the case of coastal aquaculture, and indeed many activities in the coastal zone, there is a strong case for such interventions to be planned and strategic, rather than reactive and uncoordinated.

The problems associated with coastal aquaculture development may be grouped into three broad categories as follows:

- *unsuccessful development*, where the potential for development is not realised, especially among the poorer sectors of society;
- the *vulnerability of aquaculture* to poor water quality and aquatic pollution, caused by industrial, domestic, agricultural and aquacultural (i.e. its own) wastes;
- *over-rapid development*, where the undoubted successes of the sector have been tarnished by environmental and social problems, disease, and in some cases, marketing problems.

Investors have responded to these problems with more rigorous project appraisal: financial and economic analysis, and in some cases cost benefit analysis. Governments have responded with specific regulations relating to farm operation (such as effluent limits or design standards), and/or with more rigorous requirements for social and environmental impact assessment (EIA). The market itself is increasingly demanding sustainably produced goods, at least in western countries.

These responses have significant weaknesses. They arise mainly from the small scale and incremental nature of most aquaculture (and agriculture) development. While individual developments may have no significant impact on the environment or society, a large number of developments, however small, may have significant impacts on the wider social and economic environment, and on each other. Farm drainage in western countries, and shrimp farming in some regions of Asia are classic examples of this problem. Project or enterprise level approaches cannot deal with this problem (see for example Box 1.1), and the market is likely to respond only once damage is done. Furthermore, EIA and economic/financial studies tend to be undertaken by different specialists, ignoring the close links between the two, and commonly presenting contradictory conclusions.

Nor can these approaches facilitate or promote aquaculture development in those areas to which it is most suited. This is a particular problem with aquaculture, because site requirements are frequently much more demanding than those for other activities. Inadequate attention on the part of new entrants to site selection is a major cause of failure in aquaculture development, and commonly exacerbates environmental impacts.

In practice, the problems and opportunities associated with coastal aquaculture development can only be addressed or realised through:

- improvements in siting, design, technology, and management at the farm level (requiring a set of incentives and constraints to promote these changes at the sector level);
- better location and spatial distribution of the sector as a whole (implying some form of zoning);
- better water supply for the sector as a whole;
- better fish health management, including disease and stock control at individual farm and sector levels;
- improved communication and information exchange;
- improved access to markets and trade opportunities; and
- more equitable distribution of the benefits derived from coastal aquaculture development.

This implies strategic intervention by government and producer associations or industry organisations to allocate and use resources more equitably and efficiently in both time and space – in other words, more effective and integrated planning and management of the sector.

Box 1.1: EIA of a shrimp farm in Tanzania

The importance of a broader environmental management framework for effective EA

In 1994 a private company sought assistance from NORAD for the establishment of a medium-large shrimp farm near Bagamoyo, Tanzania. The farm site was set adjacent to the mangroves of the Ruvu River, the largest single expanse of mangrove in the Bagamoyo District.

NORAD commissioned an initial EIA based on the NORAD Guidelines. The overall tone of the assessment was positive, and the final paragraph of the executive summary stated:
"*We believe that if such (mitigation) procedures are followed, the proposed project might become a model for the development of sustainable shrimp culture throughout the world, and in this sense offers a unique opportunity for realising the undoubted and substantial potential benefits offered by well planned and managed farms".*However, it had already cautioned:

> *"If appropriately designed and managed,* ***and if considered in isolation****, this farm is unlikely to have a significant impact on the environment. However, in many other parts of the world successful farms have attracted uncontrolled smaller scale satellite developments which in places have had a serious cumulative impact on the environment and the sustainability of shrimp farming itself……. It is essential that this and future developments take place within a planning and regulatory framework which will prevent uncontrolled development and ensure on-going responsible management practices. …Without such a framework, this development may simply become a small part of a wider development problem"*

It would appear that this caution, and the evident lack of any wider environmental management framework, was taken seriously, and funding for the project was rejected.

This example demonstrates that EIA in the absence of a broader environmental management framework cannot be used as a positive planning or management tool. It will either allow or restrict development, on a relatively ad hoc basis, dependent largely on the knowledge or bias of the EIA contractor and the decision maker. It will be based on no broadly accepted decision criteria. If mitigation measures are recommended, there will be little chance of them being implemented, especially if they are associated with additional costs.

After Hambrey et al., 2000.

1.2 Aquaculture and coastal management – a brief review of theory and practice

Strategic planning has traditionally addressed the inadequacies of the enterprise level approaches highlighted in the previous Section. With some notable exceptions however (such as the Great Barrier Reef in Australia), these approaches have tended to place limited emphasis on natural resource issues, which have traditionally been addressed by sectoral agencies such as Fisheries, Agriculture and Forestry Departments.

A range of more comprehensive approaches to coastal resources management have therefore been proposed as frameworks for addressing the wider issues of sustainable coastal resource use, the minimisation of conflict, and optimal allocation of resources, including in particular land and water. These range from sector related environmental planning and management initiatives (referred to below as enhanced sectoral management or ESM), to more ambitious integrated coastal management (ICM) programmes.

The following Sections examine the various frameworks for coastal management which have been used or proposed, and discuss their strengths and weaknesses. Brief case studies are presented in boxes illustrating the application of different approaches in practice.

1.2.1 The scope of coastal management

Coastal management implies something broader than addressing the development or resource issues associated with one particular activity or sector in the coastal zone. Olsen *et al*. (1997) have proposed the following typology of coastal management:

Enhanced Sectoral Management (ESM)	Coastal Zone Management (CZM)	Integrated Coastal Management (ICM)
Focus on a single sector or topic but explicitly accounts for impacts and interdependencies with other sectors, ecosystem functions, and institutional capacity.	Multi-sectoral planning and regulation focused upon the characteristics and needs of narrow, geographically delineated, stretches of coastline.	Expands the cross sectoral feature of CZM to consideration of the closely coupled ecosystem processes within coastal watersheds and oceans

In practice there is a broad range, or continuum, of coastal management initiatives relevant to aquaculture which are more or less integrated in terms of geographical scope, horizontal (sectoral) integration and vertical (policy) integration. CZM and ICM type initiatives in particular overlap significantly in practice, and are difficult to assign to these sub-categories. For practical purposes they are therefore grouped together in the discussion below.

1.2.2 Enhanced sectoral management (ESM)

Initiatives which seek to enhance the sectoral management of aquaculture and aquaculture development are widespread in developed countries (Black, 1991; GESAMP, 1996a; ICES, 1997; Ibrekk *et al.*, 1993; Kryvi, 1995; PAP/RAC, 1996; PAP/RAC,1995; Rosenthal *et al.*, 1993; Rosenthal and Burbridge, 1995; Truscott, 1994). Interest in these approaches has been generated because of heightened awareness of sustainability issues in general, and those related specifically to aquaculture, as described above in Sections 1.1.2-4. Enhanced sectoral management tends to be conservative in nature, the initiatives usually arising within existing institutions, and based on existing responsibilities and powers.

These initiatives are diverse. They include the use of environmental impact assessment (EIA) at sector or farm level, and/or a package of tools and incentives to promote better siting or more sustainable practices (Box 1.3). In some cases assessments of environmental capacity and its relation to the quantity or location of aquaculture production have been undertaken (Box 1.2). Other initiatives focus on the identification of suitable sites or zones for aquaculture development, facilitated through the use of GIS or remote sensing. In Tasmania, a more comprehensive approach is now in place that requires the development of local marine farming development plans (Box 1.4)

Initiatives in this category have been funded by government at all levels, by development banks or aid agencies, and by private companies. However, the lead institution is generally that with traditional responsibility for fisheries and aquaculture.

Box 1.2 Enhanced sectoral management in Norway

In the early 1990s a coastal management programme for aquaculture, known as ***LENKA***, was developed in Norway.

Aims
- *To encourage the development of aquaculture while minimising conflict with other uses of coastal resources;*
- *to contribute to environmental planning in the coastal zone;*
- *to contribute to the process of siting of aquaculture facilities.*

Procedure:
1. classification of the coastal environment in terms of sensitivity to organic loading and nutrients;
2. assessment of the natural capacity of each category to tolerate organic loadings and nutrients;
3. assessment of total existing loadings/inputs;
4. estimation of the maximum acceptable additional organic loading, which is converted into an aquaculture production equivalent;
5. assessment of the physical area available for aquaculture development, arrived at by subtracting all unsuitable areas and all areas currently occupied from the total area;
6. estimation of total additional production possible without exceeding available area, or available nutrient capacity.

Despite its undoubted potential, LENKA has not become a significant planning tool for the aquaculture industry, or for coastal management in general. It has not been brought into a wider planning framework where it could be used to clarify or implement planning objectives and targets.

This failure highlights the importance of paying adequate attention to institutional issues, and ensuring that there is a mechanism for deploying effectively a suite of incentives and constraints to meet economic and environmental objectives. LENKA is a powerful tool without a framework.

Reference: Ibrekk *et al*.,1993.

Strengths
- avoids the risks of more radical approaches to institutional change (e.g. confusion over powers and responsibilities; lack of institutional capacity);
- builds on and enhances existing knowledge and skills;
- allows for relatively rapid assessment and research, followed by implementation of improved planning and management of aquaculture development - *if* appropriate institutional powers and capacity already exist.

Weaknesses
- sometimes "top down" and driven by technological priorities and considerations;
- the values and concerns of other stakeholders may be inadequately understood or taken into account;
- where the lead agency also has responsibility for aquaculture development, the initiative may be biased in favour of development;
- assessment, evaluation and monitoring of the effectiveness of interventions may not be objective or effective, because of a lack of external perspective;
- may ignore rather than resolve conflict;
- may end up as paper research and project style exercises, if planning and regulatory powers and institutional capacity are lacking;
- may partially duplicate the efforts of other sectoral agencies also involved in enhanced sectoral planning;
- may be more costly in the long term (because of duplication of effort), and less consistent and effective (because of duplication of policy, or formulation of contradictory policies) than more integrated approaches.

Box 1. 3 Enhanced sectoral management in Hong Kong

In Hong Kong the rapid unregulated development of marine cage culture in the 70's led to water quality problems and conflicts with recreational uses. As a result a legislative framework for the management of the industry was introduced, and a sector environmental assessment undertaken.

The industry is now closely regulated with management overseen by a government inter-departmental working group. Legislation includes zoning, licensing and production limits. Production is being steadily phased out in areas where there is poor flushing, and environmental impacts of the industry are now considered to be acceptable.

Unfortunately the industry has suffered in recent years from fish kills and marketing problems related to "red tides" suggesting that a broader approach is required which takes account of all forms of nutrient load to the water around Hong Kong.

Reference: Wong, 1995.

Box 1.4 Tasmania – a more institutional approach to enhanced sectoral management

The Tasmania Marine Farming Planning Act 1995 provides for the development of *Marine Farming Development Plans*. The plans consist of:

- a (sector) Environmental Impacts Statement
- a Development Proposal, including maps of the area suitable/available for marine farming;
- management controls and operational constraints affecting activities within the zones, including provision for a comprehensive environmental monitoring programme.

The plans are developed following a process of public consultation that takes account of:

- the physical suitability of the sites for aquaculture;
- the current legal situation;
- the desire to minimise impacts on other users of the coastal zone.

General management controls for the *Marine Farming Zones* are as follows:

- environmental controls relating to carrying capacity;
- environmental controls relating to monitoring (water quality, benthos, shellfish growth);
- chemicals (must comply with legal requirements);
- disposal of waste;
- disease controls;
- visual controls to reduce visual impacts;
- access controls;
- other controls, e g. controls related to other legal requirements (such as predator control, other environmental management legislation).

This approach places more emphasis on the planning framework, and less on the science of environmental capacity than the LENKA approach. It remains to be seen whether it is successful, but it has the great strength of a clear procedure for implementation, supported by specific legal provisions.

1.2.3 Coastal zone and integrated coastal management

Coastal Zone Management, Coastal Area Management, and Integrated Coastal Management have been widely proposed as more comprehensive approaches to coastal management which address the limitations and difficulties associated with sectoral and enhanced sectoral approaches, particularly in relation to aquaculture (Chua, 1997). Coastal zone management implies multi-sectoral planning and regulation, and therefore some form of co-ordinating body or authority to assess and balance the various sectoral interests. ICM also implies mechanisms for addressing trans-boundary issues (for example between land, coast and ocean).

CZM and ICM initiatives have varied enormously in terms of specific objectives, overall approach, geographical and sectoral scope, initiating or implementing institutions; and in terms of the influence they have on decision making and resource use in coastal areas. They have arisen from academic or political initiatives, aid funded projects, or directly in response to an environmental problem or development need. Nonetheless, most ICM initiatives have certain key features in common.

The *goals or objectives* usually include reference to one or more of the following:

- the optimal allocation of resources to competing activities or functions;
- the resolution or minimisation of conflict;
- the minimisation of environmental impact, and the conservation of natural resources.

In some cases ICM may also have more strictly social and political objectives, such as quality of life; the more equitable distribution of derived economic benefits; social and inter-generational equity; and poverty alleviation (Chua, 1997; Gomez and McManus in GESAMP, 1996b; Yap, 1996).

There have been many reviews and guidelines related to ICM published in recent years (Chua, 1997; Chua and Fallon-Scura, 1992; Cicin-Sain *et al.*, 1995; Clark, 1992; GEF/UNDP/IMO, 1996; GESAMP

1996b; OECD, 1993; Pernetta and Elder, 1993; UNEP, 1995; Post and Lundin, 1996; Sorensen, 1997; Scialabba, 1998; Cicin-Sain and Knecht, 1998; Lowry *et al.*, 1999). Although there is a broad consensus as to the main components of ICM, emphasis and details vary widely. Cicin-Sain *et al.* (1995) compared coastal management guidelines developed by five different international entities (IPCC, 1994; OECD, 1991; Pernetta and Elder, 1993; UNEP, 1995; World Bank, 1993). Based on their comparisons, the authors developed a "consensus set of ICM guidelines" (Table 1.1).

Table 1.1: A consensus set of integrated coastal management guidelines

Source: Cicin-Sain et al., 1995.

Purpose of ICM	The aim of ICM is to guide coastal area development in an ecologically sustainable fashion.
Principles	ICM is guided by the Rio Principles with special emphasis on the principle of intergenerational equity, the precautionary principle and the polluter pays principle. ICM is holistic and interdisciplinary in nature, especially with regard to science and policy.
Functions	ICM strengthens and harmonises sectoral management in the coastal zone. It preserves and protects the productivity and biological diversity of coastal ecosystems and maintains amenity values. ICM promotes the rational economic development and sustainable utilisation of coastal and ocean resources and facilitates conflict resolution in the coastal zone.
Spatial Integration	An ICM programme embraces all of the coastal and upland areas, the uses of which can affect the coastal waters and the resources therein, and extends seaward to include that part of the coastal ocean which can affect the land of the coastal zone. The ICM programme may also include the entire ocean area under national jurisdiction (Exclusive Economic Zone), over which national governments have stewardship responsibilities both under the Law of the Sea Convention and UNCED.
Horizontal and vertical integration	Overcoming the sectoral and intergovernmental fragmentation that exists in today's coastal management efforts is a prime goal of ICM. Institutional mechanisms for effective co-ordination among various sectors active in the coastal zone and between the various levels of government operating in the coastal zone are fundamental to the strengthening and rationalisation of the coastal management process. From the variety of available options, the co-ordination and harmonisation mechanism must be tailored to fit the unique aspects of each particular national government setting.
The use of science	Given the complexities and uncertainties that exist in the coastal zone, ICM must be built upon the best science (natural and social) available. Techniques such as risk assessment, economic valuation, vulnerability assessments, resource accounting, benefit-cost analysis and outcome-based monitoring should all be built into the ICM process, as appropriate.

ICM in practice

Integrated coastal management approaches have been widely promoted, and the approach has been widely approved (with some recent exceptions: Davos, 1998; Nichols, 1999). Indeed it is difficult to criticise the *idea* of ICM. Unfortunately implementation has been difficult, and success in practical terms mixed. Sorensen (1997) has reviewed the rather disappointing achievements of coastal management efforts in general. Very few of the many recent initiatives have been rigorously evaluated according to specified criteria; there is little evidence of success; and many examples of failure. He attributes much of this failure to a lack of genuine vertical and horizontal integration.

Aquaculture and integrated coastal management

In many ways aquaculture is a classic example of why ICM is needed:

- coastal aquaculture commonly straddles the boundary between land and sea;

- resource (land, water, and their products) ownership or rights allocation, and related administration, is often complex or ambiguous in prime aquaculture locations[4];
- aquaculture may be seriously affected by water quality and habitat degradation caused by other activities;
- aquaculture itself may affect environmental quality and the interests of other users through conversion of natural habitat, through pollution of recipient waters with nutrients, organic substances, and potentially toxic (hazardous) chemicals, and through the spread of disease;
- poorly sited or planned aquaculture may result in negative feed-back and self pollution.

Unfortunately, there are few clear examples of the successful integration of aquaculture into comprehensive ICM. It is arguable that this is because there have been very few genuine ICM initiatives, where aquaculture has been assessed alongside the full range of existing or potential activities in the coastal zone using consistent and rational assessment criteria, agreed across a range of interests and agencies. However, to do this thoroughly takes time, and this poses a dilemma in many developing country situations where aquaculture is developing very rapidly. The case of Ecuador, where population pressure, industrial development and shrimp farming have had significant negative impacts on estuarine resources throughout a period in which a long term ICM project was underway, is particularly notable. Shrimp farming has also recently developed uncontrollably in Sri Lanka (Box 1.5), with adverse environmental consequences and self-pollution, despite a strong ICM awareness, and a variety of ICM initiatives in place.

In other countries, where existing institutional and planning structures are favourable, and where the development pressures are less extreme, ICM may be both desirable and feasible. An example is the case of New Zealand (Box 1.6).

Box 1. 5 Coastal zone management in Sri Lanka

In **Sri Lanka**, the need for some form of coastal resource and environmental management was recognised as early as the mid 70's, mainly as a response to the destruction of coral for building purposes. The Coastal Environmental Management Plan (for the West Coast) was developed in 1984 with the objective of preventing the environmental degradation of coastal areas. It included setback standards; EIA's for development activities; and the prohibition of activities that would degrade designated natural areas.

Since 1987 a Coastal Resources Management Programme has resulted in a range of measures, including a Coastal Zone Management Plan. This seeks to promote sustainable yields from multiple uses of estuaries, lagoons and mangroves in the region. Under these initiatives and recent legislation, aquaculture operations must be registered, and EIA's, (assessed by a wide variety of government agencies and other interests) are normally required for farms over 4 ha in size.

Despite these provisions, shrimp farming has developed rapidly and uncontrollably, resulting in self-pollution, disease, user conflict in some areas, and significant mangrove destruction. The failure of these coastal management initiatives relates largely to the difficulties of enforcing registration, and the inability of single enterprise EIA to cope with the problems associated with small incremental, but substantial cumulative impacts. In other words, despite its name, this Coastal Zone Management Plan lacked a strategic approach to planning for aquaculture development, and depended instead on a piecemeal and bureaucratic regulatory approach, which inevitably failed.

References: Nichols, 1999; Rohitha, 1997.

Strengths

- the values and concerns of the full range of stakeholders are specifically taken into account;
- relevant institutions are encouraged to communicate, co-ordinate and co-operate;
- a broader base of information and opinion is available to decision makers;
- less technically driven than sectoral approaches;
- more "bottom up" than "top down" (if correctly implemented);
- potential development activities are assessed objectively, using a broad range of criteria, against all other possible resource uses, not just those from the same sector;
- the resolution of conflict and balancing of interests is usually a specific objective;

[4] for example, aquaculture is commonly administered by Fisheries Departments, although it may take place in the inter-tidal zone, or on land or forest areas administered by the Department of Agriculture or Forestry, or, as in the case of the UK, the Crown

- should result in consistency of policy and legislation between different levels and sectors of government.

Weaknesses

- may make inadequate use of existing institutional memory and skills: new institutions need to learn – they may repeat past mistakes or re-invent old solutions;
- since it requires institutional change, it may carry institutional risks (e.g. confusion over powers and responsibilities, and lack of institutional capacity);
- takes much time, effort and cost;
- may generate a wealth of assessment and research data with little consensus on how it should be used (as for enhanced sectoral approaches);
- may (at least in the early stages) exacerbate conflict by addressing and highlighting differing values and perspectives on resource use in the coastal zone.

Box 1.6 Integrated coastal management and aquaculture in New Zealand

New Zealand now has a relatively comprehensive framework for integrated coastal management based on the "planning cascade" (vertical integration) approach.

Under the Resource Management Act of 1991, broad policy and principles are defined in a national Coastal Policy Statement. This is interpreted and implemented on the ground through more detailed and strategic Regional Coastal Plans.

Hearing committees operate at regional level to address specific problems, and an environmental court operates at national level to deal with specific grievances arising from the implementation of legislation.

Two fundamental principles are defined in this hierarchy:

- all coastal developments require a permit unless explicitly allowed (or prohibited) in the Regional Coastal Plan; and
- the granting of permits should be related to the effects of the enterprise rather than to its scale.

The rationale for this is to encourage the adoption of improved technology to minimise environmental impact, rather than restrict the scale of development per se. It should also allow ultimately for the allocation of environmental use rights, or the allocation of a proportion of environmental capacity to particular users or user groups.

Applicants for permits must demonstrate environmental responsibility by undertaking EIA, and showing how they will minimise and mitigate environmental impact. The main problems encountered so far are:

- the difficulty of assessing environmental effects;
- the traditional tendency for officials to opt for the (easier) regulation of activity; and
- the difficulties of ensuring consistency and quality of EIA's when they are sponsored by applicants themselves, and administered by different councils with different resources and different social, environmental and political priorities.

1.2.4 Lessons learned

Constraints to integration

The reasons for the rather limited success of ICM are not difficult to find. There are usually institutional and political barriers to the key requirement for vertical and horizontal integration. There may be significant political barriers to full participation, and the resource use issues are usually complex. Control or ownership of land and water in the coastal and especially inter-tidal areas (commonly used for aquaculture) is also ambiguous or inconsistent in many countries.

The scope of comprehensive ICM (as defined in Table 1.1) can make it a long and complex exercise. Dealing with this complexity, and defining the level of detail or accuracy required for any resource appraisal or participatory process is a great, and sometimes overwhelming, challenge for ICM practitioners.

A further problem is that very detailed and comprehensive plans with specific development prescriptions may be undermined by the sheer power of financial and political/economic interests

(Yap, 1996). This may be a particular problem with those types of aquaculture, such as shrimp farming, which are the most profitable.

Local ICM

Many of the problems associated with comprehensive ICM may be overcome by developing initiatives at a local level. Although this may appear to undermine the principle of vertical integration, it should reduce complexity and make stakeholder participation more manageable and effective. The locally based schemes now evolving in Thailand (Box 1.7) to promote more sustainable shrimp farm development appear to have considerable potential in this regard, since they retain integration but at a much smaller scale, and since local planners or community leaders are well acquainted with more integrated approaches. Once underway, specific problems related to lack of vertical integration may become apparent, and pressure may be exerted from below to achieve change and/or integration at higher administrative levels. Aquaculture itself, and the potentials and problems associated with it, may thus serve as a stimulus and starting point for a developing and evolving ICM process.

Box 1.7 Management of coastal aquaculture in Thailand

In Thailand the dramatic successes and failures associated with the rapid development of the shrimp farming industry, and its vulnerability to poor water quality (arising from other resource users and the aquaculture industry itself) have led to a set of operational regulations, and a variety of coastal management efforts with emphasis on the sustainable development of aquaculture. It is as yet too early to comment on the successes or failures of these initiatives, but several features are worthy of note.

The first is the scale of the initiatives. Several projects involve the use of strategic coastal resource planning (zoning) at a local or district level. In some cases these are associated with infrastructure development (sea-water irrigation systems) which should encourage better siting, design and water management in small scale developments. There is also increasing interest in quality labelling initiatives (e.g. ISO 14000), as a means of generating a market premium, which may then be wholly or partly taxed and used for infrastructure improvements and research.

In addition to these more forward-looking projects, there is a framework for the regulation of the industry (the Fisheries Act (1947) through regulations announced by the Ministry of Agriculture and Co-operatives (1991). These regulations cover annual registration with the district fisheries office; water treatment (sedimentation) requirements for farms larger than 8ha; and effluent standards (BOD). The implementation of these regulations is however inconsistent.

Enhanced sectoral initiatives

In other situations, where local initiatives may be difficult or inadequate because of the nature of resources or existing resource management systems, enhanced sectoral initiatives may provide the most appropriate starting point for improved planning and management of aquaculture. Once underway, these initiatives are likely to be constrained by the lack of horizontal integration in specific areas, but, as with local ICM, they may serve as a stimulus to more fundamental change for greater integration as required.

Zoning and environmental capacity

The New Zealand model (Box 1.6) appears to be close to the ideal of ICM, and although there remain problems, there is as yet no reason to think it will not be successful in the long term. There are several important features in the New Zealand system, which are worthy of emphasis:

- the system is vertically integrated (“planning cascade”);
- the emphasis is on effects rather than the type or scale of activity.

The latter highlights the possibility of two significantly different approaches to integrating aquaculture in coastal management. The more conventional approach, epitomised in the provisions for the Great Barrier Reef Marine Park in Australia, relies on zoning, which is inherently an *allocation of space*. In contrast, the emphasis on effects implies an *allocation of environmental capacity* to a particular user or user group, and is likely to better meet the criteria of efficiency and adaptability. It also links more readily to the economic approaches to implementation. Particular emphasis is therefore laid on these alternative approaches in Part 2. However, these approaches epitomise the technocratic and command and control approaches to resource management which have been criticised by some authors (Davos, 1998).

The need for incentives

It is notable that very few initiatives, either enhanced sectoral or more integrated approaches, include much in the way of *incentives* for implementation. They tend to be based on recommendations or regulations. Given the nature of coastal aquaculture as a mainly small-scale activity, the implementation of recommendations may be difficult for the farmer, and the enforcement of regulation difficult for the authorities. Much greater attention needs to be given to financial incentives for better siting and management of aquaculture.

Developed versus developing country experience

In the developed countries aquaculture development has often been singled out for restriction, partly because it is a new activity in many areas, and also because of the high priority afforded to the environment. In developing countries by contrast, there has been very little control of aquaculture. This relates partly to the lack of institutional and administrative frameworks appropriate to the implementation of coastal management, and also to the higher priorities afforded to development rather than environment.

Australia, New Zealand and the USA exhibit well developed coastal management schemes, supported by corresponding legislation, which are generally much more integrated and comprehensive in scope than those of developing countries. In contrast the coastal management process in developing countries has often been ***ad hoc***, responsive, and commonly funded as a project, rather than being implemented through existing planning and management frameworks. Coastal management initiatives must build on existing institutions, or else change them (if this is both necessary and possible). They cannot run in parallel.

1.2.5 Conclusions and recommendations

1. There is no single planning and management framework that can be applied universally to promote more sustainable coastal aquaculture development. Policy makers and planners must therefore critically appraise the options open to them, and make their own choices depending on local circumstances.
2. Despite their theoretical qualities, the more comprehensive (national; regional) forms of ICM are unlikely to offer an effective solution to the immediate needs of improved planning and management of existing or rapidly developing coastal aquaculture development. In these cases it may be more appropriate to begin with more focused local coastal management initiatives, or enhanced sectoral initiatives.
3. The more comprehensive forms of ICM should be more effective where coastal aquaculture is in the early stages of development; where institutions for resource management are flexible or undeveloped; where appropriate legal and institutional frameworks are in place or can be developed rapidly; and where scientific and technical capacity is substantial.
4. Zoning (an *allocation of space)* offers a practical focus for more integrated planning of aquaculture development. The a*llocation of environmental capacity* provides an alternative, which although sometimes difficult, should be efficient and adaptable, and links readily with economic approaches to resource management. An approach which combines the two may be particularly effective.
5. Implementation, and in particular the use of economic and financial incentives to influence the nature and location of development, and the management of operations, should be given much greater attention

1.3 Guiding principles

Notwithstanding the diversity of experience and approaches, it is possible to present a set of core principles, which should guide as far as possible the development of any aquaculture planning and management initiative, whether it be a local initiative, an enhanced sectoral initiative, or more comprehensive ICM. They may be summarised as follows:

1. *the Rio principles:* sustainable development; the precautionary approach; the polluter pays principle;
2. *integration or co-ordination:* with other sector activities or plans; with national sector plans; with ICM where such initiatives exist;
3. wide ranging *public involvement*;
4. thorough *assessment of costs and benefits* (financial, economic, social, environmental) of aquaculture in a specific area (e.g. estuarine or lagoon system) and *comparative* assessment of costs and benefits of aquaculture relative to other resource uses;
5. some assessment of *environmental capacity*;
6. use of *incentives* rather than regulation where possible;
7. emphasis on the *control of effects,* rather than the scale of activity;
8. *evaluation*, *iteration and adaptation;* and
9. *effective institutions* and representative organisations.

1.3.1 Adherence to Rio Principles

Agenda 21 generated at the Rio (Earth) Summit emphasises sustainable development, and in particular its core value or principle of inter-generational equity. It also states a commitment to the precautionary approach, and the polluter pays principle.

Inter-generational equity cannot be defined simply in practice, but needs to be incorporated as a recurrent theme in the assessments, discussions and stakeholder exchanges related to different development and resource use issues. Aquaculture, like other development activities, may change the balance and distribution of different resources or *capital.* This capital includes natural capital; human capital; physical plant (equipment, machinery, buildings) and infrastructure; financial capital; and other forms of capital valued by particular societies. These changes must be assessed to ensure that the sum total of this capital, or specific vital components, are sustained or increased in the long term, and available for future generations.

The precautionary approach implies that we should more carefully plan and rigorously evaluate developments that have uncertain implications for the environment. Under conditions of great uncertainty developments may have to be delayed or halted. This principle is controversial, since its widespread application could slow or halt much development activity. Furthermore, the most successful development has often been associated with substantial financial and environmental risk and uncertainty. This principle should therefore be applied with care, taking full account of both the magnitude and likelihood of adverse environmental impacts. This implies some form of risk assessment.

The polluter pays principle is now widely agreed, and is a central tenet of much environmental policy. It is subject to a range of interpretation, from a requirement upon polluters to pay the costs of monitoring and management, through the requirement to pay the costs of clean-up, to the responsibility to pay for the cost of environmental damage as well as that of clean-up. Applying the principle may be simple or complex, depending on the nature of the environmental effects. Environmental economic assessment, and some form of economic planning instrument, are required in order to meet this principle.

1.3.2 Integration and co-ordination

By definition integrated coastal management implies a greater level of integration than is typical of more conventional approaches. The rationale for this, especially in relation to aquaculture, has been clearly stated above.

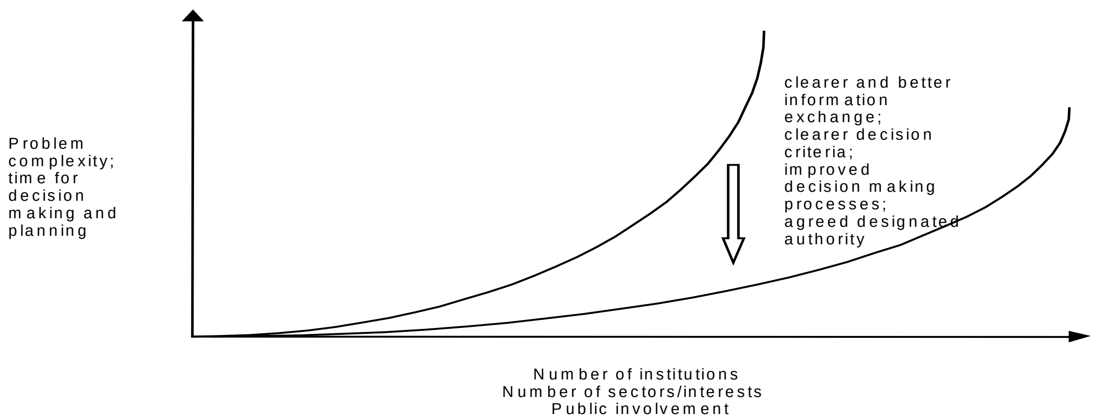
Integration implies the involvement of a broad range of institutions in the decision making process. It implies the involvement of a wide range of stakeholders, with differing values, dealing with a wide range of development issues. It implies the facilitation of a broadened perspective on the part of these stakeholders. It implies an holistic analysis and synthesis of complex technical, social, economic and ecological information. It implies a correspondence between local initiatives and regional or national level policies, and vice versa. It implies better co-ordination between different sector policies. It implies increased cross-links between institutions, and/or new institutions.

Increased integration therefore implies increased complexity. Decision-making is likely to be slower and more difficult as the degree of integration increases. Figure 4 is a schematic representation of this problem, and offers some pointers as to how this complexity can be reduced, and decision making facilitated. Key requirements are:

- high quality, well presented and effectively communicated/exchanged information;
- clear and widely agreed decision criteria;
- clear and transparent decision making processes; and (if necessary)
- a clearly designated (and widely agreed) final authority and arbiter (whether individual or committee).

In the case of less ambitious local or enhanced sectoral initiatives, these problems are reduced, but the potential for real integration more limited.

Figure 4: Tackling the complexity generated by integration



1.3.3 Public involvement

Significant public involvement is a desirable and necessary part of any planning initiative. It takes different forms, all of which are important:

- communication of information: from decision makers, planners or technical specialists to other stakeholders, and vice-versa;
- participation: shared responsibility and decision making

Comprehensive public involvement is increasingly emphasised in any assessment or planning exercise for the following reasons (adapted from UNEP, 1996):

- planning makes assessments and judgements about issues of widespread public concern: the quality of life, the value of resources, and the trade-offs between different resource uses;
- many of the assessments are subjective, and can only be agreed and/or validated through the widest possible consultation;
- local people can provide essential information about local natural resources, their status, use and value (sometimes referred to as indigenous technical knowledge);

- early exchange of views on key issues allows for the identification of information needs and improved focus of survey or research;
- public involvement may also reduce conflict through the early identification and resolution of potentially contentious issues;
- widespread consultation may generate new ideas for development alternatives, and possibilities for zoning/siting, design, and mitigation of adverse environmental effects;
- the more participatory forms of public involvement allow otherwise under-represented groups access to the decision making process;
- public involvement may contribute to, and/or reduce, the costs of monitoring and quality control;
- by engaging all stakeholders in the evaluation and decision making processes, it creates a sense of accountability, ownership and responsibility; and
- it increases transparency and accountability in decision-making, and ultimately increases confidence in decision makers.

1.3.4 Assessment of costs and benefits

The costs and benefits associated with aquaculture or other developments are rarely assessed objectively or comprehensively. If planning is to have any success in terms of optimal resource allocation to aquaculture and other activities, assessments of this kind must be thorough.

This principle implies the need for risk assessment, as well as comparative and environmental economic appraisal of the full range of alternative development (or conservation) options or strategies, including non-aquaculture developments.

1.3.5 Estimation of environmental capacity

Environmental capacity is much quoted in relation to coastal aquaculture development. Although it is often difficult to quantify accurately, the concept is useful, and serves as a framework for the discussion of issues such as environmental standards, ecological processes, and the environmental values and perceptions of different stakeholders. It is dealt with briefly below (Section 1.5.5) and in detail in Section 2.4.

1.3.6 Emphasis on incentives rather than constraints

Regulatory approaches to the planning and management of aquaculture development often have limited impact, especially where aquaculture is small scale and widely distributed. Policing is in many cases difficult, costly, and unpopular. It may be made more effective if responsibility for design, implementation and enforcement is located at the proper administrative level, and full use is made of self-management and self-enforcement capacity by industry and farmers' associations.

Incentives, on the other hand, do not suffer from the problems of evasion and non-compliance, and in some cases can be used to stimulate innovation leading to more environmentally friendly technologies.

The use of economic instruments to influence both siting and operation holds considerable promise. Although some positive incentives may be costly, it should be possible to pay for them with negative incentives (e.g. taxes on undesirable locations, activities, technologies). However, regulation may nonetheless be necessary, and a balanced approach is required.

1.3.7 Control of effects rather than scale of activity

Many forms of regulation of aquaculture (and indeed other coastal activities) are related to scale – either the area of land or water directly used by aquaculture, or the total production. For example, in line with the precautionary principle, an upper limit may be placed on aquaculture production in a bay, estuary or lagoon.

This limits the potential economic development, while providing no incentive to improve the environmental efficiency of the operation. It would not, for example, provide an incentive for the use of low pollution diets. A limit on effects (for example the concentration of nitrogen in the water at critical times of year) would provide an incentive for improved environmental efficiency through technology or management, while also allowing for increased production.

However, there are some difficulties with this approach. The relationship between cause and effect may be only partly known or understood especially where multiple uses of the resource already exist.

1.3.8 Evaluation, iteration and adaptation

Evaluation, iteration (repeated cycles of research, assessment, consultation and planning) and adaptation are required to:

- allow for a steady refinement and improved understanding of physical, ecological, social and economic parameters and processes over time;
- allow for a steady refinement and improvement of the planning instruments (incentives and constraints) used to meet the objectives of the plan.

Integration implies the need to understand a wide range of physical, ecological, economic and social processes. These cannot all be addressed in a comprehensive manner at the start of a planning initiative – it could take many years. Public involvement and expert consultation must be used in the first place to help focus research and data collection. Once the plan is implemented, the need for new research or data, or the redundancy of some research or data, should be assessed, and research and monitoring adapted accordingly.

It is also likely that some of the planning instruments themselves will fail or be inefficient in terms of meeting the objectives of the plan, and they will need to be adjusted or changed.

In general it is better to build from modest and widely agreed initiatives and adjust or expand the scope of activities as required, in the light of thorough evaluation. This also allows for much more rapid implementation of the most important elements of the plan.

1.3.9 Effective institutions and representative organizations

The importance of institutional structures, roles and capacity cannot be over-emphasised. However, it is impossible to provide simple prescriptions for appropriate institutions and procedures without reference to specific contexts. An important part of any integrated planning initiative should therefore be an institutional analysis.

Institutional change is difficult and risky, especially where many different organisations are involved. Significant structural change should therefore be approached with caution. More modest changes to procedures, both within and between existing institutions, may be the most appropriate first step. Once the initiative is underway, the need or otherwise for more institutional change can be assessed. This again reinforces the principle of evaluation and adaptation discussed above.

Effective stakeholder representative organisations should facilitate the process of public involvement. Furthermore, such organisations may take active roles in the exchange and dissemination of information, and policy development. They are particularly important for minority or highly dispersed groups whose opinions may be difficult assess in public meetings or through survey.

1.4 Legal and institutional frameworks

The importance of legal, procedural and planning frameworks designed to facilitate sustainable aquaculture development is emphasised in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995; FAO Fisheries Department, 1997):

9.1.1 States should establish, maintain and develop an appropriate legal and administrative framework, which facilitates the development of responsible aquaculture.

9.1.3 States should produce and regularly update aquaculture development strategies and plans, as required, to ensure that aquaculture development is ecologically sustainable and to allow the rational use of resources shared by aquaculture and other activities.

The need for a clear and comprehensive legal framework has been explicitly recognised by all those countries that have become significant producers of farmed shrimp. At the FAO Technical Consultation on Policies for Sustainable Shrimp Culture (FAO, 1998) the following recommendation was made:

> *"Governments should have a legal framework which applies specifically to coastal aquaculture, including shrimp culture"*

and appropriate objectives for such a framework should be to:

- *"facilitate and promote the development of sustainable aquaculture practices;*
- *promote the protection of coastal resources;*
- *promote the contribution of aquaculture to food security, national and international wise."*

The approach adopted will depend on existing laws, traditions, and institutional structures. For example, an enhanced legal and institutional framework to promote planning for sustainable coastal aquaculture development could be built up around existing legislation and/or procedures for:

- sector planning;
- regional or district planning;
- watershed or coastal zone planning and management;
- environmental assessment.

The key point is to develop or adapt a system that allows for the comprehensive application of the principles set out in Section 1.3. Where the introduction of new legislation is difficult, or will cause excessive delay, *guidelines* for developing new initiatives may be introduced prior to specific legislation, as a means of testing out different approaches.

1.4.1 Ideal frameworks

The ideal is perhaps a "tiered" system, sometimes known as a "planning cascade" and exemplified in the coastal management policy and legislation of countries such as Australia and New Zealand (Box 1.6). Broad national level policies define the scope, power, and responsibilities for lower level assessment and planning initiatives relating to aquaculture, coastal, or aquatic resources. These more local initiatives (at district, coastal bay, estuarine system or watershed levels) may in turn define or feed back into higher level policy. National and local level policy and planning should evolve steadily in parallel, each informed by the other, and be progressively adapted and refined, with the overall objective of promoting or facilitating sustainable development, and/or constraining or preventing unsustainable development. Enhanced sector plans or more comprehensive ICM plans could be developed at national, regional or local level, depending on national circumstances. In general however, more locally developed initiatives will tend to be both simpler and more integrated. Such a framework would contribute significantly meeting the principles presented in Section 1.3.

1.5 The planning process

1.5.1 Main stages

The planning process is broadly similar irrespective of the administrative level at which it takes place, or the degree to which it is integrated.

A major international workshop on ICM in tropical countries, held in 1996 in Xiamen, China P.R., discussed lessons learned from successes and failures experienced with ICM efforts (GEF/UNDP/IMO, 1996). The workshop generated an overview of the processes of formulating, designing, implementing and extending ICM within the East Asian region as well as to other regions, and a set of *Good ICM Practices*. Their summary of the main stages of ICM is presented in Box 1.8.

This agrees closely with the outline presented by GESAMP (1996b). It is applicable to local and enhanced sectoral initiatives as well as to more integrated approaches. The whole process should be seen as part of a dynamic and repetitive cycle leading steadily toward more sustainable forms of coastal development in general, and coastal aquaculture development in particular.

Box 1.8: Main stages of Integrated Coastal Management

1. *Stage setting and Planning*
   - Issue identification and analysis
   - Definition of goals and objectives for this generation
   - Selection of strategies
   - Selection of implementing structures
2. *Formalisation*
   - Formal adoption of the program
   - Securing of implementation funding
3. *Implementation*
   - Development actions
   - Enforcement of policies / regulations
   - Monitoring
4. *Evaluation*
   - Analysis of progress and problems encountered
   - Redefinition of the context of coastal management

Reference: GEF/UNDP/IMO, 1996

1.5.2 Operational components

The first stage (stage setting and planning) can be broken down into a more detailed set of operational components, each of which may draw on a range of tools (Table 1.2). These components are not necessarily in chronological order. Indeed, it is highly desirable that components 1 to 5 take place in parallel, since each should serve to inform the scope and focus of the others. The tools associated with each stage may or may not be used according to local circumstances and the scope of the initiative.

The operational components, and the tools applicable to them, are described briefly below. The tools themselves, and their application to aquaculture development, are reviewed in more detail in Part 2.

It is apparent that the inclusion of all these components in any planning initiative is a formidable task. Attempts at more integrated planning for aquaculture development, and indeed ICM initiatives in general, have rarely encompassed all these elements. However, if the ideals of sustainable development are to be realised, the main operational components must be included, and facilitated where appropriate by the various tools available. The process can be made more manageable, and the research/information collection more focussed, if the principles of public involvement, evaluation, iteration and adaptation, as described in the previous Section, are applied at all stages of the process. Massive technical research and assessment exercises, however thorough, are unlikely to provide a sufficient basis for solving resource management problems, and should be used rather as an on-going input to a rolling and adaptive planning process.

The following Sections provide an introduction and outline of the main processes and procedures involved in the development of integrated approaches to coastal aquaculture development planning. Detailed descriptions and scientific review of the various tools referred to (introduced here in bold italics), and their specific application to aquaculture development, can be found in part 2.

Table 1. 2. Stage setting and planning:
operational components and associated activities and tools

Main component	Sub-components	*Possible associated activities and tools*
Initiation	1. Identifying the means/mechanism and level of planning	• *Review of relevant policy and legal framework;* • *Institutional analysis;* • *Stakeholder analysis*
	2. Gaining the trust, involvement and commitment of key stakeholders	• *Communication, consultation, participation;* • *Preliminary identification of funds*
Issue identification and analysis	3. Understanding the development context: natural and human resources and economy	• *Description and mapping* • *Analysis of physical and ecological processes* • *Assessment of environmental capacity and limits to change* • *Review of sector/regional economy* • *Understanding human resources, needs and values: public involvement and social survey;*
	4. Understanding the development options	• *Technical-economic assessment* • *Sector Environmental Assessment* • *Cost-Benefit Analysis* • *Environmental economic analysis*
Definition of goals and objectives	5. Defining goals and objectives	• *Stakeholder consultation;* • *Public involvement/participation*
Selection of strategies	6. Identifying development priorities and acceptable practices	• *Economic approaches to decision making* • *Consultative and participatory approaches to decision making* • *Conflict resolution*
	7. Defining broad development strategies (strategic planning)	• *Production and environmental targets (quantity and quality);* • *Criteria for locating activities;* • *Criteria for assessing activities;* • *Definition of zones (identification and/or allocation of suitable space/locations)*
Selection of implementing structures and instruments	8. Designing/agreeing planning and management instruments (incentives and constraints)	• *Infrastructure development* • *Training, education and awareness raising* • *Economic instruments* • *Regulatory instruments* • *Codes of practice* • *Markets and labelling*
	9. Building institutions and institutional capacity	• *Defining institutional arrangements* • *Institution building* • *Procedures*
	10. Monitoring, reporting, evaluation and response procedures	• *Physical and ecological monitoring* • *Social and economic monitoring* • *Synthesis and analysis of monitoring data;* • *State of the environment reporting;* • *Public consultation and participation;* • *Performance evaluation;* • *Management capacity assessment;* • *Outcome assessment* • *Mechanisms for adjustment and adaptation*

1.5.3 Identifying the mechanism and level of planning

Any attempt to improve the planning and management of aquaculture, either from a sectoral perspective or as a component in a broader integrated management exercise, must be initiated with great care. Such initiatives are likely to be seen as threatening to some stakeholder interests. The "who" and "how" of initiation can have a major impact on long term success.

There are four key elements or pre-conditions:

- a policy or legal framework which requires, facilitates, or (at minimum) allows for improved and more integrated planning and management;
- an organisation or body which can lead or oversee the planning process, which is widely respected and trusted by the stakeholders, and which can effectively "deliver" on the guiding principles presented in Section 1.3;
- an awareness of the need for improved planning and management on the part of the stakeholders; and
- adequate funding and/or staff time to undertake the process.

Where these conditions do not already exist, they must be created before any form of improved planning or management can be initiated.

A review of relevant policy and legal framework should be undertaken to determine what is possible, and how the initiative is to be taken forward. In the case of enhanced sectoral initiatives the analysis would normally identify the most appropriate mechanisms for consultation, exchange of information, and policy integration within the existing legal/institutional framework. It would also consider how the outcomes of the initiative could be implemented.

In the case of more ambitious and integrated initiatives, it may be useful to undertake ***institutional analysis*** and a preliminary ***stakeholder analysis***[5] to help in the choice or definition of an appropriate body to co-ordinate and oversee the planning and management process. This may be some form of committee, working group, or steering group including representatives of relevant government departments and agencies, industry and user groups and community representatives. It must be able to integrate technical and socio-economic information, including the needs and aspirations of stakeholders, and co-ordinate or implement interventions to meet coastal and aquaculture management objectives. This body would normally be convened and chaired by local or regional government, depending on the scale of the planning exercise.

The main tasks and responsibilities of the co-ordinating body would be to:

- clearly delineate the responsibilities of all involved in the different stages of the planning process, especially with regard to implementation;
- facilitate, and set in place procedures, for consultation between agencies and between agencies and other stakeholders;
- set in place procedures for the exchange of relevant information between different interests;
- set in place procedures for defining and implementing planning interventions;
- set in place procedures for monitoring the effectiveness of interventions in terms of overall ICM objectives;
- set in place procedures for adapting interventions in the light of experience;

Clearly funds must be identified, preferably from a range of cross-sectoral sources to maximise ownership of the initiative. In some cases a re-allocation of staff time (again, preferably cross sectoral) may be all that is required for the initial stages. Identification and raising of further funds would also normally be a responsibility of the co-ordinating body. In principle however, once the planning and management system is set up, and in the long term, it should be largely self-financing. The ways in which this can be done are dealt with in relation to specific management interventions discussed below.

---

[5] For more detail see Section 2.1

1.5.4 Gaining the trust, involvement and commitment of key stakeholders

The trust and support of key stakeholders is essential from the outset. This can be gained through consultation and public involvement (Section 2.2) and is closely related to the establishment of the co-ordinating or advisory body, and the openness of its deliberations.

Trust and support is likely to be lacking if the need for improved planning and management is not widely accepted, particularly by aquaculturists themselves. A series of public meetings and/or focus group discussions related to problems and potentials in aquaculture development, with a strong emphasis on more strategic development, may help gain support for the process, and serve as a useful input to any stakeholder and institutional analysis.

1.5.5 Understanding the development context

Key issues for improved management of coastal aquaculture may be social, environmental, technical, or economic. Identifying these issues implies a thorough understanding of both the development context (natural resources and ecology; human resources and economy), and the nature of actual and potential activities or developments (technical, economic, social and environmental characteristics). This can only be done effectively using an iterative and adaptive approach:

- assimilate existing information;
- identify key issues;
- identify further information and research needs;
- collect information and undertake research;
- refine key issues;
- etc.

Public involvement

Four basic approaches/tools[6] can be used to identify key players, collect information, identify issues and possible conflicts, and encourage participation and ownership:

- ***social survey***, supplemented with public information campaigns and limited public meetings;
- ***rapid appraisal*** (relatively informal but structured interviews and discussions with a wide range of stakeholders to gain information and understanding);
- ***participatory appraisal*** (wide-ranging exchange of views and information, with direct involvement of stakeholders in the decision making process);
- ***stakeholder consultative committees***

The first approach is the most traditional, but is difficult, costly, and sometimes misleading. The second and third approaches avoid many of the problems associated with social survey, especially in relation to values and quality of life issues. Rapid appraisal is by definition rapid and relatively cheap. Participatory approaches, since they directly involve people in the planning process, should lead to a greater and wider sense of ownership and responsibility, and therefore increase compliance with planning provisions or regulations at a later stage. However, participatory approaches have their own problems, including the cost and time required, and the difficulty of involving all relevant stakeholders.

More effective participation of coastal resource users may be facilitated through the establishment of user groups or organisations to represent particular interests on consultative committees, or in higher level decision making processes. It is notable that an ICM initiative in Ecuador (Robadue, 1995; Ochoa, 1995), by setting up consultative committees of resource user representatives, actually stimulated the establishment of user organisations. It is also notable that in Thailand the establishment of shrimp farmer associations has greatly enhanced shrimp farmer representation at meetings and on committees charged with developing aquaculture development policy. Even where a significant new planning and management initiative is lacking, the establishment of consultative committees may provide a basis for enhanced planning and decision making through existing procedures (Box 1.9).

[6] for more detail see Section 2.2.1

Box 1.9 Stakeholder involvement and natural resource inventories in the UK

In the United Kingdom there is no comprehensive coastal management framework. At least 240 organisations or institutions are involved, and 80 Acts of Parliament are relevant. Salmon farming has been treated as a rather unique activity because of its relation to the seabed, which is owned by the Crown Estate. It has not featured as a significant part of any comprehensive forward planning process, although desirable and undesirable zones for aquaculture have been defined, with specific requirements in terms of consultation.

However, a variety of local coastal management initiatives have been set up in recent years, supported by the government conservation agencies or local or regional councils. They have sometimes taken the form of "fora" for discussion, debate, and exchange of information between a wide range of organisations and stakeholders with an interest in a particular coastal area or estuarine environment. These fora have served as a stimulus to the collection and organisation of natural resource data in a variety of formats, including GIS.

Description and mapping

The collection and assimilation of data relating to natural and human resources has received widespread attention, and has been facilitated through the use of ***remote sensing*** (RS) and ***geographic information systems***[7] (GIS). The latter can be used to assimilate effectively pre-existing information (for example relating to soil or water), any new information collected using the social survey techniques described above, or any more specific information collected in response to identified research needs. GIS can also be used as an accessible database for monitoring information both before and during plan implementation. The scope of GIS is usually restricted to physical parameters, but attempts have been made to extend it to financial and economic parameters.

In the case of aquaculture, this stage or component is commonly closely linked to issues of site suitability and possible ***zoning***.

It is essential that mapping, description, RS and GIS are carefully focussed, and undertaken in parallel with, and guided by, discussions relating to issues identification and the setting of goals and objectives (see below). This is an example of the iterative and adaptive process described above: RS and GIS may help in the identification and clarification of key issues; but equally, the identification and analysis of key issues (e.g. through public consultation) should serve to define the focus and scope of RS and GIS. This can then further illuminate the key issues. Without constant feedback and adaptation of this kind, RS and GIS can get out of hand, and become themselves costly ends, rather than planning tools. There must also be a clear rationale and mechanism for their use and maintenance (Box 1.10).

Box 1. 10 ODA/Dinas Perikanan North East Sumatra Prawn Project : use of GIS/RS

A project whose focus was largely on shrimp disease evolved naturally into one with a focus on coastal management, through the recognition that the problems and potentials associated with shrimp farm development could not be tackled in isolation, but required a more integrated and planned approach, based on sound information about natural resources.

The project was effective in assimilating a large amount of relevant information on natural resources, socio-economic conditions, and financial and economic profiles of alternative coastal activities. It developed a comprehensive GIS, based on maps, ground survey and remote sensing.

Unfortunately, its initiation within Dinas Perikanan (the Fisheries Department) limited its influence in terms of wider coastal management issues, and the costs and skills associated with the GIS have been difficult to maintain since project completion. It has had little long term impact on coastal aquaculture development planning.

In this case GIS/RS became an (expensive) end in itself, rather than a carefully focussed tool used in support of a broader planning and management initiative.

References: McPadden, 1993; Hambrey, 1993.

---

[7] Section 2.3

Understanding physical and ecological processes

The coastal environment is dynamic. A static description of resources must be supplemented with an understanding of processes, dynamics, and interactions. This is particularly important for coastal aquaculture, which is often dependent on tidal regimes and hydrography, plankton communities and water quality, and soil, water and nutrient fluxes. This relates closely to issues of ***environmental capacity*** discussed below and in detail in Section 2.4.

In many cases a descriptive synthesis of existing knowledge will be adequate in the first instance. In the longer term, and relating to critical components in the system, it may be useful to develop physical models (such as nutrient flux models), ecological models, and ultimately systems models.

The development of the more sophisticated of these models is usually difficult and time consuming, and cannot be considered as a pre-condition for either enhanced sectoral or fully integrated coastal management. Rather, the scientific research, and any associated modelling effort, must evolve and focus in parallel with, and informed by, participatory approaches to issues and problem identification. Once a plan is implemented, thorough and regular evaluation should help identify or focus specific research and modelling needs, which can then be used as a direct input to the planning and management process.

Where physical or ecological issues are complex, or modelling capacity limited, it may be more convenient and cost effective to invest in an environmental monitoring programme, with basic parameters to be recorded (related to environmental objectives discussed below), and clearly defined (and widely agreed) response procedures.

Environmental capacity

Environmental capacity is a key concept in the idea of sustainable development (see, for example, Agenda 21, 1992 UN Conference on Environment and Development; GESAMP, 1991b; IUCN/UNEP/ WWF, 1991) and must therefore be addressed in any initiative designed to promote sustainable development.

Environmental capacity (otherwise referred to as assimilative capacity) is “a property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact”. Different mechanisms of impact can be identified for a particular situation, and the capacity of the environment to absorb each of these can be estimated.

Environmental capacity measures the resilience of the natural environment in the face of impact from human activities, and must be measured against some established standard of environmental quality. Understanding and measuring environmental capacity allows for the determination of the scale of activity (using a specified technology) which can be accommodated without threat to an environmental standard.

In the case of aquaculture, environmental capacity in relation to a specified area (e.g. a bay, lagoon, estuary, fjord or loch) might be interpreted as:

- the rate at which nutrients can be added without triggering eutrophication;
- the rate of organic flux to the benthos without major disruption to natural benthic processes; or
- the rate of dissolved oxygen depletion that can be accommodated without causing mortality of the indigenous biota (GESAMP, 1996a).

If environmental capacity can be determined, this opens the door to controls on effects, rather than activity – a key principle presented in Section 1.3. Furthermore, there arises the possibility of allocating or selling a share of environmental capacity, or a share of something which affects it (e.g. total acceptable pollution loading) to a particular user or user group. This is likely to offer an incentive to producers to modify technology or management so that production may be increased without exceeding the target. This contrasts with the use of area or production limits, which are directly restrictive, and offer no such incentive.

Environmental capacity is much easier to estimate for small semi-closed marine and brackishwater systems. Methods for estimating environmental capacity are reviewed in more detail in Section 2.4.

1.5.6 Understanding the development options

A comprehensive description of the technical, economic and resource use characteristics of different technical production systems or species ***(technical-economic assessment[8])*** is a prerequisite for the rational appraisal and comparison of the sustainability of different development options. It is essential for the clarification of key issues, and as a basis for any kind of strategic planning or market intervention.

The objectives for such an assessment are:

- to identify financially viable aquaculture and alternative production systems (in the short, medium, and long term);
- to provide resource use/transformation information which can be used for accurate environmental and social assessment, and cost benefit analysis;
- to provide "sustainability" profiles of alternative development options (summaries of social, economic and environmental characteristics) which can be used to inform participatory discussions and decision making.

Ideally such assessments would include, for each type of development:

- screening for technically feasible development options;
- market assessment;
- a description of suitable location and site requirements;
- standard financial analysis, investment appraisal and sensitivity analysis;
- a profile of resource use and waste output, including temporal or seasonal variations;
- a profile of socio-economic characteristics, including potential employment generation, labour seasonality, income generation and distribution, and barriers to entry (skills, capital, natural resources requirements);
- risk analysis
- synthesis - comparative economics and technical appraisal of different options;

This kind of information is commonly generated in respect of individual projects through feasibility studies and investment appraisal, although resource use and socio-economic characteristics are rarely specifically or adequately addressed. Nor are these studies commonly applied to a whole sector, or to a range of possible development options. Information is therefore usually inadequate for comprehensive and *comparative* environmental assessment, cost benefit analysis, and other formal decision making processes or techniques.

Each development option should also be assessed in terms of how, and to what extent, it might contribute to the objectives of the planning and management initiative. This will be easier if clear criteria for measuring progress against objectives have been agreed.

Site/location requirements

The identification and selection of suitable coastal aquaculture sites is critical not only to successful aquaculture practice, but also to the overall management of the coastal ecosystem.

Assessment of location and ***site suitability[9]*** is a key factor in technical, economic and environmental assessment of the aquaculture sector and individual aquaculture projects.

Site suitability, according to specified criteria, may form the basis for the control and management of aquaculture development and is discussed further under planning instruments below.

Key issues in practice

Although many different issues are likely to be identified, depending on local circumstances, resource allocation (of water, land, forest, reef etc) is a key issue that must be addressed as coastal resources become more and more scarce. This has both a technical and socio-economic dimension:

---

[8] Section 2.5
[9] Section 2.5.2

- what are the important resources?;
- how are they affected by aquaculture and other developments?;
- how should resources be allocated (to activities, individuals, organisations)?; and
- how should interactions and conflicts be resolved or controlled?

Resource use rights in many coastal areas are notoriously ambiguous, and clarifying rights and allocation procedures will commonly be a significant component in the planning process. Box 1.11 provides an example of what can happen in the absence of clear allocation procedures.

Rights allocation can be used not only as a tool for social development, but also as a means of regulation of aquaculture development, and should be thoroughly addressed early on in the planning process.

Box 1.11 Coastal aquaculture and resource allocation: the case of India

Shrimp farming in brackish-water ponds developed rapidly in India in the ’80s, based mainly on improved extensive and semi-intensive techniques. It was very profitable. In the late ’80s several large national and international corporations entered the sector with medium to large intensive operations. Access to fisheries was restricted in some areas, and there was local salination of ground and drinking water. There were also concerns about pollution.

Local fishermen began protests in the early ’90s. They and environmental activists took the issue to the High Court in Tamil Nadu, and restrictions were placed on brackish-water aquaculture. The conflict then spread to other States, and culminated in a Public Interest Writ submitted to the Supreme Court of India in 1994. A final judgement was made in December 1996 based on existing coastal zone regulation which banned all non-traditional aquaculture within 500m of the high water mark, or within 1,000m of Lakes Chilka and Pulicat. Existing farms within these zones were to be demolished by March 31st 1997. An Authority was set up comprising environmental and aquaculture interests led by a judge to administer the ruling, and assess compensation for pollution impacts. Workers laid off from demolished farms were also to be paid compensation under existing labour laws.

In practice demolition has been limited, but the industry remains in a highly uncertain state. Much employment and income generation has been lost. "Traditional aquaculture", which covers the largest areas, has not however been affected.

This kind of problem is extremely difficult to address once conflict has arisen and positions polarized. Facing up to difficult resource allocation issues in the early stages of planning, before contentious individual cases arise, is essential if this kind of problem is to be avoided.

Reference: Murthy, 1997

1.5.7 Definition of goals and objectives

Draft objectives can be developed during the course of general consultations and public involvement as described above, but it will normally be desirable to conduct meetings and workshops to finalise these objectives, bringing together both policy makers and resource users. Agreeing to clear and practical objectives within a reasonable time frame will be the first major test of the strength of the institutional arrangements for improved planning, and in particular the effectiveness of the co-ordinating body.

Higher level objectives or *goals* will relate to the main component ideas of sustainable development. Examples are given in Box 1.12. More ambitious and comprehensive integrated coastal planning initiatives may also include more complex goals relating to the quality of life, inter-generational equity, and poverty alleviation (Yap, 1996; Chua 1997; Gomez and McManus in GESAMP 1996b).

More practical and specific objectives should also be developed which directly address identified issues relating to these broader goals.

The scope and wording of objectives must be agreed at a local level, but some basic principles should be observed:

- objectives should be achievable; and
- progress toward objectives should be measurable.

This implies agreement on the ***criteria*** (e.g. nutrient concentration) that will be used for measuring progress or assessing impact, and specific ***targets* or *standards*** (e.g. xmg/l) to aim for over a specified time frame. These criteria and targets should relate to social, economic and environmental objectives While some may be very simple, others may be complex; for example, criteria for measuring optimal allocation of resources would be required if the first objective in Box 1.12 were to be adopted.

Box 1.12: Goals for planning and management initiatives designed to promote more sustainable aquaculture development

- to optimise the allocation of resources (especially land, water and labour) to aquaculture and competing activities or functions;
- to maximise the economic returns from aquaculture and other coastal activities;
- to minimise the environmental impact of aquaculture and other coastal activities;
- to minimise and/or resolve conflict; and
- to promote a more equitable distribution of benefits from aquaculture and other coastal development.

Standards and targets related to the various objectives of the planning initiative are essential if there is to be rational and consistent social, economic and environmental appraisal of alternative activities and possible planning interventions. They are also essential for monitoring and performance evaluation[10].

Economic targets may relate for example to per capita GDP, disposable income, trade surplus. ***Social targets*** may relate to health, education, equity or other quality of life indicators. ***Sector targets*** will typically refer to the levels of activity in different sectors (such as aquaculture) required to meet the broader social and economic targets. ***Environmental targets*** may constrain economic and sector targets, and may be a component in social targets. They may be of two kinds: area based, or quality based. Area related environmental targets (such as natural reserves) have been widely used, and represent the commonest form of ***zoning***[11]. ***Environmental quality standards***, such as acceptable concentrations of nutrients or pesticides in receiving waters, presence or absence of indicator species, species diversity, and other indicators of environmental quality, may also serve as planning targets.

Environmental quality standards are an essential component in the application of the concept of environmental capacity, and its use to define sector targets (see Box 1.13 below). Monitoring of environmental quality against targets and standards is also an essential component in ***State of the Environment Reporting***[12]***,*** which is required, for example, from individual States in Australia, and other forms of performance evaluation. Standards and targets are also a precondition for consistent assessment of significance in environmental impact assessment.

1.5.8 Identifying development priorities and preferred options

The information collected and assimilated, relating to both the development context and the nature of existing activities or development options, should provide a sound basis for the assessment of development alternatives (activities, technologies, operational practices) against planning objectives, standards and targets, and the selection of preferred options. This assessment should identify:

- undesirable or low priority activities/developments;
- desirable or high priority activities/developments;
- design, technology and management practices likely to maximise social, economic and environmental benefits from different activities;
- mitigation measures to minimise any adverse social or environmental impacts related to otherwise desirable activities or developments;

[10] Section 2.6
[11] Section 2.11
[12] Section 2.13

There are three main techniques or approaches for presenting, analysing, comparing and prioritising the alternatives:

- Environmental assessment;
- Cost Benefit Analysis;
- Participatory decision making

Ideally, all three approaches should be used, each informing the other.

Environmental Assessment (EA)

Environmental assessment[13] is a comprehensive format for the assessment of a development or set of developments. It brings together information about the development context and development issues with the technical-economic appraisal, allowing for a comprehensive assessment of the environmental and social effects of a proposed development, or development option, in a particular location. It has become a standard planning tool, with a significant impact on development decisions, and has been used widely in coastal management. In recent years increasing emphasis has been placed on integrating social and economic considerations into the EA process.

Unfortunately EA has commonly been applied on a project basis (usually referred to as EIA), and normally only to larger projects. Although such an approach is useful, and indeed essential for large business or infrastructure, it cannot address the incremental but cumulative social and environmental problems associated with large numbers of small agricultural or aquaculture developments. It has also often been applied in the absence of clear and agreed criteria (such as environmental quality standards) against which impacts can be assessed.

To be effective as a tool for more integrated coastal management, EIA should be applied to all sectors in the form of Integrated Environmental Assessment[14]. If this is beyond the scope of the planning exercise (e.g. in the case of enhanced sectoral initiatives) EA should be applied to the whole aquaculture sector, and should be used as a tool for strategic planning rather than as a regulatory instrument. If the resource and technology assessment as described above has been done thoroughly, this process should be relatively straightforward. The likely environmental and social impacts of a range of technologies or development options in different locations can be compared, and planning interventions to minimise environmental impact devised. Sector environmental assessment has the potential to become a standard tool for strategic planning.

EA typically assigns “significance” to social and environmental impacts. The level of significance is typically used as a decision criterion. It is therefore important that significance itself is measured against some consistent and objective standard. This implies the existence of social and environmental standards or targets against which significance can be measured.

The principles and practice of EA are similar whether applied to individual projects or to a “sector” and are now well established.

Economic analysis

Economic analysis provides a formal framework for comparing the multiple functions and uses of the coastal zone. In particular, it allows for a systematic evaluation of alternative uses, which in turn can lead to the identification of options for planners and decision-makers with regard to the allocation of resources (Gittinger, 1982; Mishan, 1982; Pearce and Nash, 1981). It may also provide a framework for a rigorous assessment of the costs and benefits of interactions between activities. In its more sophisticated forms it seeks to aggregate social, environmental and financial values relating to a particular enterprise or sector into a single index of *total economic value*, allowing for a standardised comparison of development alternatives. ***Cost Benefit Analysis***[15] provides an overall framework for the comparison of development options and is widely described in the literature. ***Environmental economic techniques*** allow for the inclusion of non-market or traded goods and services.

[13] Section 2.7

[14] See for example the frameworks proposed by GESAMP (1991a) and Chua (1997).

[15] Section 2.8

Although there are many advantages in bringing together all the diverse values within a single overall framework, these approaches should be treated with caution. They commonly require complex and sometimes questionable sets of assumptions. They should only be used when the methodology and underlying assumptions can be clearly explained to decision-makers. This may be difficult in the case of more participatory decision making, involving many individuals and interests with radically different educational levels.

Where comprehensive CBA and environmental economics are not used, simpler economic analyses can nonetheless shed light on specific issues such as the “costs” of pollution or habitat degradation associated with particular activities. Where such figures are difficult to estimate, it may be possible to provide information on the “opportunity costs” associated with *not* developing or polluting resources. In other words simple economic analysis can provide information on the nature of the “trade-off” between competing uses of coastal resources, which is vital for economically sound and well informed decision making.

Participatory approaches

There are a variety of decision-making techniques that avoid the problems of aggregating dissimilar values and quantities noted above. These rely on meetings, discussions or interviews to determine (and in some cases aggregate) values, and examine the trade-offs between different options. For example, some options may yield higher environmental benefits, while others yield higher financial benefits. Decision makers will generally seek to balance the two, essentially trading environmental benefit for financial benefit up to a point which reflects their relative valuation of financial and environmental benefit.

There are a variety of group/participatory tools that facilitate decision making of this kind, commonly referred to as ***multi-objective decision analysis***[16]. Most are based on ranking (which is usually much easier than assigning absolute values), or paired comparisons of development options against different decision criteria. Financial or money values are used to a variable degree according to the nature of the alternatives.

These approaches rely heavily on:

- effective communication of the various characteristics or possible values and impacts (economic, social, environmental) of different development alternatives - and the trade-off between them (i.e. how much is lost or gained of different benefits as the options are changed);
- clarification of development/environmental objectives and targets, so that development alternatives can be measured (and therefore valued) against them.

The use of such approaches necessarily encourages a more integrated assessment, and allows for a wide range of stakeholders to make an input to the decision making process.

Transparency

Given the technical difficulty and cultural subjectivity of assigning values, especially in respect of social and environmental issues, the key to both approaches is *transparency*. The assumptions lying behind any aggregate figures or trade-off calculation must be clearly understood by those involved in the decision-making process.

1.5.9 Conflict identification and resolution

Conflict between different resource users may already exist in the coastal zone. Indeed, an integrated planning initiative may be a response to this conflict. Where conflict does not already exist, it may actually arise during the planning process. Public involvement and participatory decision making, environmental assessment, cost benefit analysis, and other techniques which seek to identify and compare social, economic and environmental values, may bring into the open previously hidden differences in terms of development needs, and values and aspirations between different resource users and other stakeholders. For example, public consultation in relation to shellfish farming in Sweden, and shrimp farming in India and East Africa has led to serious conflict (Ellegard, 2000; Hambrey *et al*., 2000; Murthy, 1997).

---

[16] Section 2.9

Clearly this kind of conflict should be avoided as far as possible, and the way in which issues are presented for public consultation should be handled with great sensitivity. One important rule is to establish broad public agreement on overall development objectives, strategy, and decision criteria, before addressing specific development cases or projects. Trying to establish decision criteria on an ad hoc basis in relation to individual projects will inevitably polarise opinion.

This reinforces the need for comprehensive stakeholder participation in the initial setting of planning objectives, which should reduce the likelihood of conflict arising during the formulation and implementation of the plan. It may be that the outcome of any conflict resolution is in fact a tightening or reformulation of the planning objectives.

Should conflict nonetheless arise, a variety of approaches are available for its resolution[17], including ***litigation, arbitration, mediation, and negotiation***. The second two are usually more desirable than the first two. Litigation and arbitration both involve the imposition of a solution, and may not address or resolve the underlying causes of conflict, which may therefore re-surface at a later date. Mediation and negotiation on the other hand seek to resolve differences through an emphasis on common objectives.

1.5.10 Defining broad management strategy

The process of public involvement, agreeing broad objectives, and evaluating alternative development (and conservation) options, should provide a comprehensive information base for defining an overall planning strategy or framework.

Sector/activity targets

A significant part of strategic planning is the setting of targets relating to particular sectors or activities. Sector targets may be set in terms of *total output* (production and/or value), or *total allocation of resources* (e.g. zoning of land or water; allocation of environmental capacity). They may be set in relation to an entire coastal area, or in relation to specific zones as defined above.

Output targets have commonly been associated with planning in centrally planned economies, but with rather little emphasis on land or resource use, environmental effects and environmental capacity. In contrast, they have generally had a minor role in integrated coastal management, where the emphasis is typically on the resource base and environmental conservation.

As discussed above, environmental capacity assessment attempts to define the relationship between sector activity levels and environmental quality, and should therefore be of particular interest in strategic conservation planning. It is an important tool for integrating aquaculture into broader coastal planning and management initiatives. An outline for the use of environmental capacity as the basis for setting different kinds of sector target is presented in Box 1.13, and is discussed in more detail in Section 2.4.

Output targets may be associated with a resource allocation target – for example a particular level of production from a specific zone.

Criteria for locating aquaculture

A key component in the integration of aquaculture in strategic planning is an understanding of the specific needs of aquaculture in terms of ***site and location***[18] requirements. These should have been defined during the technical and economic assessment phase of the planning process. These requirements may be developed into a set of criteria which can be used as the basis for a variety of planning and management interventions (such as zoning, or screening development proposals) to influence location and siting of aquaculture activities.

[17] Section 2.10

[18] Section 2.5.2

Appropriate siting of aquaculture and other development activities in coastal areas will:

- minimise the risks to, and maximise the returns from, coastal aquaculture;
- maximise the overall economic return from all activities in the coastal zone;
- minimise conflict between aquaculture and other resource uses; and
- minimise environmental impact.

Box 1.13: Using environmental capacity and EQS as the basis for planning interventions

The following is an example of how environmental capacity can serve planning needs:

1. Define a specific area or zone in which aquaculture and compatible activities are to be allowed or promoted;
2. Set environmental quality standards (EQS) in terms of acceptable nutrient concentrations;
3. Estimate environmental capacity (e.g. total quantity of nutrients which can be released into the area without breaching EQS);
4. Calculate acceptable nutrient loads (the environmental capacity) that will not lead to breach EQS;
5. Develop incentives or regulations to prevent aquaculture and other activities exceeding the acceptable load. These might include:

    - allocation or sale of a portion of environmental capacity;
    - cessation of issue of permits once a critical total production threshold is reached;
    - cessation of issue of permits once an environmental quality standard is reached;
    - pollution tax related to quantity of discharge

The first of these has several significant advantages. The rules are clear. There is a cost associated with pollution, and a strong incentive to develop more environmentally friendly technology, which will allow for higher levels of production and economic activity while maintaining environmental quality.

The second and third are likely to cause frustration and possible conflict when they are introduced.

The fourth will be universally unpopular, and will be difficult to fine-tune to achieve the desired EQS.

Criteria for assessing aquaculture

A variety of other criteria for assessing the social, economic and environmental impact of individual projects or proposals should be developed, based on the planning objectives. They might, for example, relate to scale, design, technology, management, or labour relations. These might be used in support of the various planning instruments described below. For example, the assessment criteria could be used as the basis for credit or grant aid, for the issuing of permits, for screening proposals for environmental assessment, or as standard criteria to be used when undertaking environmental assessment.

Zoning

Zoning (Section 2.11) implies bringing together the criteria for locating aquaculture and other activities in order to define broad zones suitable for different activities or mixes of activities. GIS is particularly well suited to facilitating this task.

Zoning may be used either as a source of information for potential developers (for example by identifying those areas most suited to a particular activity); or as a planning and regulating tool, in which different zones are identified and characterised as meeting certain objectives (see for example Box 1.14).

Zoning of land (and water) for certain types of aquaculture development may:

- help to control environmental deterioration at the farm level;
- reduce adverse social and environmental interactions;
- serve as a focus for estimates of environmental capacity (see Box 1.13)
- serve as a framework for the provision or improvement of water supply/drainage infrastructure to small scale farmers.

The strength of zoning lies in its simplicity, its clarity, and its potential in terms of streamlining procedures. For example, once a zone is established and objectives defined, then developments that meet the objectives and general conditions for the zone may need no further assessment (such as EIA). What is allowed and what is not allowed is clear, and developers can plan accordingly. Any monitoring required can be applied to the whole zone rather than individual farms.

Box 1.14 An example of zoning for aquaculture

The Republic of Korea offers an interesting example of coastal management stimulated by the need to protect an aquaculture industry threatened by land based pollution. Environmental degradation in coastal waters led to significant problems in the oyster industry beginning in the 1970s. Habitat destruction affected spat settling areas, and eutrophication led to reduced water quality, red tides, reduced production, and occasionally direct toxic and health effects on shellfish and consumers. Oysters became difficult to sell for high quality export market.

These problems have been addressed in some areas through the declaration of *Clear Zones*, and establishment of appropriate water quality standards. The Clear Zones include four “Blue Zones”, associated with water quality standards designed specifically for the protection of aquaculture. The designation of these zones is integrated with controls on developments immediately adjacent to the zone, in addition to controls on development and land-use upstream within the watershed, ensuring the achievement of water quality standards required for the production of export quality oysters. Oyster producers may seek legal compensation from polluters for any related losses, and may seek compensation from government for losses related to wider environmental problems such as algal blooms or natural events. Equally, oyster producers are required to have a license and abide by siting and operational rules related to environmental capacity (in this case related to available food).

Whilst the zoning appears to have worked to a point, resulting in production and economic benefits from export quality oysters, there have been some problems to the oysters caused by red tides, arising from coastal eutrophication from non-aquaculture sources. This is an indication that - even with initially successful integration of aquaculture into coastal management - ultimate success may depend upon a much wider and more horizontally integrated coastal management process.

Reference Kim, 1995

Its weakness lies in its rigidity. No zone is perfect, land/water capability assessment may have been inadequate, boundaries are frequently arbitrary, and conditions may change. There may be small pockets of land or water of high potential for aquaculture, which were not recognised in the resource assessment process, which are not part of an aquaculture zone, and which are therefore prevented or subject to severe regulation. In some situations this could restrict access of poor people to the opportunities for aquaculture development. Furthermore, it may actually be undesirable to encourage a concentration of aquaculture in one particular area, however suitable it may be, because of the increased risk of rapid spread of disease.

1.5.11 Planning instruments: incentives and constraints

A wide range of actions may be undertaken to influence the nature, direction and location of development, so that the strategy can be implemented, and the planning objectives met. To be effective, these must be capable of serving as incentives for, or constraints to particular activities, forms of development, or the location of development. They might include (OECD, 1993):

- infrastructure development;
- training, education and awareness raising;
- economic instruments;
- regulatory instruments;
- codes of practice;
- markets and labelling; and
- improved institutional linkages

Many of these instruments work best in combination. Infrastructure, tax incentives, and regulations may all work together to achieve some particular objective. They may be associated with zoning to provide differential incentives (e.g. applied in some zones but not in others) and thus reinforce the zoning system.

Box 1.15 Infrastructure and services to promote sustainable aquaculture in Thailand

The Kung Krabaen Bay Royal Development Sudy Centre in Chantaburi province, Thailand, was founded in 1981 with the objective of increasing villager's income through the application of integrated environmental management practices. The area is surrounded by a mangrove fringe, behind which numerous small-scale shrimp farms have been established. In the high land between the bay and hill, rice fields and fruit orchards form the major component of the agro-ecosystem. The upland area is still covered with mixed forest, orchards and rubber plantations.

A significant activity of the project was to provide local poor farmers with the land and extension support to develop shrimp farming. A 1.6 ha plot was granted to each of 100 farmer households, of which 0.96 ha was for three ponds (0.32 ha each), 0.16 ha for dikes and ditches and 0.48 ha on the seaward side for houses and mangrove plantation.

Most of the farmers have been successful, with production rates generally in the range of 5-10MT/ha/yr, providing a very high net income relative to their previous agricultural activities. The incidence of disease has however increased in recent years, with declining earnings and significantly increased risk.

This has been blamed in part on poor water quality, causing stress and increased susceptibility to disease. It may also be related to the partial mixing of influent and effluent, allowing for the rapid spread of disease.

The Centre provides a variety of services to farmers, including seed, veterinary services, and technical advice. Recently, a sea-water irrigation system has been completed, comprising a water intake on the open coast (outside the bay) and pumping facility to supply a network of supply canals. It also includes provision for rationalizing effluent canals, and water treatment prior to discharge into the Bay. The objective is to provide high quality, low pathogen water to all farms within the project, thus maximizing shrimp health and minimizing disease. Water treatment, and an overall flushing of water, should also lead to improved water quality within the bay, thus reducing possible environmental impact on fish and shrimp nursery grounds in the bay.

Infrastructure and services

Infrastructure development may be used to improve the performance of aquaculture in particular locations, minimise environmental impact, and reinforce zoning by offering a comparative advantage to farmers who operate within the zone[19].

For example, new or improved water supply and wastewater treatment for aquaculture (such as that described in Box 1.15) may make a significant contribution to sustainability. They may:

- reduce problems associated with existing aquaculture developments (such as exposure to pollution from upstream industry, agriculture and domestic sources; the rapid spread of disease between farms; downstream pollution associated with aquaculture effluents);
- pre-empt such problems arising in relation to new developments; and
- influence the location of new aquaculture development, with a view to ensuring that it is located in areas where it is most likely to succeed, and where conflicts with other activities or resource users are minimised.

The provision of improved marketing and processing facilities, or the provision of infrastructure to stimulate more rapid development of private sector services, may also have a significant influence on the success and location of new aquaculture development. Access to credit (see below) may also be considered as a form of infrastructure or service.

Training, education and awareness raising

There is growing awareness of the importance of environmental issues, but this awareness is "patchy" and may be inadequate in areas experiencing very rapid development. Raising environmental awareness will reinforce the impact of specific incentives or constraints.

Research, extension services and training can be used to influence the sustainability of the sector, by offering information and advice about environment friendly technology and practice, or advising on site selection.

Economic approaches and instruments

There is increasing interest in the use of economic incentives and constraints to promote environmentally and socially friendly aquaculture siting, design and operation. Most measures of this

[19] Sections 2.11 and 2.12

kind require legislation and implementation at provincial or national government levels. Their use in relation to aquaculture (which has been limited to date) is therefore discussed in some detail in Section 2.12.2

Economic instruments include:

- access charges (e.g. to sites or space);
- pollution charges;
- tradable permits for resource use, harvesting rights, pollution/emission rights (the latter may take the form of rights to a share of environmental capacity);
- various forms of subsidy and/or credit for environment friendly location, technology or management;
- refundable deposits and bonds laid against possible environmental damage, or set aside for restoration purposes;
- process or product standards linked to labelling and marketing initiatives.

Economic instruments appear to have many strengths. They:

- can be used to directly implement the polluter/user pays principle;
- require little in the way of enforcement (they influence farmers directly through their effect on profits);
- promote innovation (since less pollution is associated with lower costs);
- are flexible and efficient;
- may not require farm specific information on operation or discharge (a major problem with many regulatory approaches);
- can be linked to environmental capacity;
- can be used to address cumulative problems; and
- can generate government revenue for environmental management.

They also have weaknesses:

- the actual effects on farmer behaviour are not very predictable;
- they may need sophisticated institutions (to define; monitor; adjust, adapt etc);
- they are not always popular with government agencies, since they imply less direct control;
- they are not always popular with industry, since (negative instruments) imply extra costs.

To date these instruments have been little used to influence the course of aquaculture development and deserve serious consideration. It is probable however that regulatory instruments will still be required to complement these approaches.

Regulatory instruments

Regulation has been commonly used in an attempt to manage the development of and impacts from aquaculture. This has succeeded in many instances, especially in developed countries, but has a rather poor record in many developing countries where the enforcement of regulation may be particularly difficult.

Regulation may include any or all of the following:

- restrictions on location. For example some zoning schemes may explicitly bar certain types of development or activity;
- prohibition of specific activities, materials or technologies (for example prohibition on the use of specific chemicals or antibiotics);
- requirements for specific activities, technology or design (for example, requirement for settling ponds in intensive shrimp culture; prescribed feed quality);
- effluent standards (e.g. acceptable N, P, BOD; TOC, chemical residues etc);
- receiving water standards (e.g. acceptable N, P, BOD; TOC, chemical residues etc);

These may be stand-alone regulations, or may be directly linked to registration, licensing or the issue of permits.

Many regulations are difficult to implement in practice, and may lead to an attitude of limited responsibility by the farmer. Their use should be limited as far as possible, but they remain an important last resort, and may serve to reinforce more positive incentives and economic instruments.

Codes of practice

Where the rationale for regulation is clear, and particularly when it relates to the interests of farmers themselves (for example where it is designed to minimise self pollution, or exchange of pathogens between farms), every effort should be made to promote self-regulation through codes of practice. These may be reinforced through peer pressure, and in some cases actually enforced by associations of farmers themselves. In Thailand for example (Box 1.16), the Surat Thani Shrimp Farmers Association has agreed to its own set of standard procedures related to water quality and disease management for a group of neighbouring farms with common water supply.

Codes of practice, including best management practice, may be used as a basis for ***certification and quality labelling***[20] .

Box 1.16: Farmer associations and self regulation

The Surat Thani Shrimp Farm Association have agreed to set regulations to minimise the impact among the members of their shrimp farm cluster area:

(i) The timing for pumping and discharge water into the canal are set daily. This practice has the benefit of maximising seawater quality and minimising the impact of discharge water.

(ii) The national regulation concerning pond sludge disposal, allows the association to prohibit any farmer from using pumps for pond sludge disposal.

(iii) In case of an occurrence of disease, especially virus disease, in culture ponds, the farmer must clean the ponds and settle suspended solids before pumping or discharging water. This practice should reduce the likelihood of a wider disease outbreak.

Markets and labelling

Farm gate price has a major impact on farmer behaviour. If this price can be linked in any consistent way to better siting and management of aquaculture operations, change will follow rapidly. Quality or “green” certification and product labelling offer significant opportunities, albeit relatively untested, in this regard.

However, the benefits from such schemes may accrue largely to the wholesaler or retailer rather than the producer, and directly linking farm gate price to environmental management will not be easy. Furthermore the process of certification is difficult and costly, and the impact on price will depend on consumer trust of the certification system. These approaches may also be easier for larger scale and well organised producers, with consequent difficulties for small scale producers.

1.5.12 Monitoring, reporting, evaluation and response/adaptation procedures

These four activities are brought together in this Section because they are intimately related and cannot be considered in isolation from each other.

Monitoring

A broad range of monitoring is required to provide information for evaluation of the overall success or otherwise of the plan, and the reasons for success or failure of individual components. The former may be relatively straightforward, but the latter implies a thorough understanding of the operation of the plan in practice, and the functioning of physical, ecological and human systems.

[20] Section 2.12.2

A monitoring program may collect information on:

- Indicators relating to specific objectives of the plan (for example, environmental quality; biodiversity; living standards; productivity; income distribution; economic activity). These are sometimes known as outcome indicators;
- Indicators relating to the efficiency or effectiveness of the planning procedures. These may relate more directly to the performance of individual components and implementing mechanisms of the plan and those associated with them (performance indicators).

If the latter are found to be wanting, it may be appropriate to initiate some form of ***management capacity assessment***[21].

The outcome indicators should be designed and serve not only to measure success in meeting objectives, but also to enhance understanding of physical, ecological and economic systems , and the causal links between development activity and environmental effects. Many gaps in knowledge and understanding in these areas will have been highlighted in the assessment phase, and long term monitoring of key variables and parameters may be required to better understand the dynamics of physical, ecological and economic systems, so that planning and management can be further improved.

More detailed discussion of ecological and other forms of monitoring in relation to aquaculture can be found in Section 2.13.

Public involvement

The general public, and other stakeholders, should be encouraged to take an active part in monitoring, and may effectively supplement more formal monitoring procedures. This will also maintain the participatory dimension of the plan, and encourage broad responsibility for meeting the objectives of the plan.

Response procedures

Monitoring of specific environmental or socio-economic indicators is of limited use if it is not linked to a pre-determined management response in the event that the monitored variables are found to lie outside their acceptable limits. There should be *a priori* agreement about the action that will be taken if, for example, environmental impacts exceed predicted levels. This action might take the form of a reduction (where monitoring indicates that environmental capacity has been exceeded) or increase (where capacity is under-utilised) in (for example) number of farms, allowable waste emissions; stocking density, or production.

Synthesis and reporting

It is equally clear that monitoring must include effective synthesis, analysis, reporting, and effective communication of monitored parameters and variables, so that agreement can be gained on any specific response, or adaptation of the plan. Reporting procedures and response mechanisms must be clearly spelt out in the plan.

State of the Environment reporting is desirable in order to synthesise, rationalise, integrate and communicate the wide range of monitoring information generated from different activities and environmental management initiatives. It is a key component of more integrated approaches. It should be developed as a format for reporting, which may also be used at higher levels of government or as a guide to research activity.

Evaluation and adaptation

As noted repeatedly, any new plan is likely to be inadequate and in some cases flawed, and clear procedures must be established for more general evaluation, including subjective assessments, coupled with specific procedures for adapting or changing the plan. This could take the form of "stakeholder committees", public meetings or other specified consultation procedures, and possibly periodic evaluations by external consultants. Once again it is clear that these committees must have access to well presented and analysed monitoring data, as well as more subjective assessments and

[21] Section 2.13

submissions. They must also have the power to modify the plan as required, on a regular (and clearly defined) basis.

1.5.13 Institutional arrangements and implementing structures

Although institutional issues will have been addressed at the outset, it will be necessary to reconsider institutional needs for effective implementation, following detailed consideration of development options and planning and management needs.

As noted above and in many other publications (e.g. Chua, 1997; FAO, 1996; Post and Lundin, 1996), institutional arrangements for implementing, monitoring and adapting a coastal management plan are rarely afforded sufficient emphasis. Actual arrangements will vary tremendously according to local and national circumstances, but there are a few simple rules:

- responsibilities for implementation must be clearly allocated to particular institutions and individuals;
- overlapping responsibilities between agencies should be minimised;
- institutions must be able, willing and allowed to implement or administer the incentives and constraints contained in the plan;
- there must be co-ordinating and integrating institutions - which may take the form of institutional procedures; or particular agencies or individuals with a co-ordinating role;
- the institutional responsibilities must be defined within, or allowed for by, a legislative framework.

It is clear that any comprehensive and integrated planning initiative will require a competent lead agency or powerful co-ordinating committee to compile the information, synthesise the various points of view, develop a strategy, design planning instruments or actions, and ensure that they are implemented. An example is presented in Box 1.17.

Box 1. 17 Xiamen demonstration project

Xiamen is a modern maritime and scenic city in Fujian Province, China. Xiamen is designated as a special economic zone, and development has been very rapid in recent years. This has resulted in severe space competition; resource use conflict; pollution; degradation of natural habitat; siltation; and erosion. The area was chosen for a demonstration project under the GEF/UNDP/IMO Regional programme for the Prevention and Management of Marine Pollution in East Asian Seas.

A steering group for integrated coastal management in Xiamen Municipality was established with the Mayor or Deputy Mayor of the municipality as chairperson. This group oversees the Office of the Steering Group which is essentially the wing of municipal government responsible for coastal management. A consultative committee for Integrated Coastal Management provides advice and scientific and technical services. Together these bodies are responsible for:

- medium and long term plans on coastal development, infrastructure development and protection;
- coastal functional zonation schemes;
- coordination and formulation of local regulations, rules and standards concerning ICM;
- organization and coordination of various concerned sectors in discharging their respective mandates and law enforcement relating to ICM;
- deciding on the major issues pertaining to coastal development, infrastructure and management;
- coastal monitoring, surveillance, information management;
- review and endorsement of coastal development projects;
- public awareness activities for ICM;
- guidance to district level government on ICM.

One of the key factors in the success of the project to date appears to have been strong Municipal Government which has, for example, enacted legislation related to functional zoning, and which is sufficiently powerful to effectively co-ordinate the (12) sectoral administrations involved in coastal management.

Source: GEF/UNDP/IMO, 1996

1.5.14 Formal adoption of the plan

A written draft plan should be produced including at least the following:

- an analysis of social, economic and resource/environment issues;
- agreed objectives with associated standards and targets;
- a broad strategy and principles to meet these objectives;
- planning actions and instruments (incentives and constraints) to guide development and practice in order to meet the targets and fulfil objectives;
- procedures for monitoring, feedback and adaptation
- an estimate of costs and revenues related to the plan for each year for the duration of the plan;
- responsibilities and commitments of key participants/players

Whatever the level of public involvement in the formulation phase, it is essential that the plan is agreed and receives broad support from all stakeholders, and especially from those likely to be most affected. A wide range of public involvement techniques may be used to finalise and agree the plan, after which it can be formally adopted.

However participatory the process, it is nonetheless likely that some elements of the plan may be unpopular with a minority. In this case the procedures for implementation – and in some cases enforcement – must be studied very carefully.

1.5.15 Implementation and adaptation

If the procedures described above have been followed, and in particular, if the planning instruments have been carefully selected and their implementation thought through, then the implementation, reporting and monitoring, adaptation and refinement, *should* flow smoothly.

However, planning and management is about modifying, co-ordinating and in some cases integrating the behaviour and actions of varied individuals, groups and organisations, and this requires great management skill. It is beyond the scope of this report to discuss organisational management or human psychology, but some key points can be made.

Finance is always likely to be a problem. Pooling of finances from several sources will not only help raise the required funds but will also involve a greater range of stakeholders. It is also essential to develop trust and commitment among the various players.

Other general rules include the need to be:

- realistic and patient;
- pragmatic and practical;
- flexible.

1.5.16 Criteria for evaluation of integrating aquaculture into coastal management

Evaluation of more integrated planning and management is vital. Planning and management is expensive, and its difficulty and complexity means that it is prone to “drift”. It is often ineffective, and it is important that poor performance is identified quickly and put right.

GESAMP in its 1996 Session recognised that:

> *“There is an urgent need for an accepted evaluation methodology for assessing the impacts of coastal management programmes so that their efficacy can be assessed and required changes identified and implemented. Indicators and methodologies are required for establishing timely baselines and appropriate monitoring and assessment programmes. When an evaluative framework is in place it will be possible to document trends, identify their likely causes and objectively estimate the relative contributions of ICM programmes to observed social and environmental change.”* (GESAMP, 1996c).

Since that time a study has been commissioned by UNDP to address these issues (Olsen *et al.*, 1997). It identifies three types of evaluation: *performance evaluation; management capacity assessment; and outcome assessment* (see Part 2). It also emphasises the potential of the pressure-state-response (PSR) framework (OECD, 1994) to *"structure the collection of data on the condition and trends in the natural environment and as a tool to assist policy makers in analysing the effects of public policies on the environment."*

There is no reason why evaluation criteria should differ when considering the management of aquaculture rather than any other coastal activity. Indeed it is essential to the philosophy of integrated coastal management that the success of the integration of aquaculture into coastal management be evaluated against the same criteria as those used for other activities.

In practice, the evaluation of any coastal planning and management initiative should be relatively straightforward, since a basic component of the planning process is the establishment of practical objectives and associated measures, standards or indicators, which can be used to measure progress against objectives.

It is worth noting that several of the approaches to the management of coastal aquaculture discussed here are particularly amenable to outcome assessment in terms of environmental quality. The assessment of environmental capacity, which has already been the subject of several studies related to aquaculture, necessarily implies a simple outcome criterion: environmental capacity, as defined during the planning process, shall not be exceeded. Equally, zoning approaches provide relatively clear benchmarks in terms of land use against which performance can be measured.

A manual for assessing progress in coastal management produced by Olsen *et al.* (1999) should be referred to for a detailed discussion and guidance.

1.6 REFERENCES

ADB/NACA, 1996. Aquaculture sustainability action plan. Regional study and Workshop on aquaculture sustainability and the environment (RETA 5534). Manila, Asian Development Bank; and Bangkok, Network of Aquaculture Centres in Asia-Pacific: 21 pp.

Bagarinao, T.U. & Flores, E.E.C. (eds), 1995. Towards sustainable aquaculture in Southeast Asia and Japan. Proceedings of the Seminar. Workshop on aquaculture development in Southeast Asia. Iloilo City, 26-28 July 1994. Iloilo City, The Philippines. SEAFDEC Aquaculture Department. 254 pp.

Bailey, C., 1988. The social consequences of tropical shrimp mariculture development. <u>Ocean Shorel.Manage.</u>, 11:31-44

Bailey, C., 1989. Shrimp mariculture development and coastal resources management: lessons from Asia and Latin America. <u>In</u> Olsen, S.B. & Arriaga, L. (eds). Establishing a sustainable shrimp mariculture industry in Ecuador. Kingston, Rhode Island, University of Rhode Island, Coastal Resources Center, pp. 45-70

Bailey, C., 1997. Aquaculture and basic human needs. <u>World Aquacult.</u>, 28(3): 28-31

Bailey, C. & Skladany, M., 1991. Aquaculture development in tropical Asia: a re-evaluation. <u>Nat.Resour.Forum.</u>, 15(1):66-71

Bardach, J.E. (ed.)., 1997. Sustainable aquaculture. New York, John Wiley & Sons, 251 pp.

Barg, U.C., 1992. Guidelines for the promotion of environmental management of coastal aquaculture development (based on a review of selected experiences and concepts). <u>FAO Fish.Tech.Pap.</u>, (328): 122 pp. (issued also in French and Spanish)

Barg, U. & Phillips, M.J., 1997. Environment and sustainability. <u>FAO Fish.Circ.</u>, (886) Rev. 1:55-66

Barg, U.C., Bartley, D.M., Tacon, A.G.J., & Welcomme, R.L., 1997. Aquaculture and its environment: a case for collaboration. <u>In</u> Hancock, D.A. et al (eds), Developing and sustaining world fisheries resources: the state of science and management. Proceedings of the Second World Fisheries Congress. Collingwood, Victoria, Australia, CSIRO, pp. 462-70

Beveridge, M.C.M., Phillips, M.J. & Macintosh, D.J., 1997. Aquaculture and the environment: the supply of and the demand for environmental goods and services by Asian aquaculture and the implications for sustainability. <u>Aquacult.Research</u>, 28:797-807

Black, E.A.,1991. Coastal resource inventories: a Pacific coast strategy for aquaculture development. <u>In</u> De Pauw, N. & Joyce, J. (eds). Aquaculture and the environment. <u>Spec.Publ.Eur.Aquacult.Soc.</u>, 16:444-50

Chamberlain, G. & Rosenthal, H.,1995. Aquaculture in the next century: opportunities for growth - challenges of sustainability. <u>World Aquacult.</u>, 26(1):21-5

Chua T.-E., 1997. Sustainable aquaculture and integrated coastal management. In Bardach, J.E. (ed.), Sustainable aquaculture. New York, John Wiley and Sons, pp. 177-99

Chua, T.-E. & Fallon-Scura, L. (eds), 1992. Integrative framework and methods for coastal area management. ICLARM Conf.Proc., 37:169 pp.

Chua, T.-E., Paw, J.N., & Guarin, F.Y., 1989. The environmental impact of aquaculture and the effects of pollution on coastal aquaculture development in Southeast Asia. Mar.Pollut.Bull.,20(7):335-43

Cicin-Sain, B. & Knecht, R.W., 1998. Integrated coastal and ocean management: concepts and practices. With support from the Intergovernmental Oceanographic Commission UNESCO and the Graduate College of Marine Studies of the University of Delaware. Washington, D.C. Island Press, 517 pp

Cicin-Sain, B., Knecht, R.W. & Fisk, G.W., 1995. Growth capacity for integrated coastal management since UNCTED: an international perspective. Ocean Coast.Manage., 29(1-3):93-123

Clark, J.R., 1992. Integrated management of coastal zones. FAO Fish.Tech.Pap., (327):167 pp. (issued also in Chinese)

Clay, J.W., 1997. Toward sustainable shrimp culture. World Aquacult., 28(3): 32-37

Davos, C. A., 1998. Sustaining cooperation for coastal sustainability. J. Environ.Manage., 52:379-87

Ellegard, A., 2000. Stakeholder and conflict analysis regarding mussel culture on the western coast of Sweden. In Man and coastal areas towards a sustainable aquaculture. Final report of the European Workshop for a sustainable development of aquaculture, edited by Service Scientifique et Technologique, Ambassade de France, et al. Presence scientifique française en Suède. Stockholm, Moderna Grafiker AB, pp. 45-49

FAO,1995. Code of Conduct for Responsible Fisheries. Rome, FAO, 41 pp. (issued also in Arabic, Chinese, French and Spanish)

FAO, 1996. Integration of fisheries into coastal area management. FAO Tech.Guidel.Responsible Fisheries, (3):17 pp (issued also in French and Spanish) .

FAO, 1998. Report of the Bangkok FAO Technical Consultation on policies for sustainable shrimp culture. Bangkok, Thailand, 8-11 December 1997. Informe de la Consulta Técnica FAO/Bangkok sobre politicas por el cultivo sostenible del camarón. Bangkok, Tailandia, 8-11 de diciembre de 1997. FAO Fish.Rep./FAO Inf.Pesca, (572):31 pp.

FAO, 1999. Papers presented at the Bangkok FAO Technical Consultation on policies for sustainable shrimp culture. Bangkok, Thailand, 8-11 December 1997. Documentos presentados a la Consulta Técnica FAO Bangkok sobre politicas para el cultivo sostenible del camarón. Bangkok, Tailandia, 8-11 de diciembre de 1997. FAO Fish.Rep./FAO Inf.Pesca, (572) Suppl./Supl. 266 pp.

FAO, 2000. Aquaculture production 1998. General notes: the definition of aquaculture (p.3). FAO Yearb.Fish.Stat.Aquacult.Prod., (86/2):169 pp.

FAO, 2001. Aquaculture production: Quantities 1970-1999, and Values 1984-1999 (included in Fishstat Plus Version 2.3: universal software for fishery statistical time series). FAO Fishery Information, Date and Statistics Unit.
Ftp.fao.org/fi/stat/windows/fishplus/aquaq.zip; Ftp.fao.org/fi/stat/windows/fishplus/aquav.zip

FAO Fisheries Department, 1997. Aquaculture development. FAO Tech. Guidel.Responsible Fisheries, (5):40 pp. (issued also in French and Spanish)

FAO/FIRI (Inland Water Resources and Aquaculture Service),1997. Review of the state of world aquaculture. FAO Fish.Circ., (886) Rev.1:163 pp.

FAO/NACA, 1995. Report on a Regional Study and Workshop on the environmental assessment and management of aquaculture development (TCP/RAS/2253). Bangkok, Network of Aquaculture Centres in Asia-Pacific. NACA Environ.Aquacult.Dev.Ser., (1):492 p.

GEF/UNDP/IMO, 1996. Enhancing the success of integrated coastal management: good practices in the formulation, design and implementation of integrated coastal management initiatives. Quezon City, Philippines, GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas and Coastal Management Center. MPP-EAS Tech.Rep., (2):32 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1986. Environmental capacity: an approach to marine pollution protection. Rep.Stud.GESAMP, (30):49 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1991a. Reducing environmental impacts of coastal aquaculture. Rep.Stud.GESAMP, (47):35 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1991b. Global strategies for marine environmental protection. Rep.Stud.GESAMP, (45):34 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1995. Biological indicators and their use in the measurement of the condition of the marine environment. Rep.Stud.GESAMP, (55):56 pp. (issued also in Russian)

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1996a. Monitoring the ecological effects of coastal aquaculture wastes. Rep.Stud.GESAMP, (57):38 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1996b. The contributions of science to integrated coastal management. Rep.Stud.GESAMP, (61):66 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1996c. Report of the twenty-sixth session. Paris, 25-29 March 1996. Rep.Stud.GESAMP, (60):29 pp. (issued also in French, Spanish and Russian)

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1997. Towards safe and effective use of chemicals in coastal aquaculture. Rep.Stud.GESAMP, (65):40 pp.

Gittinger, J.P., 1982. Economic analysis of agricultural projects. Baltimore and London, Johns Hopkins University Press, 505 pp.

Gomez, E.D. & McManus, L., 1996. Case study 4. Coastal management in Bolinao town and the Lingayen Gulf, the Philippines. Rep.Stud.GESAMP, (61):57-60

Hambrey, J.B., 1993. Comparative economics of different land-use options in the mangrove forest area of North Sumatra Province. Report prepared for NESPP/ODA and Direktorat Jenderal Perikanan, Indonesia, by Nautilus Consultants, Edinburgh, 60 pp.

Hambrey, J.B., Phillips, M.J., Chowdhury, M.A.K. & Shivappa, R.B., 2000. Guidelines for the environmental assessment of coastal aquaculture development. An environmental assessment (EA) manual to assist governmental agencies, coastal aquaculture developers, non-governmental organisations (NGOs) and community organisations. Maputo, Mozambique, Secretariat for Eastern African Coastal Area Management (SEACAM) 213 pp.

Hartwick, J.M., 1977. Intergenerational equity and investing of rents from exhaustible resources. Am.Econ.Rev., 66:972-4

Ibrekk, H.O., Kryvi, H. & Elvestad, S., 1993. Nationwide assessment of the suitability of the Norwegian coastal zone and rivers for aquaculture (LENKA). Coast.Manage., 21(1):53-73

ICES, 1997. Report of the ICES Working Group on Environmental Interactions of Mariculture. Weymouth, United Kingdom, 1-5 March 1997. Copenhagen, International Council for the Exploration of the Sea, Mariculture Committee, CM 1997/F:35 pp. plus annexes

IPCC (Intergovernmental Panel on Climate Change), 1994. Preparing to meet the coastal challenges of the twenty-first century. Conference report. World Coast Conference 1993. Noordwijk, The Netherlands, 1-5 November 1993. The Hague, National Institute for Coastal and Marine Management, Intergovernmental Panel on Climate Change (IPCC)

IUCN/UNEP/WWF, 1991. Caring for the earth: a strategy for sustainable living. Gland, Switzerland, IUCN/UNEP/WWF:228 pp.

Kryvi, H., 1995. Aquaculture in Norway: the use of areas - conflicting interests. In Reinertsen, H. & Haaland, H. (eds). Sustainable fish farming. Proceedings of the First International Symposium on sustainable fish farming. Oslo, Norway, 28-31 August 1994. Rotterdam, Balkema, pp.195-9

Lowry, K., Olsen, S. & Tobey, J., 1999. Donor evaluations of ICM initiatives: what can be learned from them? Ocean Coast.Manage., 42:767-89

Mäkinen, T. (ed.) et al., 1991. Marine aquaculture and environment. Copenhagen, Nordic Council of Ministers. Nord, (1991:22):126 pp.

McPadden, C.A., 1993. The Malacca Straits coastal environment and shrimp aquaculture in North Sumatra Province. NESPP/ODA in cooperation with Dinas Perikanan (N. Sumatra) and Directorate General of Fisheries, Indonesia. London, Department for International Development (DFID UK)

Mires, D., 1995. Aquaculture and the aquatic environment: mutual impact and preventive management. Bamidgeh, 47(3-4):163-72

Mishan, E.J., 1982. Cost-benefit analysis. London, George Allen & Unwin, 384 pp.

Muir, J.F., 1995. Aquaculture development trends: perspectives for food security. Contribution to the International Conference on the sustainable contribution of fisheries to food security, organized by the Government of Japan in collaboration with the Food and Agriculture Organization of the United Nations (FAO). Kyoto, Japan, 4-6 December 1995. Rome, FAO, KC/FI/95/TECH/4:133 pp.

Muir, J.F. 1996. A systems approach to aquaculture and environmental management. In Baird, D.J., Beveridge, M.C.M., Kelly, L.A. & Muir, J.F. (eds). Aquaculture and water resource management. Oxford UK, Blackwell Science, pp.19-49

Munday, B., Eleftheriou, A., Kentouri, M. & Divenach, P. 1992. The interactions of aquaculture and the environment: a bibliographical review. A report prepared for the Commission of European Communities. Directorate General for Fisheries. Brussels, Directorate General for Fisheries of the Commission of the European Communities, pag.var.

Murthy, H.S., 1997. Impact of the Supreme Court judgement on shrimp culture in India. INFOFISH Int., (3/97):30-4

NACA, 1996. The second five year programme of the Network of Aquaculture Centres in Asia-Pacific (NACA), 1996-2000. Theme: aquaculture sustainability. Bangkok, NACA, 27pp.

Nambiar, K.P.P. & Singh, T. (eds), 1997. Sustainable aquaculture. Proceedings of the INFOFISH-AQUATECH 96 International Conference on aquaculture. Kuala Lumpur, Malaysia, 25-27 September 1996. Kuala Lumpur, INFOFISH, 248 p.

Naylor, R. L. et al., 1998. Nature's subsidies to shrimp and salmon farming. Science (Wash.), 282(5390): 883-884

Nichols, K., 1999. Coming to terms with "integrated coastal management": problems of meaning and method in a new arena of resource regulation. Prof.Geogr., 51(3): 388-399

Ochoa, E., 1995. Manejo costera integrado en Ecuador. Guayaquil, Programa de Manejo de Recursos Costeros, 417 pp. http://crc.uri.edu.eccover.html

OECD, 1991. Report on CZM: integrated policies and draft recommendations of the Council on Integrated Coastal Zone Management. Paris, Organization for Economic Cooperation and Development.

OECD, 1993. Coastal zone management: integrated policies. Paris, Organization for Economic Cooperation and Development, 126 pp.

OECD, 1994. Environmental Indicators. OECD core set. Paris, OECD, 157 pp.

Olsen, S.B., Lowry, K. & Tobey, J., 1999. A manual for assessing progress in coastal management. Coast.Manage.Rep.Coast.Resour.Cent.Univ.R.I., (2211):56 pp.

Olsen, S.B. et al., 1997. Survey of current purposes and methods for evaluating coastal management projects and programs funded by international donors. Coast.Manage.Rep.Coast.Resour.Cent.Univ.R.I., (2200):28 pp.

PAP/RAC, 1995. Report of the Workshop on the selection and protection of sites suitable for aquaculture. Iraklion, Greece, 1-4 November 1995. Split, Croatia, Priority Actions Programme/Regional Activity Center (Mediterranean Action Plan-UNEP), PAP-10/EAM/W.2/1: 23 pp.

PAP/RAC, 1996. Approaches for zoning of coastal areas with reference to Mediterranean aquaculture. Split, Croatia, Priority Actions Programme/Regional Activity Center (Mediterranean Action Plan -UNEP). PAP-10/EAM/GL.1:35 pp.

Pearce, D.W. & Nash, C.A., 1981. The social appraisal of projects: a text in cost-benefit analysis. London, Macmillan, 225 p.

Pedini, M. & Shehadeh, Z.H., 1997. Global outlook. FAO Fish.Circ., (886) Rev.1: 30-37

Pernetta, J.C. & Elder, D.L., 1993. Cross-sectoral integrated coastal area planning (CICAP): guidelines and principles for coastal area development. A marine conservation and development report. Gland, Switzerland, IUCN in collaboration with World Wide Fund for Nature, 63 pp.

Phillips, M.J., 1995a. Aquaculture and the environment - striking a balance. In Nambiar, K.P.P. & Singh, T. (eds). Aquaculture towards the twentyfirst century. Proceedings of the INFOFISH-AQUATECH '94 International Conference on aquaculture. Colombo, Sri Lanka, 29-31 August 1994. Organized by INFOFISH and the Sri Lanka Export Development Board. Kuala Lumpur, INFOFISH, pp.26-55

Phillips, M.J., 1995b. Shrimp culture and the environment. In Bagarinao, T.U. & Flores, E.E.C. (eds). Towards sustainable aquaculture in Southeast Asia and Japan. Iloilo, The Philippines, SEAFDEC Aquaculture Department, pp.37-62

Phillips, M.J. & Barg, U., 1999. Experiences and opportunities in shrimp farming. In Svennevig, N., Reinertsen, H. & New, M. (eds). Sustainable aquaculture - food for the future. Proceedings of the Second International Symposium on sustainable aquaculture. Oslo, Norway, 2-5 November 1997. Rotterdam, Balkema, pp.43-72

Phillips, M.J. & Macintosh, D.J., 1997. Aquaculture and the environment: challenges and opportunities. In Nambiar, K.P.P. & Singh, T. (eds). Sustainable aquaculture. Proceedings of the INFOFISH-AQUATECH '96 International Conference on aquaculture. Kuala Lumpur, Malaysia, 25-27 September 1996. Kuala Lumpur, INFOFISH, pp.159-170

Pillay, T.V.R., 1996. The challenges of sustainable aquaculture. World Aquacult., 27(2):7-9

Pillay, T.V.R., 1997. Economic and social dimensions of aquaculture management. Aquacult.Econ.Manage., 1(1):3-11

Post, J.C. & Lundin C.G. (eds), 1996. Guidelines for integrated coastal zone management. World Bank Environ.Sustain.Dev.Stud.Monogr.Ser., (9):16 pp.

Pullin, R.S.V., 1993. An overview of environmental issues in developing country aquaculture. In Pullin, R.S.V., Rosenthal, H. & Maclean, J.L. (eds). Environment and aquaculture in developing countries. ICLARM Conf.Proc., (31):1-19

Rana, K.J., 1997. Status of global production and production trends. FAO Fish.Circ., (886) Rev. 1:3-16

Reinertsen, H. & Haaland, H. (eds.), 1995. Sustainable fish farming. Proceedings of the First International Symposium on sustainable fish farming, Oslo, Norway, 28-31 August 1994. Rotterdam, Balkema, 307pp.

Robadue, D. (ed.), 1995. Eight years in Ecuador: the road to integrated coastal management. Coast.Resour.Cent.Tech.Rep.Univ.R.I., (2088):319 pp. http://crc.uri.edu.eccover.html

Rohitha, W.R., 1997. Strengthening the institutional framework to promote coastal aquaculture in North Western Province, Sri Lanka. Masters thesis, Bangkok, Thailand, Asian Institute of Technology, 105 pp.

Rosenthal, H., 1997. Environmental issues and the interaction of aquaculture with other competing resource users. Aquacult.Assoc.Can.Spec.Publ., (2):1-13

Rosenthal, H. & Burbridge, P., 1995. Report of the ICES Workshop on principles and practical measures for the interaction of mariculture and fisheries on coastal area planning and management. Kiel, Germany, 19-22 July 1995. ICES Working Group on Environmental Interactions of Mariculture. Copenhagen, International Council for the Exploration of the Sea Mariculture Committee/FS:31 pp.

Rosenthal, H., Hilge, V. & Kamstra, A. (eds)., 1993. Workshop on fish farm effluents and their control in EC countries. Hamburg, Germany, 23-25 November 1992. Kiel, Germany, Institute of Marine Science, 205 pp.

Saenger, P., 1993. Some environmental aspects of aquaculture planning and operation. In Al-Thobaiti, S. et al. (eds). Proceedings of the First International Symposium on aquaculture technology and Investment opportunities. Riyadh, Kingdom of Saudi Arabia. Riyadh, Ministry of Agriculture and Water, pp. 590-600

Scialabba, N. (ed.), 1998. Integrated coastal area management and agriculture, forestry and fisheries. FAO Guidelines. Rome, FAO, Environment and Natural Resources Service, 256 pp.

Solow, R.M., 1986. On the inter-generational allocation of natural resources. Scand.J.Econ., 88:141-149

Sorensen, J., 1997. National and international efforts at integrated coastal management: definitions, achievements and lessons. Coast.Manage., 25(1):3-41

Stewart, J.E., 1997. Environmental impacts of aquaculture. World Aquacult., 28:47-52

Tacon, A.G.J., 1996. Trends in aquaculture production with particular reference to low-income food-deficit countries, 1984-1993. FAO Aquacult.Newsl. , (11): 6-9

Tacon, A.G.J., 1997. Contribution to food fish supplies. FAO Fish.Circ., (886) Rev.1: 17-21.

Tobey, J., Clay, J. & Vergne, P., 1998. A difficult balance: the economic, environmental and social impacts of shrimp farming in Latin America. Coast.Resour.Cent.Coast.Manage Rep.Univ.R.I., (2002)

Truscott, S.J., 1994. Capability studies for finfish and shellfish aquaculture as a prerequisite to coastal planning. In Wells, P.G. & Ricketts, P.J. (eds). Coastal zone Canada '94: cooperation in the coastal zone. Coastal Zone Canada Association Conference Proceedings. Dartmouth, Bedford Institute of Oceanography, Vol.1:1611-29

UNEP, 1995. Guidelines for integrated management of coastal and marine areas with special reference to the Mediterranean basin. UNEP Reg.Seas Rep.Stud., (161): 80 pp.

UNEP, 1996. Environmental impact assessment training resource manual. Prepared for the United Nations Environment Programme by the Environment Protection Agency, Canberra, Australia under the guidance and technical support of the UNEP International Working Group on EIA. Preliminary version June 1996. Nairobi, UNEP and Canberra, Australian Environment Protection Agency. 699 pp. (loose-leaved binder)

Videau, C. & Merceron, M., 1992. Impact de la pisciculture marine intensive sur l'environnement: revue bibliographique. Brest, France, IFREMER, 105 pp.

Wong, P.S. 1995. Hong Kong. In Report on a Regional Study and Workshop on the environmental assessment and management of aquaculture development (TCP/RAS/2253). Bangkok, Network of Aquaculture Centres in Asia-Pacific. NACA Environ.Aquacult.Dev.Ser., (1):113-139

World Bank, 1993. The Noordwijk guidelines for integrated coastal zone management. Paper presented at the World Coast Conference, 1-5 November 1993. Noordwijk, The Netherlands. Washington, DC, World Bank, Environmental Department, 21 pp. (mimeo)

World Commission on Environment and Development (WCED), 1987. Our common future. Oxford UK, Oxford University Press, 383 pp. (issued also in French and Spanish)

Wu, R., 1995. The environmental impact of marine fish culture: towards a sustainable future. Mar.Pollut.Bull., 31:159-66

Yap, H.T., 1996. Attempts at integrated coastal management in a developing country. Mar.Poll.Bull., 32(8/9):588-91

PART 2

TOOLS AND METHODS

Part 2 of this report is designed primarily for scientists and technical specialists who may draw on these methods in the course of their professional lives. It should also serve as a reference and resource for others with an interest in, or a need to understand the strengths, weaknesses and application of different approaches and techniques. **Part 1** should be read as background material, since it describes the context and rationale for the use of these tools.

It is beyond the scope of this report to review in detail all the individual tools and methods of relevance to more integrated coastal planning and management of aquaculture. Nor is this necessary: there already exist excellent reviews and guidelines that focus on particular tools and methodologies.

We therefore summarize the more generally applicable tools, comment on specific issues related to aquaculture, and refer the reader to more comprehensive reviews or guidelines where possible. The working group discussed some tools of particular relevance to aquaculture in more detail, and in this case the review is more thorough, and the main findings and recommendations of the group are presented. For example, particular emphasis is laid on zoning and environmental capacity, since these highlight particular problems and opportunities for integrating aquaculture into wider coastal management initiatives.

The structure of this Section is based loosely on the components presented in Table 1.2 and the overview of procedures presented in Section 1.5.

2 TOOLS AND METHODS

2.1 Institutional and stakeholder analysis

2.1.1 Institutional analysis

Institutional analysis is an essential part of any new planning and management initiative, especially where a greater degree of integration is sought. The nature and operation of institutions, and their mode of decision making, will have major implications for the implementation of any strategy or planning related to the promotion of sustainable development. The nature of the existing institutions should therefore be assessed, and new institutions, or frameworks for institutional collaboration and joint decision making, should be established if necessary. Great care should be taken with "model" institutional frameworks for more integrated planning. An institutional structure transformed to a new cultural context is unlikely to operate in the same way.

Institutional analysis related specifically to aquaculture and fisheries has been reviewed by Townsley (1996) , Pido *et al.* (1996), and Scialabba (1998). Only a brief summary will be provided here.

Institutional analysis covers both formal and informal institutions. Formal institutions are those such as government agencies, and they typically have a legally defined role, structure, and in some cases, sets of procedures. Informal institutions are those such as business, social or family networks or associations. The latter also have structure and sets of procedures, although these may have no legal or written basis. In either case institutional analysis requires that both structure and procedures are described and analysed. In essence this requires that the following questions be addressed in relation to any planning issue (such as land or water use):

- What are the rules?
- Who decides, and how (i.e. process and decision criteria)?
- Who implements, and how?
- How and when is progress assessed?
- What are the relationships between different institutions (formal and informal) ?

The main types of institution which are likely to be relevant to planning and management of aquaculture are:

- Local, district, provincial and national government (formal);
- Agencies and advisors of government;
- Formal and informal business associations;
- Non-governmental organizations (NGOs);
- Religious institutions;
- Town, village or commune decision making structures (formal and informal).

Townsley (1996) presents a summary of the institutions and levels to be considered and the specific tools which can be used to analyse them (Table 2.1). These tools are described in more detail below (Section 2.2.1).

Pido *et al*. (1996) present a set of guide questions which can be used as a framework for research, and as a basis for discussions and interviews.

Table 2.1: Institutional Issues: Rapid Rural Appraisal Tools (from Townsley, 1996)	
Community level institutions	• Venn diagrams showing membership, spheres of influence, overlaps and relative importance of different community institutions; • Decision trees for land distribution, water use and other community level decisions
Local administration	• Mapping areas of responsibility; • Venn diagrams of spheres of responsibility; • Flow charts of organizational structures; • Key informant interviews with local extension officers, local officials
Development support agencies	• Venn diagrams showing areas of activity of different development agencies, overlaps, membership; • Local peoples ranking of intervention by local agencies according to effectiveness and frequency; • Decision trees for local people regarding contacts with local institutions, requests for assistance; • Ranking of problems and priorities of different institutions and agencies; • Comparison of problem hierarchies of different agencies.
Effectiveness of aquaculture support agencies	• Local people's ranking of interventions by aquaculture extension services by effectiveness and frequency; • Decision trees for aquaculturists showing reactions to different problems: disease, input supply, etc – who they contact and why; • Comparative ranking of effectiveness of aquaculture and other support services – agriculture, forestry, fisheries, etc.

2.1.2 Stakeholder analysis

Stakeholder Analysis is related to institutional analysis, but places far more emphasis on individual motivation and/or collective interest, than on structures and procedures. It may be summarized as an approach to *understanding a system, and changes in it, by identifying key actors or stakeholders, and assessing their respective interests in that system.* It is of particular importance where competition for, or depletion of natural resources is an issue, and is therefore of great relevance to planning for sustainable aquaculture development. It is a necessary starting point for any kind of public involvement, since it will help to define who needs to be involved, and how.

Stakeholders are all those who have interest in the issues being addressed - as measured in terms of welfare or utility. Some are active – they *affect* the system; some are passive – they *are affected* by it.

They may be considered in detail because of their:
- importance – as possible beneficiaries of development;
- influence – their power over the success of project; or
- because they can be identified as winners or losers in the development process.

Stakeholder analysis seeks to:
- identify, assess and compare their sets of interest;
- examine inherent conflicts and/or compatibilities, and
- describe and explore trade-offs.

(Source: Grimble and Chan, 1995; Grimble and Wellard, 1997).

Exploring trade-offs (e.g. short term benefits of income from habitat destruction and conversion, versus long term benefits of biodiversity, storm protection etc.) as perceived by different stakeholders, is of particular importance, and is discussed further in Sections 2.9 and 2.10. It can be used as one method for assigning values and/or ranking objectives and development or management alternatives.

2.2 Public involvement

The widest possible range of stakeholders should be consulted or actively involved in the planning process, ideally following on from a stakeholder analysis. At minimum, the following should be actively involved:

- existing and potential fish farmers and other aquaculture industry representatives;
- the administering (sectoral) agency;
- the people, individuals or groups in local (affected) communities;
- specialist government agencies;
- NGOs and technical specialists;
- others, such as donors, banks, development agencies, academics

Whatever the particular mix of techniques used (Box 2.1) which may be suitable according to local circumstances, it is important that some basic principles are adhered to (adapted from UNEP, 1996a):

- sufficient relevant information should be provided in a form that is easily understood by non-experts early in the planning process;
- sufficient time should be allowed for stakeholders to read, discuss and consider the information and its implications;
- sufficient time should be allowed to enable stakeholders to present their views;
- the selection of venues and the timing of events should encourage maximum attendance and a free exchange of views by all stakeholders (including those that may feel less confident about expressing their views); and
- responses should be provided to issues/problems raised or comments made by stakeholders, so that confidence in the public involvement and planning process can be maintained.
- provisions should be made for updating the public and providing feedback on progress with the planning;
- more formal planning and management procedures should be integrated with more traditional decision making processes where possible

Box 2.1. Techniques for promoting public involvement in planning and management of natural resources

- Media (television, radio, pamphlets, presentations, exhibitions);
- Open houses and field offices (manned information displays, access, opinion exchange);
- Participatory appraisal;
- Workshops;
- Public meetings; public hearings;
- Small representative or specialist meetings;
- Employment of community interest advocates;
- Individual interviews and two way consultations;
- Questionnaires;
- Advisory panels, working groups, task forces;
- Interim consultative reporting;
- Demonstration projects.

Adapted from UNEP, 1996a

A variety of relatively standard techniques are available to collect information, identify issues and possible conflicts, and encourage participation and "ownership".

2.2.1 Rapid rural appraisal and participatory rural appraisal

Rapid rural appraisal (RRA), and participatory rural appraisal (PRA) have been widely promoted as tools for promoting more sustainable development, and especially rural development. They have been described in detail, particularly as they relate to aquaculture and fisheries, by Campbell (1996), Townsley (1996), Campbell and Townsley (1996) and Pido *et al.* (1996). Although their use may follow on from institutional and stakeholder analysis, they may also contribute to such analyses.

The key features of these approaches are the use of a variety of tools and techniques to facilitate the exchange of information and opinion between stakeholders, researchers and planners, and in particular to synthesise information about resource use, exchange and interactions. They include the use of:

- simple maps and transects showing resource use and exchange;
- matrices to show interactions and exchanges between activities, or the allocation of resources through time;
- “history lines” to explore key events or decisions in the past;
- “venn diagrams” to illustrate the nature of, and relationships between, institutions or social groupings;
- ranking exercises to gain insights into perceptions, values and priorities;
- decision trees to discuss and explore the way that complex decisions are made;
- flow charts to exchange information or ideas about processes.

In almost all cases, flexible check lists rather than rigid questionnaires are used to structure the interactions.

The line between rapid appraisal and participatory appraisal is blurred, and many of the tools used are common to both. The key difference is that while RRA seeks to provide the researcher with a thorough understanding of local resources and stakeholders, with a view to more informed and rational decision making at a higher level, PRA implies direct participation of stakeholders in the decision making process, and the tools are used to empower and develop local decision making capacity.

Where comprehensive PRA across all the various stakeholders is not possible, more effective participation of coastal resource users may be facilitated through the establishment of user groups or organisations to represent particular interests in the higher level decision making processes. Care should be taken to ensure that all interests are adequately represented by such organisations.

2.2.2 Socio-economic survey

In some circumstances it may be appropriate to undertake a detailed socio-economic survey. There is a large literature on socio-economic survey techniques and questionnaire design, as well as training manuals (e.g. Miller, 1983; UN, 1989; Weber and Tiwari, 1992), and these should be consulted prior to any major survey initiative.

Full-scale social survey however should be approached with some caution. It is expensive and time consuming, and may be rather inefficient in terms of issues identification compared with the more flexible and participatory techniques described above. It is therefore best used to clarify or explore in more detail important issues that have been raised or identified using RRA or PRA.

2.3 Remote sensing and geographic information systems

Description and mapping is a basic starting point in the identification of many issues, especially with regard to resource use and allocation, and may also form the basis for specific planning interventions related to site selection criteria, and in some cases zoning.

In recent years advances in Remote Sensing (RS) have greatly enhanced our ability to describe and understand natural resources and human activity. In parallel with these developments in information collection, the rapid development of Geographic Information Systems (GIS), has greatly enhanced our ability to store, analyse and communicate this information.

The use of GIS and RS in planning for aquaculture development has been reviewed by Meaden and Kapetsky (1991), Beveridge *et al.* (1994), Kapetsky and Travaglia (1995), and particular examples are provided by Kapetsky *et al.*, (1987; Costa Rica); Kapetsky *et al.*, (1988; catfish); Kapetsky (1989; aquaculture development in Johore State, Indonesia), Ali *et al.* (1991; carp culture in Pakistan), Ross *et al.* (1993; cage culture of salmonids in Scotland), Aguilar-Manjarrez and Ross (1995; Mexico); McPadden (1993; shrimp farming in North Sumatra), Bohra (1996; shrimp farming in Thailand), Kapetsky *et al.* (1990; Ghana).

The scope of GIS is usually restricted to physical parameters, but attempts have been made to extend it to financial and economic parameters (Hambrey, 1993).

There is little doubt that RS and GIS are useful tools, but they have sometimes been "technically driven" and taken a disproportionate share of the resources allocated to sector and integrated planning initiatives (see for example Part 1, Box 1.10). They also have some limitations. Important factors which are commonly not taken into account in GIS and macro level site appraisal are the availability and cost of land (the major factor in site selection in practice), "micro" site features such as site water supply (canals, dykes, groundwater etc), and the diversity of soil conditions within broader soil type zones.

For local or enhanced sectoral initiatives the use of existing maps, field visits and "rapid appraisal" will be the most cost effective approach. RS and sophisticated GIS are usually more suitable as higher level planning and management tools (for example as part of more ambitious ICM initiatives) where their cost can be effectively spread across sectors, and where the mechanisms for their maintenance can be set in place.

2.4 Assessment of environmental capacity and limits to change

This topic is dealt with in some detail here because of its potential as a tool for integrating aquaculture into broader coastal management initiatives.

Environmental capacity (sometimes referred to as absorptive capacity or assimilative capacity) is:

> *"a property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact" (GESAMP, 1986)*

In practice and in relation to aquaculture, this may be interpreted (GESAMP, 1996a) as:

- the rate at which nutrients are added without triggering eutrophication; or
- the rate of organic flux to the benthos without major disruption to natural benthic processes.

The concept may also be extended to such matters as impacts related to reduction of natural habitat, and impacts on amenities such as scenic value.

The use of environmental capacity and methods of application to aquaculture and environment issues have been discussed by GESAMP (1991a) and by Barg (1992).

Estimation of environmental capacity allows assessments of cumulative or combined impacts and of acceptable levels of environmental change compatible with the goals of coastal management. The estimate of total capacity can be allocated among different uses of the environment (aquaculture, other human users and components of the natural ecosystem) and among users within each category of use (GESAMP, 1996a). The approach provides a potential solution to the "tyranny of small decisions" (Odum, 1982), and the problems of cumulative impact discussed elsewhere in this report. There are some examples of its use for aquaculture, both to estimate the amount of aquacultural production that an area can accommodate, and to allocate this capacity among different users. In general, however, the approach has not so far been widely implemented in relation to aquaculture, no doubt largely because of the lack of quantitative information about causal links between aquacultural wastes and their environmental effects, and the large cost of obtaining and applying such information.

Ideally, the environmental capacity of the whole coastal resource system, including effects of all the various economic development activities, should be addressed within the framework of Integrated Environmental Impact Assessment (Chua, 1997; GEF/UNDP/IMO, 1996).

Quantifying environmental capacity in relation to scenic or habitat quality is at least partly subjective, and should be dealt with as part of environmental target setting (see Section 2.6.1). The following Section deals mainly with the estimation of environmental capacity for nutrient assimilation, which can be calculated more objectively.

2.4.1 General approach to estimating environmental capacity

To be cost-effective, estimation of environmental capacity should only be applied to those forms of environmental impact likely to occur in a given situation. In principle, it need only be applied to the form that becomes limiting first. In practice this may be difficult to determine. A scoping exercise can identify relevant forms of impact with respect to the environment and technologies in question. In the case of intensive finfish and crustacean aquaculture for example, these will normally include the impacts of nitrogen, phosphorus, organic matter, and certain chemicals. In the case of shellfish (especially molluscs) they would include the reduction in the phytoplankton food source.

Once this has been done, prediction of capacity follows in three phases:

- define acceptable limits of environmental change for a particular area or zone (see Section 2.11) in terms of measurable variables ("measurement variables");
- define, and if possible quantify, the relationship between aquaculture (and ideally other activities) and measurement variables;
- calculate the maximum rate or level of activity which will not breach acceptable limits.

Establishing acceptable minimum or maximum limits for measurement variables (such as nitrogen concentration) should ideally be based on quantitative predictions of environmental consequences of the changes in these variables, such as destruction of organisms or habitats, eutrophication, or resource depletion to a level at which it becomes limiting to other users. Environmental standards related to these broader environmental features should have been agreed as a part of setting planning objectives and associated targets. Back-calculations can then be made to give acceptable levels for measurement variables. These are known as "effects based" standards.

In practice the relationship between measurement variables and environmental quality of relevance to the various stakeholders is often difficult to establish, and the measurement variables themselves are commonly used directly as the basis for environmental standards. These environmental quality criteria (in reality *indicators*) may already exist, derived for other purposes of environmental protection, but which must be adhered to for legal reasons.

If effects-based standards cannot be established, and existing standards are not available or relevant, it may be necessary to start with conservative values, which will provide a reasonable level of protection. These can be refined progressively once the procedure has been applied and its success monitored, as discussed below. Ideally they should be widely discussed and agreed with the stakeholders.

Clarifying the relationships between aquaculture activities (such as feeding), the measurement variables, and the environmental consequences, will depend on an understanding of physical, chemical and ecological processes including:

- the dispersal of nutrients (or other substances) in receiving water;
- the dilution of these substances in the receiving water;
- the degradation or breakdown of these substances in the water column or sediments;
- the adsorption of these substances by sediments;
- the assimilation of these materials by plants or animals;
- the effects of these materials on different components of the ecosystem

In practice the last four of these (discussed in more detail below) are complex and often ignored or approximated, while the first two are addressed using mass balance and dispersal models. These may be relatively simple or rather complex, depending on local hydrology. Some worked examples of the simpler ones (essentially dilution models) are presented in GESAMP (1996a). Simple computerised settling and dispersion models for aquaculture have been developed specifically in relation to cage culture (Gowen *et al.*, 1994) and are also discussed further below. More sophisticated computer models are available to deal with more complex patterns of settling and dispersion (for example those produced by the Danish Hydraulic Institute).

Environmental capacity represents the difference between the maximum or minimum limits of the measurement-variables (calculated or agreed) and current values - the 'spare' capacity. It can be converted into units of discharge (e.g. nitrogen) using dilution or dispersion models.

Capacity in terms of discharge can then be allocated among the various uses. Existing uses may have been included in current values of the measurement-variable, or may be separated out to allow reallocation of capacity. Within each use, the total share of capacity for that use is allocated among the various users (i.e., farms). The allocation (e.g. of nutrient loading) can be converted for convenience into units of production, or use of inputs (such as feed) using industry production parameters. If production parameters change (e.g. through the development of better quality feed, technology or management practices) acceptable production can be increased. This serves as an incentive for the development and application of environment friendly technology and management.

Box 2.2 Management of salmon farms in Puget Sound, USA

Recommended maximum levels of production of fish are stipulated for parts of Puget Sound, defined by their hydrographical and geomorphological properties, (Washington State Department of Ecology, 1986). These levels are based on a permissible increase in the flux of nitrogen into the area.

Existing flux was estimated from the flushing-rate of the area, using existing hydrographical information, and concentrations of nitrogen in surface waters. A 1% increase in the flux of nitrogen into an area was specified throughout the Sound as the maximum permissible effect of farming. In the absence of information on the ability of the waters of the Sound to assimilate additional nitrogen or of the ability to predict it, this was considered to be small enough that it would provide protection from adverse environmental effects. Using published data on the release of nitrogen from cage-farmed salmon, the amount of nitrogen was expressed in terms of production of fish. The existing flux, permissible increase and maximum permissible rate of production of salmon were then calculated for each of the areas of the Sound.

The final and, given the large uncertainty generally associated with estimates of limits of acceptable change, crucial stage is the monitoring of aquaculture activity, the measurement-variables, and associated environmental changes. This assesses the suitability of the environmental quality standards (for example, whether those based on measurement variables are suitable indicators for higher levels of environmental quality), and the success of the estimation of capacity, or whether it has been exceeded or under-used. The role of monitoring is summarised below in Section 2.13 (see also GESAMP, 1996a)

2.4.2 Models of phytoplankton dynamics and environmental capacity

Much of the modelling of the ability of coastal areas to support populations of bivalves has approached the question from an aquacultural perspective. The objective of such modelling has been to estimate how many animals can be grown in the area without inducing a reduction in individual growth and a net reduction in productivity of the stock. More sophisticated types of models, however, include various ecosystem-components (physical, chemical and biological) and interactions among them, which permit predictions of impacts of farmed stock on other parts of the system, such as natural populations of filter-feeding animals. Most published studies are more concerned with the effects of natural components on the farmed stock.

The simplest models involve correlations between observed growth-rates of stock and single or multiple environmental variables (Grant *et al.*, 1993). Long-term sets of data for particular parts of the coast can be used to identify the relationship between the total biomass of farmed stock and their growth-rate (e.g. Heral, 1993). This relationship generally describes a curve of decreasing growth-rate with increasing numbers of animals. The trade-off between yield and number of animals can also be expressed as a change in survival of individual animals, or in the time taken for individuals to grow to market-size. Such models are discussed by Heral (1993). Extrapolation from this curve can be used to estimate the capacity of the environment for aquaculture but, since it does not involve quantification of the factors responsible, it does not readily allow other uses to be incorporated.

Partial ecosystem budgets provide an alternative approach to assessing the suitability of an area for aquaculture and, more importantly in the present context, allow prediction of the environmental capacity of an area for aquaculture. These budgets can be based on phytoplankton abundance or productivity, or on other suitable variables such as carbon, nitrogen or energy. Inputs of the limiting variables to the system are balanced against consumption by the farmed stock, natural populations of organisms, burial within the sediments, and loss to adjacent water-bodies, the atmosphere or other neighbouring habitats. In the case of nutrients and phytoplankton, inputs may include regeneration and renewal within the system (from decomposition of organic matter and recycling of the nutrients, reproduction of phytoplankton, etc.) in addition to replenishment through water-movement. The relative contributions of these sources and sinks is site-specific, but the degree of specificity depends on the sophistication of the model, its purpose (how generic it is intended to be) and the amount of information which is available or obtainable to define the parameters of the model. The output from such a model is a prediction of the concentration of the relevant variable (nitrogen, carbon, phytoplankton, etc.) under the conditions of input and output set out in the model. It provides an indication of the relative importance of different sources and sinks, including farms. By altering the sizes of these, predictions can be made of the ability of the system to support larger numbers of farms.

Carver and Mallet (1990) estimated the carrying-capacity of a coastal inlet in Nova Scotia for blue mussels, based on the supply of food. Rosenberg and Loo (1983) made similar calculations for a blue-mussel farm in Sweden based on energy-flow. Fréchette *et al.* (1991) calculated the flux of suspended organic material into an aquaculture site in France in relation to consumption by the stock, and concluded that stocking-density could be increased and the distance between farms decreased without adverse effects on rates of growth. From a similar perspective of maximising the yield of cultivated stock, Rodhouse and Roden (1987) estimated the potential maximum yield from a harbour in Ireland on the assumption that the stock could utilise all the carbon currently being consumed by zooplankton. Clearly, in such a situation it must be assumed that there will be some ecological consequences and that such a yield is, therefore, probably not sustainable.

The budget-approach to prediction of environmental capacity can be extended to incorporate ***feedback-loops***. For example, abundance of phytoplankton depends on the availability of nitrogen, and affects the rate of growth of mussels. The mussels, in their turn, influence the abundance of phytoplankton both directly, through feeding, and indirectly, through the excretion of nitrogen. More sophisticated models are required in order to incorporate this kind of feedback. As with the budget-models, the ecosystem is divided into ‘boxes’ representing those components of the system relevant to the variables of interest (referred to as ‘state variables’). In the case of a model of the food-supply for mussel-growth, there would be boxes representing the farmed mussels, the natural populations of filter-feeders, the sediments, the water-column, etc. Depending on the level or resolution required, each of these boxes can be resolved into smaller units, such as filter-feeding shellfish and filter-feeding worms on the seabed, filter-feeders encrusting the structures of the farm and filter-feeding zooplankton. Components can also be resolved into smaller spatial units, such as dividing the water-body up into different areas on the basis of their relative flushing-times. Different variables can be linked by sub-models so that, for example, the movement of nitrogen through the system can be linked to the abundance of phytoplankton by a sub-model which estimates production of phytoplankton in relation to the availability of nitrogen, as described in the example of Big Glory Bay, New Zealand (Box 2.3)

Box 2.3 Management of nitrogen input from salmon-farms in New Zealand

Following a bloom of planktonic algae, leading to the deaths of cage-farmed salmon, a mass-balance model for nitrogen, phosphorus and chlorophyll was developed for Big Glory Bay, Stewart Island (Pridmore and Rutherford, 1992). The model assumed steady-state conditions of exchange of nutrients with the adjacent Paterson Inlet and open ocean under conditions of varying tidal and wind-driven flushing. The objective in this case was to predict likely impacts of salmon-farming on phytoplankton abundance as a result of the release of nitrogen and phosphorus from the farms.

Predictions from the models were tested against spatially-averaged observed concentrations of nitrogen and phosphorus, with reasonable success. This approach was then extended to predict the response of phytoplankton to nutrients derived from aquaculture. This model of the nitrogen budget for Big Glory Bay was combined with a simple (logistic) model of phytoplankton-growth to examine the effects on abundance of phytoplankton of nitrogen availability and of flushing of the Bay by water from Paterson Inlet. This sequential linking of models was based on the assumption that the maximum abundance of phytoplankton is determined by the balance between their growth-rate and the flushing-rate of the embayment. Growth rate, in turn, is controlled by the availability of nutrients. In most situations, however, abundance will be limited still further by factors such as grazing by zooplankton and other filter-feeders and reduced productivity by the phytoplankton themselves because of poor water-clarity.

The amount of increase in the concentration of nitrogen compatible with preventing increase in phytoplankton to unacceptable levels was then used to set the maximum biomass of salmon to be farmed in the Bay. This approach potentially allows allocation of biomass among farms and among other uses. In the case of Big Glory Bay, salmon-farming was the only human activity likely to contribute nitrogen to the system at the time. Subsequently, the amount of salmon farmed there has declined (for economic reasons) and longline-farming of mussels has become important. The nitrogen-budget model has been modified to accommodate this change.

A similar, hypothetical example of estimating likely change in the abundance of phytoplankton in response to release of nitrogen from a fish farm is given by GESAMP (1996a).

In these ‘***simulation’*** models, flows of energy or materials between compartments are estimated from ‘internal biological fluxes’, such as feeding or sedimentation, modified by external ‘forcing functions’, such as temperature, light or salinity (i.e. factors which are taken as fixed and not subject to feedback). Changes in the variables are then calculated using sets of differential equations. The terms that are included in the equations relating to a particular variable are based on their assumed importance. Subsequent testing of the predictions of the model against experimental data then allows refinement of these equations (by removal or addition of terms) and adjustment of coefficients of the model that determine the fluxes.

Simulation models of populations of blue mussels (*Mytilus edulis*) have been developed by Brylinsky & Sephton (1991), Smaal (1991) and Grant *et al.* (1993), for populations of Pacific oysters (*Crassostrea gigas*) by Bacher (1991), Bacher *et al.* (1991) and Raillard and Ménesguen (1994) and for populations of American oysters (*Crassostrea virginica*) by Hofmann *et al.* (1994). Herman and Scholten (1990) described a simulation model of carbon-flow in the Oosterschelde Estuary, Netherlands, in which blue mussels played a significant role.

The effects of increasing the size of the farmed stock on other biological components of the system, such as the probability of phytoplankton-blooms, can be estimated by changing either the inputs of nutrients via food (e.g., finfish-farming) or the biomass of bivalves (e.g., mussel-farming). Predictions derived from models are sensitive to 'boundary conditions', the values of the state variables at the edges of the system and/or the fluxes across these edges (such as the movement of water and associated nutrients into the system from the adjacent open coast).

Models for allocation may or may not include contributions from natural sources. In general, although the incorporation of these sources is logical, it adds an extra dimension of complexity while contributing rather little to management. Marginal approaches may therefore be more appropriate in most cases.

2.4.3 Models of the input of organic matter to the seabed

Although there are numerous empirical and mechanistic models available for predicting the input of organic matter from marine farms to the seabed, quantitative connections between input and ecological changes have not yet been developed (GESAMP, 1996a). Changes in the benthic fauna caused by accumulations of aquacultural wastes have often been found to fit the general responses to gradients of organic pollution, described by Pearson and Rosenberg (1978). The descriptions by Findlay *et al.* (1995) of changes in the benthic fauna below salmon-cages in Maine, USA, which did not fit patterns described by Pearson & Rosenberg’s model, however, illustrate the way that temporal and spatial variability can obscure predicted patterns. As a consequence, even though rates of input of wastes (and the nutrients they contain), rates of accumulation of waste (input minus decomposition and resuspension), rates of release of sulphides and nutrients, and even rates of microbiological activity can be predicted, consequent changes in the benthic fauna are only predictable, at best, in broad terms.

Toxicological data on effects of decreased concentrations of oxygen or increased concentrations of microbial metabolites (e.g., sulphides, ammonium) on benthic organisms provide a potential guide to maximum levels of organic input consistent with protection of benthic communities. The reliability of such data, usually obtained from laboratory studies, in the natural environment is, however, open to question. Studies in British Columbia showed increased but variable toxicity of sediments from below fish cages to a range of species of invertebrates (EAO, 1997b).

Various guidelines for maximum rates of input of organic matter have been estimated on theoretical grounds taking into account factors such as rates of dispersion, resuspension and microbial decomposition (e.g., Hargrave, 1994). Findlay and Watling (1994, 1997) estimated theoretical maximum rates of assimilation of organic carbon by sediments based on the ability of local water currents to supply enough oxygen to prevent the overlying water from becoming anoxic. They used this model to predict situations where sediments would become anoxic and mats of anaerobic bacteria would develop. Empirical data have also been used to develop guidelines, such as correlations between rates of input and loss of diversity of the benthic fauna (EAO, 1997b). Most of these estimates have been developed for cold-temperate regions of the world and are unlikely to be directly transferable to warmer climates (e.g. Angel *et al.*, 1995).

Aure and Stigebrandt (1990) used a similar approach to model capacity in terms of level of input of organic waste consistent with maintaining levels of dissolved oxygen, as an adjunct to the LENKA system in Norway (previously summarized in Box 1.2 of Part 1). Inputs of nutrients and organic waste to the fjord from excretion by the stock and from waste food were estimated and used to predict depth-profiles of concentrations of nutrients and dissolved oxygen. Environmental loading of organic matter and nutrients from fish-farming was estimated from published data on excretion rates of nutrients by the stock, and rates of deposition and microbial decay (about 10% per year). Estimates of rates of consumption of oxygen by the sediments were also made from these figures, including that consumed in the water column by oxidation of ammonium released from the sediments. For a given loading of nutrients or organic waste, the response of different systems may be quite different, depending on local factors such as the surface area and volume of the water body, rate of flushing and vertical stratification. The supply of oxygen to the sill-basin of fjords is dominated by the inflow of new water from outside, rather than by vertical mixing within the fjord, with the time-scale for renewal of oxygen being the same as that for renewal of water. The rate of inflow of new water is, in turn, dependent on the rate of change of water density in the sill-basin. As this water becomes less dense, it rises and is replaced by oxygen-rich water drawn in over the sill from outside the fjord. The rate of reduction in density, *R* (hence the name of the so-called '*R*-model'), relative to the rate of consumption of oxygen determines the minimum concentration of dissolved oxygen that is likely to occur in the sill-basin.

The predictions presented by Aure and Stigebrandt were based on the assumption that the farm was sited over a depositional (rather than erosional) area of seabed. In erosional areas, wastes are likely to be dispersed further and, therefore, more thinly and, since rates of oxygen consumption by the waste is proportional to its depth, oxygen will be consumed at a larger rate. The converse of this assumption is that, in areas where flushing rates of water are rapid, dispersion of waste will reduce its rate of accumulation and, hence, its environmental impact.

Aure and Stigebrandt modelled the exchange of water between the fjord and the adjacent coast, and the environmental effects in the surface and intermediate layers of the water column in the fjord caused by fish-farming using a numerical, time-dependent model of the fjord. The model was horizontally-integrated but had high vertical resolution. The state variables (i.e. the variables that were modelled) were salinity, temperature, concentrations of oxygen, nutrients, suspended particulate organic matter and dead organic matter on the seabed. Application of the model requires time-series data from outside the fjord on salinity, temperature, nutrients and suspended organic matter at several depths down to below the level of the sill. Time series of daily meteorological and hydrological data are also required. The model predicts the vertical distribution of organic matter in the water column and the input of organic matter to the sill-basin, among other factors. It suggested that release of nutrients in bio-available form into the surface waters by the caged fish would stimulate production of phytoplankton inside the fjord. This material would not, however, sink down into the sill-basin because exchange of water between the fjord and the adjacent coast was sufficiently rapid that this material would be transported out of the fjord. Lack of sufficient light would prevent additional production by phytoplankton in the sill-basin, despite the availability of nutrients released from the sediments. Nutrient-fluxes in the water-column above the sill-basin were dominated by exchange between the fjord and the adjacent coast. Consequently, concentrations of nutrients were similar between these two bodies of water, despite inputs to the fjord from land drainage, the fish farms and from vertical mixing of nutrient-enriched water from the sill-basin.

As a means of predicting effects of nutrient enrichment from inputs of organic matter, Aure and Stigebrandt's model can be extended to other systems than fjords and to other sources of input than finfish-farms. Application to other systems would require estimation of terms in the model relating to vertical mixing and horizontal exchange of water appropriate to the system in question.

2.4.4 Tropical versus temperate systems

Most of the work on environmental capacity has related to marine cage culture and shellfish culture in temperate regions. Although the same overall approach can be taken, there are likely to be significant differences in tropical systems. For example, measurements of organic matter decomposition in sediments under fish cages in the Gulf of Aqaba suggested that the capacity of sediments to absorb organic matter loadings may be 3-4 times greater in warm than in temperate waters (Angel *et al*, 1995). There has also been some work relating to shrimp farms in Latin America (Chamberlain, 1997).

The further development of models or suitable guidelines which could assess in a broad way the capacity of coastal environments for different forms of coastal aquaculture, or for nutrient/chemical assimilation in general, would be useful to government planners, as well as investors and insurers, who could assess the risks to environmental sustainability and plan accordingly.

2.4.5 Relation to other components

Environmental capacity estimates are closely related to technology assessment, which should assess among other things waste emissions per unit production (Section 2.5). Since environmental capacity must be defined in terms of some environmental index or change, which may be partly subjective, the majority of stakeholders must agree the nature of allowable or acceptable change (Section 2.6.1). As noted above, environmental capacity estimates may be directly associated with activities within a defined zone (Section 2.11).

2.4.6 Conclusions and recommendations

1. Environmental capacity assessment can be important in clarifying and operationalizing environmental targets and objectives, and may serve as the basis for a range of planning and management tools and interventions;
2. Significant uncertainty is associated with environmental capacity estimates, which may cause over or under-protection. Risk analysis may be used to address these issues;
3. In view of these uncertainties, the process for assessing capacity must be made both public and transparent;
4. Estimates of environmental capacity should be used alongside other techniques to inform the process of setting objectives and targets, and developing incentives and constraints, rather than to define them;
5. The process should be iterative, starting with simple, conservative methods and rough estimates that are progressively refined (*estimate, monitor, refine*), including information from other sources. This is of particular importance in developing countries where finance and capacity to undertake more sophisticated assessments may be lacking;
6. Feasibility and utility will vary with amount and quality of information available, scale, and availability of resources;
7. The value of accurate assessments of environmental capacity will depend upon the likelihood of environmental standards being breached. Where these are unlikely to be breached because of social and economic constraints to development, accurate environmental capacity assessment may not be cost effective.

2.5 Technical and economic assessment

A comprehensive description of the technical, economic and resource use characteristics of different technical production systems or species is a prerequisite for the rational appraisal and comparison of the sustainability of different development options. It is basic information needed for any kind of integrated and strategic planning or market intervention.

Ideally such an assessment would include:

- screening for technically feasible development options;
- description of location and site requirements;
- market assessment;
- standard financial analysis, investment appraisal and sensitivity analysis;
- profile of resource use and waste output;
- profile of socio-economic characteristics;
- risk analysis;
- synthesis - comparative economics and technical appraisal of different options; sustainability profile

2.5.1 Screening

Basic information should be collected on a range of feasible development options, based on successful existing activities or technologies, appraisal of potential new developments/technologies, or technologies which are successful elsewhere and which might be transferred to the area in question.

The main criteria for preliminary screening should be *comparative advantage;* i.e. does the area in question have any obvious advantage in pursuing a development or technical option in terms of:

- suitable natural environment and resources (e.g. temperature, water quantity and quality, soils, elevation, topography, etc);
- price, quality, and consistent availability of inputs;
- skills and labour costs;
- access to processing facilities and markets; and
- infrastructure and support services

While screening on the basis of suitable natural environment is often done very thoroughly for aquaculture, the other criteria are often given far too little weight, and development money is often wasted as a result. It is essential that all of the above criteria are considered as early as possible in the planning process.

2.5.2 Location and siting requirements

The requirements of different activities or technologies in terms of suitable or optimal sites (micro level) or locations (macro level) are key considerations for assessing comparative advantage, and may form the basis of planning interventions related to location. Poor siting and location has been a significant factor in the failure of aquaculture in some areas, and excessive environmental impacts in others. Any technical and economic assessment of aquaculture and other activities in the coastal zone should therefore address site selection criteria. Site selection issues for aquaculture in general have been discussed by Huguenin and Colt (1989) and Barg (1992).

Aquaculture is highly diverse with radically differing requirements in terms of site characteristics. However, water quality is generally the key. Most species grow better in high quality water, and some cannot survive without it. Some species have very particular requirements in terms of both water quality and salinity. Upstream and land-based activities and pollution must therefore be taken into consideration. At the same time, the effects of aquaculture on downstream activities should be considered.

Actual site requirements are species and technology dependent, but can be divided into two main groups:

- those aquaculture practices that require the conversion of existing uses or natural ecosystems (e.g. conversion of agricultural land or wetland for coastal shrimp or fin-fish ponds);
- those that do not require conversion (e.g. floating cages and rafts for fish or shellfish in bays and estuaries; cockles on mangrove mudflats; giant clams amongst seagrass or corals).

Brackishwater ponds

The requirements for brackishwater ponds are demanding, and success depends critically on site quality (Boyd, 1995; Yoo and Boyd, 1994; Hayek and Boyd, 1994; Simpson and Pedini, 1985). Sites or areas to be avoided include the following:

- sandy soil, rocky soil, or both;
- sites with large trees;
- areas with intense acid sulphate soils and containing too high organic matter (peaty soil); and
- areas near industrial or highly populated zones.

Sites that are rocky or sandy are generally considered to be unsuitable because they are difficult or expensive to work. There are technologies for developing aquaculture ponds in sandy soils (pond liners, soil amendment techniques) which may be economically feasible in some areas under some conditions.

Forested sites with old and big trees are common in many tropical swamplands, especially as they become more elevated owing to yearly accretion and silting. Although these sites can be developed under a long-range programme, the expense involved in thoroughly preparing them for aquaculture may be great. They may also have significant alternative value in terms of biodiversity.

Coastal areas with acid sulphate soil are common in tropical regions. Although they are not usually suitable for shrimp ponds, some areas, where the acidity is not too intense, can be used for brackishwater farms after reconditioning the pH of the water by liming and/or flushing and various forms of soil treatment. A good example of aquaculture development in an acid sulphate area is the Rangsit area of Thailand. Areas with peaty soils and high acidity (such as Tamban Laur in Kalimantan) are not suitable for aquaculture development.

Industrial wastes from industrial complexes, and domestic wastes from highly populated areas alter the coastal environment significantly, making it unsuitable for aquaculture. There are two types of adverse effects resulting from industrial and domestic wastes: the direct effect, which is the toxicity of the wastes themselves; and the indirect effect such as oxygen depletion. Additionally, such wastes may result in the eutrophication of coastal waters, possibly causing red tides, which are detrimental to cultured species.

For extensive ponds location on the mid to upper tidal range is preferable. Those sited too high will require much excavation work to bring them to a workable elevation for effective water management. Additionally, even if excavation can be conveniently done, the question of where to dump the extra soil arises. Extra soil can sometimes be used to build big main bunds, and pumps may be used to bring the needed water, but this can lead to high costs of operation.

There are many areas in the world where the daily and annual ranges of tides are very great, so that tidal (generally extensive) shrimp pond construction would be impractical. Areas where the daily or monthly range usually reaches as much as 5 meters or more are not generally suitable. In some areas, the absolute range of tides during the year may reach as much as 10 m. Under these circumstances, extremely big bunds requiring much soil will be needed both to withstand pressure from outside during a very high tide, and to prevent total drainage during a very low tide. Any mistake in the water management by the shrimp or fish farmer in such circumstances can produce disastrous results.

Intensive shrimp and finfish farms are generally best sited just above the tidal range, to allow for complete drainage of ponds during harvest and conditioning. This necessarily implies the use of pumped seawater.

A detailed example of resource appraisal for the identification of suitable areas for brackishwater aquaculture development is provided by McPadden (1993).

Marine cage culture

There is a significant literature on site selection for marine cage culture (see, for example, Beveridge, 1996; Huguenin, 1997; Levings *et al.,* 1995). Critical considerations are:

- adequate shelter;
- moderate current (too strong creates problems with the set of nets, anchoring, and may be excessive for the fish; too weak and oxygen or metabolites may become limiting);
- adequate depth (to keep nets at a minimum distance from decaying organic matter and to ensure high water quality);
- ease of access for the operator;
- minimal security (poaching) problems;
- minimal predator problems;
- minimal fouling;
- suitable salinity regime (dependent upon species);
- access to a reliable supply of reasonably priced inputs;
- access to dealer distributor networks and markets;
- distance from other operators (especially where disease is a problem)

A review by Washington State provides guidelines on siting and management of salmon net-pen culture (Washington State Department of Ecology, 1986) and contains empirically-based rules of thumb on the depth and current speed required to minimise benthic impacts of waste below farms.

Shellfish culture

The Ministry of Agriculture, Fisheries & Food in British Columbia has developed a system for appraisal of sites for shellfish farming (Cross and Kingzett, 1992). Many of the criteria listed above for cage culture are relevant, but in addition, the quality and abundance of naturally occuring planktonic food is critical for success, and in some cases a local supply of wild seed is also necessary.

2.5.3 Market assessment

Market assessment is increasingly important as aquaculture becomes more competitive. Lack of attention to markets and marketing has had severe impacts on the development of both new and established aquaculture industries, and should form a major component in any planning exercise. Market assessment and marketing has been thoroughly dealt with elsewhere (Chaston 1989, Bjorndal 1990, and Shaw, 1990) and will not be further reviewed here.

2.5.4 Financial analysis

Preparing a financial profile (estimates of capital costs, operating costs, revenue) for a particular type of enterprise, or a partial budget related to a specific technology or management practice, is relatively straightforward (see for example Shang 1990). If necessary a more comprehensive economic/project appraisal can be undertaken for any major components of a plan (see e.g. Gittinger, 1982).

There are rather few examples where simple financial analysis has been used to compare a range of development options, technologies, or species, and such an approach has only rarely been incorporated in ICM initiatives in a developing country context. In practice this is relatively simple, using the kind of format presented in Table 2.2, which can be used to generate indicators of financial performance such as those summarised in Box 2.4.

Box 2.4 Selected financial indicators for assessing or comparing different enterprise and technologies

Profit. Income minus all operating costs, including interest, depreciation, maintenance, labour, inputs etc. It may be calculated as gross, or net of tax.

Unit production cost. Total operating costs/total units or quantity produced (*note* – this usually declines with output)

Pay-back (PB). The time required to pay off capital invested in the project; calculated as total investment/(annual profit+depreciation). While payback periods of 10 or more years may be acceptable to some very large corporations, most small businesses, including farmers, would hesitate to invest where payback periods exceed 2 or three years.

Profit margin. Calculated as (profit/income)*100%. A measure of vulnerability to product price change or increased costs.

Profit/ha/crop or profit/ha/yr. A simple measure of land productivity, which can be calculated for a single production cycle or for a year, whichever is appropriate. This should always be made clear.

Total investment/ha. The actual per ha cost of purchasing land and building/establishing ponds, tanks, buildings etc. Essential information for people with limited access to funds.

Gross margin. GM. Gross income or sales revenue less (minus) variable costs. Full time labour and overall management on a typical farm is commonly taken as a fixed cost and therefore excluded from GM by most agricultural economists. In many enterprise models however, labour of all kinds is taken as continuously variable and is usually related to output. For the sake of comparability between enterprises, and to allow comparison with other work, it may be appropriate to use two measures: gross margin excluding all labour (GMxl), and gross margin including all labour (including any management) (GMil). Both measures exclude all overhead costs.

Management and Investment Income (M&II). Another measure commonly used by agricultural economists. It provides an indicator of the cash surplus generated for the enterprise manager or investor. Calculated as Income - all operating costs, except interest and overhead management charges.

Return to labour and management - the net income available for the payment of labour of any kind. Calculated as (profit + labour costs).

Return on Investment (static). Profit/total capital investment)*100%. This should not be confused with internal rate of return.

2.5.5 Risk assessment

Agricultural and aquaculture projects are particularly vulnerable to the uncontrollable externalities of weather, disease, and world markets. Aquaculture development is littered with examples of failed projects that fell foul of one or more unexpected problems. Any technical-economic profile of aquaculture must include a thorough risk assessment. This is rarely done in practice, especially for small scale developments.

It is important to distinguish between *risk* and *uncertainty*. If an undesirable event may or may not happen, there is a risk associated with it. If the probability of this event is known, then the risk is quantifiable. If the probability of the event is unknown, then we are dealing with uncertainty, which (by definition) cannot be quantified. For example, the probability of achieving a particular food conversion rate on an intensive farm could be estimated from industry surveys, and the probability of feed costs could be calculated. Disease, which can drastically affect returns, is much less easy to predict, and is therefore associated with great uncertainty.

The risks associated with aquaculture can be reduced but not eliminated through good siting, design and management. The risk of disease is likely to be higher where there are many aquaculture enterprises in the same area.

There are many different measures and indicators of risk and risk exposure. Whenever these are used or quoted, the actual nature of the risk should always be discussed.

Time to market is the simplest measure of financial risk. The longer it takes to make a product or grow a crop, the higher the working capital requirements (see below), the greater the likelihood of crop loss due to climate or disease, and the greater the risk and uncertainty associated with the costs of inputs and the value of the output (market price).

Working capital[22] *requirements/crop/ha* is a relatively simple measure of *risk exposure.* Combined with the probability of crop failure or low performance, this gives an indication of the likelihood and scale of potential losses on an individual production cycle, which may cause serious cash flow problems and jeopardise project viability.

Break-even production rates (i.e. the output or production required to just cover operating costs) can be compared with the actual distribution of production rates in the sector (locally or elsewhere) to give an indication of risk and scale of losses.

Sensitivity analysis involves assessing the sensitivity of the financial model to changes in key variables and parameters such as the cost of labour or inputs, or the rate of production. For example, the sensitivity to feed costs might be calculated as the percentage increase in production cost for a 10% increase in feed price. Alternatively, the percentage increase in feed price that would result in zero profit might be estimated, and the likelihood of such an increase might be estimated. This can be done for both prices/costs and production parameters, and may be presented in a comprehensive table. If possible, the probability associated with a change in parameter value should be indicated or discussed.

The risks relating to market prices may be judged by price elasticity (if this information is available) combined with sensitivity analysis as above. If price is elastic, it declines rapidly as total production increases; inelastic prices on the other hand are relatively stable despite significant changes in production.

[22] working capital is the actual cash outlay required to fund a production cycle - ie cash needed for feed or fertilizer, employed labour etc, before the crop is finally sold.

***Table 2.2: Example of financial model or profile with resource use indicators:* Cage Seabass farm, Thailand**

production parameters			
cages	28 units	production/m^2	105kg
cage size	50m^3	production/m^3	21kg
crops/yr	1.5	total production	29,400kg
survival	50%	area	0.2ha
production/cage/crop	700kg	food conversion ratio	6
production/cage/yr	1050kg		

Nutrient composition	
P content of trash fish	0.50%
P content of fish produced	0.30%
N content of trash fish	1.00%
N content of fish produced	1.20%

investment	Q	$unit cost	total	life	depreciation
cages	28	200	5,600	2	2,800
building			-	10	-
truck			-	6	-
equip.			3,000	5	600

Operating costs	*Q (kg, l or No).*	*$Price/rate*	Total cost
depreciation			3,400
interest		5%	430
rent/license			
seed	2,041	0.17	350
feed	176,400	0.20	35,280
fuel	2,000	0.57	1,143
labour MY	4	4000	16,000
misc			1,500
total			***$58,103***

Revenue	**29,400**	**2.70**	**$79,380**

Financial and socio-economic indicators		**Resource use/waste indicators**	
gross income/ha	$396,900	N in inputs (kg)	1,764
profit	$21,277	N in product (kg)	353
profit margin	27%	total waste N (kg)	1,411
return to labour $/MY	$9,319	N waste (kg/ha/yr)	7,057
employment/ha	20	N waste (kg/$ revenue)	0.0178
return to labour/ha	$186,380	N use (kg per $) revenue	0.0222
employment/mt	0.14	N conversion efficiency	20%
capital investment/job created	$2,150	protein conversion efficiency	17%

2.5.6 Resource utilization and the generation of goods and services

Resource utilization

Planning for sustainable development is all about promoting more efficient utilisation (and in some cases distribution) of resources. Indeed, the efficiency of resource utilisation and conversion is one of the few objective and simple criteria for assessing sustainability. Profiles of the resource characteristics of different technologies or development options, which can be realistically compared, are therefore essential.

Indicators for sustainable resource utilization could be:

- the efficiency of conversion of nutrients and raw materials into usable product; or
- the quantity of raw materials or nutrients used per unit product, or per unit land.

Food conversion efficiency is the classic example of the former.

In practice this is only part of the story, since it ignores *absolute quantity* and *economic efficiency* (Hambrey, 1998). Although a process may be relatively efficient in terms of converting one material into another, if the scale of activity required to meet social and economic objectives is very high, then the absolute quantity of waste may also be high. Conversely, a process or technology may be rather inefficient in terms of resource conversion, but the returns may be so high that the scale needed to meet social and economic objectives is very small, and the absolute level of waste production is low. In order to take account of this, the following general economic indicator of resource use efficiency (and therefore sustainability) may be used:

- resource use, or waste production, per unit economic or social benefit

Specific indicators of this kind include a wide range of simple ratios, which may include both environmental and social elements. For example:

- land/unit income;
- land/unit profit;
- land/NPV[23]
- nutrient waste/unit income;
- nutrient waste/unit profit;
- land/employment;
- investment/employment;
- nutrient use/employment;
- nutrient waste/employment;
- annual cost of raw materials/employment.

In the case of aquaculture and agriculture for example, it may be informative to calculate and compare income generated per kg of nitrogen consumed, per kg nitrogen discharged, or per kg protein consumed. The relative weights given to these various indicators will depend on local conditions in terms of nitrogen supply, nitrogen pollution, or protein shortage.

There is also a range of more specifically social-economic indicators. The potential for increased wage income from different types of enterprise can be assessed using return on labour (the cost of labour that would reduce profit from an enterprise to zero). If land is in short supply, this figure can be divided by the corresponding land requirement to give potential for increased earnings per unit area of land.

As noted above, all of these indicators can be simply generated from a standard financial analysis so long as quantity as well as price/value of the various inputs and outputs are included. An outline analysis which generates some of these indicators is presented in Table 2.2, and a summary of a comparison between a range of model enterprises is presented in Table 2.3. This type of analysis typically raises many questions and provides a useful framework for discussing sustainability issues.

[23] Net Present Value

As with all such analyses, much depends on the assumptions made in setting the levels for variables and production parameters.

Table 2.3: Example of a summary of financial and resource use indicators for a range of model coastal enterprises (Hambrey, 1998)

	Seabass cage	Shrimp (intensive)	milkfish	Rice 1 (high input)	Rice 2 (low input)
Gross income/ha ($)	1,662,500	36,621	1,913	1,800	900
Profit margin	23%	65%	24%	5%	-31%
Return to labour ($/yr)	5,671	42,174	2,692	1,119	606
Employment/ha	95	0.8	0.5	0.8	0.5
Return to labour/ha ($/yr/ha)	540,119	34,266	1,346	895	424
N waste (kg/ha/yr)	33,804	705	407	180	5
N use (kg/ha/yr)	0.020	0.015	0.051	0.100	0.005
N use/unit revenue (kg/$)	0.025	0.020	0.063	0.134	0.039
N conversion efficiency	20%	27%	19%	25%	86%

Assumptions/parameters:

- Seabass: 30 hanging cages; 30MT production; trash fish.
- Intensive shrimp: 3ha; 7.5mt/ha/yr (1.5 crops); pellet.
- Milkfish: 4mt/ha/yr (2 crops); fertilizer + feed supplement.
- Rice 1: intensive; 6mt/ha/crop; 2 crops pa.
- Rice 2: improved traditional; 3mt/ha/crop; 2 crops pa.

In addition to these “efficiency” indicators, temporal and seasonal patterns of resource use associated with particular enterprise or technologies should be described, and in particular, seasonality related to labour use.

Value of goods and services

It is also important to describe, and if possible quantify and value, all the goods and services generated by an activity, over and above those which accrue to the operator/farmer. In other words to examine the *externalities*. This is discussed further in Section 2.7 (Environmental Assessment), and Section 2.8 (Cost Benefit Analysis). A useful example of such an analysis, applied to a range of management options in the coastal zone (including aquaculture), is provided by Gilbert and Janssen (1997).

2.5.7 Socio-economic characteristics

As noted above, the financial analysis can be used to generate some simple but useful socio-economic ratios or indicators, such as employment potential and wage potential, either in absolute terms, or in relation to natural and human resources. In addition, development options should be described in terms of:

- overall potential net income generation to the local economy;
- the likely distribution of income within the local economy;
- barriers to entry (for example requirements in terms of skills, capital, access to natural resources);

2.5.8 Sustainability profile

Ideally the technical and economic assessment as described above should be summarised in the form of overall “sustainability” profiles of alternative development options and technologies, so that rational comparisons can be made, trade-offs assessed, and planning and management decisions made. This information is essential for any kind of environmental assessment, cost benefit analysis, or participatory decision making (Sections 2.7, 2.8, 2.9)

2.5.9 Technology assessment of aquaculture in practice

It is beyond the scope of this report to summarize the technical, economic and environmental profile of different forms of coastal aquaculture. However, the environmental profile is particularly important in terms of the integration of aquaculture into coastal management, and, despite the enormous range of variation in species and systems, some general points can be made:

- shellfish (bivalve mollusc) culture does not involve the use of feed inputs, and therefore does not lead to a net addition of nutrients or organic matter to the wider environment. However, it does lead to a local accumulation of nutrients through the deposition of faeces and pseudofaeces, and the regeneration of nutrients such as ammonia;
- the use of "trash fish" for finfish culture results in highly variable food conversion ratios, but usually in the range of 4 to 8 (wet weight). In other words, for every kg of finfish produced, the equivalent of 3-7kg will be dispersed to the environment in the form of nutrients and organic matter;
- the use of "trash fish" for lobster culture (fattening) in the tropics may result in very poor food conversion (up to 30);
- the use of chopped trash fish, as opposed to small whole fish, will have a significantly greater polluting effect;
- pollution related to the use of moist pellet, which may include a fresh fish component, is highly variable depending on the quality of the pellet;
- pollution from the use of dry pelleted feed for salmon has been reduced radically as a result of better feed formulation and pelleting technology. Food conversion ratios have been reduced steadily from around 1.5 to less than 1; phosphorus content of feeds has also been reduced;
- the quality of dry pellets available for tropical marine finfish is much lower, and food conversion ratios correspondingly higher;
- shrimp generally are given a high protein diet and are rather poor converters of dry pelleted feed, with conversion rates typically between 1.5 and 2. This is expected to decrease as feed management and feed formulations develop and improve, similar to the reductions seen in the commercial salmon industry over the past twenty years.

Detailed discussions of resource use and waste output can be found, for example, in the following publications:

- tropical marine finfish cage culture (Angel *et al*., 1995);
- salmon cage culture (Brown et al., 1987; NCC, 1989; Washington Department of Fisheries, 1990; Ackefors and Enell, 1994; Beveridge, 1996; EAO, 1997a);
- shellfish culture (NCC, 1989);
- shrimp culture (Chua *et al.*, 1989; Briggs and Funge Smith, 1994)
- brackishwater finfish culture (de la Cruz, 1995)

2.6 Targets and standards

A significant part of strategic planning is the setting of targets relating to particular sectors or activities. Sector targets may be set in terms of total output, or total allocation of resources (e.g. land/water). They may be set in relation to an entire coastal area, or in relation to specific zones.

Output targets have commonly been associated with planning in centrally planned economies to meet social and economic objectives, with rather little emphasis on land or resource use, or environmental consequences. In contrast, they have generally had a minor role in integrated coastal management, where the emphasis has usually been on environmental objectives. Ideally sector targets should be informed by a joint consideration of economic, social, and environmental objectives. The way in which environmental capacity may be used to define sector targets (or limits) has already been discussed above in Section 2.4.

2.6.1 Environmental targets

If environmental objectives are to be achieved, there must be agreed ***criteria*** for measuring progress, and associated ***targets or standards*** to work towards or stay within. Environmental targets may be of two kinds: *area based* or *quality* based. Area related environmental targets (such as natural reserves) have been widely used, and are normally realised through some form of zoning (Section 2.11). Output or quality based targets are generally more difficult to define, and have been rather little used.

However, they offer a potentially powerful tool for coastal management, since they allow for cross boundary effects.

The most commonly used quality based targets are water quality standards (e.g. acceptable nitrogen, phosphorus, BOD, COD, oxygen concentration etc). These have been defined for most developed countries in relation to particular areas or uses of water and are widely quoted in the literature. For planning and regulatory purposes they have often been applied to individual enterprises in the form of discharge consents. Unfortunately, their application is sometimes rather arbitrary, with limited analysis of the relationship between the standards in effluents and receiving waters, the wider environment and other resources. This is particularly the case in developing countries, where standards derived from temperate countries are sometimes applied indiscriminately to very different climatic, physical and ecological systems.

Box 2.5 Chesapeake Bay Programme, USA

As part of a programme to improve the environmental quality of the Bay, a target was set of 40% reduction in the nitrogen and phosphorus loading by 2000. Specific loads of nitrogen and phosphorus were allocated among catchments of the Bay and strategies developed, with public participation, for control of sources in each. (GESAMP, 1996b).

However, applied at a broader level (e.g. in relation to a bay, lagoon or estuary) these standards may serve as a starting point for calculating environmental capacity, which can then itself be used as the management tool. This approach takes as its starting point the overall quality of the wider environment, and is therefore more likely to meet environmental and sustainability objectives.

Another simpler approach is to set targets for the reduction of pollutants which are known to reduce environmental quality. While ideally this reduction should be based on environmental capacity, in practice this may be difficult, and arbitrary targets for reduction may be taken as a starting point. An example is presented in Box 2.5.

Monitoring the measurement criteria (such as water quality) in parallel with development activity will not only allow for objective measurement of progress against objectives, but will also allow for a steady refinement of understanding of the relationship between different activities and overall environmental quality and productivity.

Box 2.6: **Hierarchies of environmental objectives and targets, and sector contributions**

Environmental objectives: e.g. maintenance of biodiversity; conservation of rare species; minimal toxic algae blooms; maximum fisheries production

Targets or standards for a bay, estuary or lagoon: e.g. area of specific habitat; presence of indicator species; water quality standards; level of fisheries production

Total environmental capacity – calculated from e.g. water quality standard

Sector allocation of environmental capacity agreed through consultation and public involvement

2.7 Environmental and social impact assessment

Environmental assessment in its various forms is an important tool (or rather suite of tools) in planning for more sustainable development, and in particular as a basis for assessing and comparing alternative development options. Its application in general terms, and specifically the important distinction between sector level and farm level assessments, has been discussed in Part 1 (Section 1.5.8).

It is beyond the scope of this report to cover EA methodology in detail, nor is this necessary. Excellent general reviews and up to date guidelines are available (e.g. ADB, 1991; UNEP, 1996a; UNEP, 1996b), as well as those specifically designed for aquaculture (UNEP, 1990; UNEP, 1988; GESAMP, 1991a; Barg, 1992; NORAD, 1992; GESAMP, 1996a; Hambrey *et al*., 2000).

2.8 Cost Benefit Analysis (CBA)

Despite being an important planning and development tool, cost benefit analysis has been rather little used in relation to aquaculture development, and it is therefore worth reviewing it briefly and assessing its potential.

There are four component stages to cost benefit analysis:

1. the delineation of the boundary of the analysis (e.g. regional aquaculture development project);

2. the identification of costs and benefits (e.g. provision of infrastructure (cost); increased fish supply (benefit));

3. the valuation of the costs and benefits in two stages:
   a) financial evaluation (based on market prices for commodities);
   b) conversion of financial to economic values (e.g. expressed in terms of opportunity costs, to allow for market imperfections in the allocation of resources between alternative uses);

4. Comparison of economic costs and benefits over time under various alternative scenarios to assess the net economic benefit (value) returned.

There is a variety of approaches to the valuation of non-traded goods and services (“intangibles”). Some are based on surrogate market techniques, such as the effect of an environmental feature or change on property values, or the transport costs incurred in accessing an environmental benefit. Others - generally known as *contingent valuation* - are based on the creation of a hypothetical market, in which peoples willingness to pay (WTP) or willingness to accept (WTA) is estimated using interview or questionnaire techniques. The latter may be used in respect of environmental quality and biodiversity issues. These approaches have been widely described in the literature (e.g., Pearce and Turner, 1990; Dixon and Scura, 1994; Grigalunas and Congar, 1995; Kahn, 1998), and in relation to the valuation of ecosystem function reviewed recently by Costanza *et al.* (1997).

It is worth noting that valuation of intangibles is commonly done in company accounting. These may be simply stated as intangible benefits with no economic value attached or, as in the case of brand names and goodwill, an economic value can be negotiated or assigned.

The performance of enhanced sectoral or integrated coastal management can be evaluated in terms of the achievement of particular objectives. In the case of an objective related to optimal allocation this will be defined in terms of the achievement of multiple objectives (environmental, economic and social). Economic analysis can be used to assess the outcome of resource allocation based on multiple objective criteria.

Where comprehensive CBA is not used, economic analyses can nonetheless be used to shed light on specific issues such as the “costs” of pollution or habitat degradation associated with particular activities. Where actual costs are difficult to estimate, the “opportunity costs” associated with *not* developing or polluting resources can be estimated, and compared with the possible negative impacts. In other words it can provide information on the nature of “the trade-off” between competing uses of coastal resources, which is vital for economically sound and well informed decision making.

Recent texts on cost benefit analysis, which increasingly emphasise environmental costs and benefits, include Johansson, 1993; Hanley and Splash, 1998; Brent , 1996; and Dinwoody and Teal, 1996.

2.8.1 Experience review

From the literature, there are indications that economic approaches such as CBA are increasingly used in coastal zone management, but mainly in developed countries. A typical example would be in the assessment of coastal engineering schemes. Experience and application in developing countries are much less. World-wide, the economic investigation of aquaculture within the context of broader coastal management initiatives has been minimal.

Ruitenbeek (1992) provides an example relating to conservation and development of coastal resources in Iryan Jaya. Hambrey (1993) provides examples of economic calculations relating to the economic "trade-offs" between shrimp farming, alternative uses of mangrove areas, the nursery function of mangrove, and mangrove conservation in Indonesia. Other recent examples of resource valuation in the coastal zone include Gren and Soderqvist (1994), and Gilbert and Janssen (1997)

2.8.2 Strengths and weaknesses

The strength of CBA lies in the unifying nature of the analysis, and the rigour which is implicit in the identification of costs and benefits. The perceived weakness is the application of theoretical and often abstract economic concepts to real world situations. Crucially, the issue of valuation, especially in respect of non-traded goods and services, is one that has generated much debate and controversy. Contingent valuation and related techniques are generally costly, and are associated with a variety of limitations and theoretical problems.

2.8.3 Conclusions and recommendations

1. economics provide a key perspective and set of methodologies for the establishment and assessment of optimal resource allocation in the coastal zone, and should be used whenever possible;
2. economic methodologies are increasingly used in the coastal zone, but mainly in developed countries. This should be expanded to developing countries.

Contingent valuation techniques should be treated with caution. However they are important evolving tools and their weaknesses can be addressed in various ways:

3. the limitations of the techniques and their implications for the reliability of the results must be understood by practitioners and decision makers (this becomes more difficult with broader participation in decision making);
4. they should be used in association with other forms of analysis (e.g. qualitative participatory approaches as described below) to provide corroboration and additional perspectives;
5. efforts should be made to test and improve methodologies.

2.9 Consultative and participatory approaches to allocation decisions

Several authors have suggested alternatives to valuation and CBA as a basis for decision making. These include the estimation of trade-offs with alternative activities that can be valued (for example what would be the *opportunity cost* of conserving bio-diversity rather than clearing an area for development?) and damage schedule approaches (Knetsch, 1994; Chuenpagdee, 1996). The latter are forms of multi-criteria decision analysis (MCDA) and are usually based on a series of pair-wise comparisons of alternative objectives, strategies or specific developments, in order to identify overall preferences or make allocation decisions. These and other techniques for decision analysis have recently been described in detail by Rios (1994) and Lootsma (1999). Most of these techniques depend upon expert and/or community estimates of *relative* (rather than cash) value of different allocation decisions.

Community involvement is a key feature of all these approaches. The various participatory techniques described above under "issues identification" (see Table 1.2) are equally applicable to decision making.

One weakness of these approaches, especially where levels of public participation are high, is that the outcome will depend to a great extent on the quality of information available to those involved in the decision making process. Those lacking technical expertise or practical experience will find technical information difficult and inaccessible. These approaches must therefore be undertaken in parallel with increased accessibility and exchange of information. This implies significant expense.

A second limitation relates to the problem of minority interests. These techniques imply decision making related to majority preference, and may take little account of specific interests. The responsibility for taking these interests into account must still rest with government and its representatives.

2.10 Conflict identification and resolution

The process of promoting greater co-ordination and consultation between government departments, agencies and stakeholders during the planning process may lead to reduced or increased conflict. Areas of common interest, or conflicting interest, are likely to be revealed during issues identification and objective/target setting, and during the application of specific tools such as Cost Benefit Analysis and EIA.

There are four main approaches to resolving conflict:

- Litigation (court judgement);
- Arbitration (binding 3rd party solution; parties agree on third party (arbitrator));
- Mediation (3rd party (mediator) facilitates agreement; agreement may be contractual);
- Negotiation (discussion and agreement between parties)

The nature and strengths and weaknesses of the four approaches to conflict resolution are discussed in detail in Scialabba (1998) and will only be summarized here.

If an integrated planning initiative leads to litigation, it has clearly failed, since one of the objectives of more integrated planning is to resolve or pre-empt resource use conflict. Indeed, it is arguable that the whole process of more integrated planning is a form of mediation between the various coastal resource users and government sectoral interests. Litigation will not therefore be discussed further here.

2.10.1 Arbitration

Arbitration is “*a process in which a neutral outside party or panel meets with the parties to a dispute, hears presentations from each side, and makes an award or decision. Such a decision may be binding on the parties if they have previously agreed that it should be”* (Scialabba , 1998) .

The advantages of this process are that the parties themselves can choose the arbitrator and agree the rules, and are therefore more likely to be satisfied with the outcome than they would be under litigation.

The disadvantage to the parties is that they relinquish control over the final decision. Much depends on the competence of the arbitrator, and there is rarely any opportunity of appeal.

2.10.2 Mediation

Mediation is a process .. *“in which an outside party oversees the negotiation between two disputing parties”* (Scialabba, 1998). The mediator is neutral and makes no judgement, but rather facilitates the process of reaching agreement.

The mediator may be able to restore communication between alienated parties, and help them discover common interests and objectives, particularly in relation to the conflict. The mediator can also generally facilitate by focussing on promising solutions and stimulating ideas, or offering an unbiased interpretation of information or research, or helping to identify research needs and approaches.

Mediation can lead to more creative solutions than arbitration, which are fully supported by both parties, and may lead to genuine long-term improvements in relations between different interests.

2.10.3 Negotiation

Negotiation is the process in which the parties to a dispute meet to try to achieve a mutually acceptable solution.

The disadvantage relative to mediation is that issues may rapidly polarize in the absence of a neutral third party.

2.10.4 Techniques

Various techniques can be used to enhance the chances of success in all cases. These include:

- clear identification of interests;
- joint fact finding;
- informed dialogues;
- joint/creative problem solving and identification of alternatives;
- identifying opportunities for mutual gain; and
- clear identification of implementation procedures for agreed solutions.

2.10.5 Pre-conditions

Conflict – in the long term - is likely to be resolved only if the following conditions prevail:

- an impartial mediator (where one is used);
- equal status and access to information and support services for the various parties;
- the option of withdrawal at any time;
- no forced agreement

Arbitration and mediation both require great inter-personal and problem solving skills.

2.11 Zoning

The diverse information relating to natural and human resources, coupled with the assessment and comparison of different development or technical alternatives, should provide a sound basis for the identification of zones which are particularly suited (or unsuited) to aquaculture development. Criteria for the identification or designation of such zones might include, for example, existing uses, land-use capability, conservation value, demographic and social characteristics and trends, hydrographic and physiographic features.

Zoning may be used either as a source of information for potential developers (for example by identifying those areas most suited to a particular activity); or as a planning and regulating tool, in which different zones are identified and characterised as meeting certain objectives. Zoning of land (and water) for certain types of aquaculture development may help in controlling environmental deterioration at the farm level, and in avoiding adverse social and environmental interactions. Conflict between different resource use activities can be avoided. By creating exclusive zones, a sense of ownership and heightened responsibility for environmental management may be created in the user community.

Zoning for aquaculture may be particularly beneficial for small-scale shrimp farmers, who can be provided with proper water supply/drainage infrastructure, avoiding the ad hoc water supply and drainage systems resulting from uncoordinated development of individual farms (ADB/NACA, 1996).

2.11.1 Main applications

Zoning is an important and powerful tool for coastal planners and has a wide range of specific applications and uses.

Where zones are delineated on the basis of site suitability, they can be used:

- as a basis for the communication and exchange of ideas about aquaculture development, as a part of wider ICM initiatives;
- to encourage aquaculture development in the most suitable areas;

- to define areas which may benefit from infrastructure schemes specifically aimed at promoting aquaculture and related activities;
- to facilitate the establishment of environmental quality standards and targets appropriate for aquaculture development;
- to promote increased responsibility for environmental quality on the part of users;
- to provide a focus for research or monitoring on such issues as environmental capacity;
- to define environmental capacity in relation to aquaculture and other uses;
- to develop area based certification, or quality/environmental labelling schemes;
- as a basis for sectoral EIA or CBA related to a particular area .

Where zones are established on the basis of a rational appraisal of all alternative development activities, they may provide the basis for:

- wider consultation in respect of coastal development issues;
- a set of incentives and constraints designed to lead to:
    - ⇒ optimal allocation of resources to different kinds of development activity;
    - ⇒ minimization of conflict between different users.

2.11.2 Main approaches

In the case of aquaculture, the expertise of aquaculture practitioners is used to identify, demarcate and inventory zones that are potentially suitable for different kinds of aquaculture. Typical criteria for site selection are provided in Section 2.5.2. However, it must be remembered that such zones are indicative rather than rigid boundaries.

Ideally however, if the objectives of more integrated coastal management are to be met, this information should be assimilated within a wider GIS framework (Section 2.3) taking account of land and water potential for other types of enterprise. On the basis of this information, and the technical-economic and environmental assessment of different types of development activity, planning zones (precise designations of water, shore and land) may be identified with different sets of development and management objectives. In the case of a zone demarcated as a priority area for aquaculture, issues related to water quality and environmental capacity might figure significantly in these objectives. A set of incentives and constraints (economic, administrative, or a mixture) would then be designed to meet these objectives.

2.11.3 Main attributes

Aquaculture within specified zones may be subject to a wide range of voluntary or statutory procedures, incentives and constraints (Bodero and Robadue, 1995; Phillips and Barg, 1999), for example:

Voluntary, co-operative and infrastructure initiatives:

- voluntary codes of practice;
- co-operative marketing schemes;
- co-operative user/owner management of the zone, its resources and facilities;
- best management practice initiatives (possibly associated with environmental and product quality certification and labelling);
- infrastructure (for example water supply, treatment and drainage facilities for more intensive farms) provided by government or through co-operation between farmers themselves.

**Box 2.7 A topical zoning issue:
use of mangroves for pond aquaculture**

Mangrove has come under increasing pressure during this century as a result of a wide variety of development pressures, including conversion to agriculture, aquaculture, and urban development, and over-exploitation for wood and wood products (FAO 1994; Hambrey, 1996). Mangroves typically comprise less than 1% to, at most, 3-4 % of the total land area of most tropical countries. They are thus a scarce natural resource. In most wet tropical areas, mangroves are a productive ecosystem and mangrove timber (e.g. for use as fuel wood, charcoal and rayon) can be harvested on a sustained basis. Many mangroves have been converted to shrimp ponds but success is limited (most of the successes are based on extensive and semi-intensive culture systems where shrimp productivity is poor and economically does not rival sustainable timber production). Additionally, mangrove forests under sustained yield forestry are able to support and sustain a substantial capture fisheries (which includes shrimps).

Intensive shrimp pond practitioners now accept that it is best to avoid mangrove areas, for a number of technical reasons. Amongst these are the problems of acid sulphate conditions (most mangrove soils are potentially acid sulphate soils), unsuitable physical characteristics of such soils, and the difficulties of completely draining and drying ponds between crops. These problems are usually most severe in the mid and lower tidal range. It is thus recommended that unless there are good technical, social and economic reasons, it is best to avoid mangroves for pond aquaculture.

Regulation:

- lists of allowable and non allowable activities;
- a regulatory procedure for issuing and enforcing permits;
- permit conditions (such as farm design, management practices, and effluent standards or total pollution limits) ;
- sanctions for violating the terms of permits

Particular attention should be given to:

- the need to ensure that farming within designated zones is kept within the assimilative capacity of the environment;
- the need to streamline permitting/licensing procedures and minimise bureaucracy;
- the explicit establishment of policies and procedures for giving variances to the zone or to non-conforming uses.

In addition, a variety of economic incentives and constraints (see 2.12.2 and 2.12.3) may be associated with a zone, or graduated/differential incentives may be associated with a series of zones with differing objectives.

2.11.4 Experience

In Malaysia, government policy is to identify specific coastal aquaculture zones, compatible with existing land use patterns. In Korea, Japan, Hong Kong and Singapore (FAO/NACA, 1995), there are well developed zoning regulations for water based coastal aquaculture operations (marine cages, molluscs seaweeds). For example, Hong Kong has 26 designated Marine Fish Culture Zones within which all marine fish culture activities are carried out (Wong, 1995). In the State of Hawaii, best areas for aquaculture have been identified, some of which may be designated as aquaculture industrial parks (Rubino and Wilson, 1993). In Thailand zones suitable for the development of seawater irrigation schemes have been identified with a view to facilitating the development of sustainable aquaculture.

Zoning can also be designed in ways to encourage multiple use if appropriate, following agreed allowable and non-allowable uses, promoting optimal and balanced coastal resource use. In Ecuador, local zoning plans have been agreed between shrimp farmers and local residents, allowing for shrimp farming to continue, alongside mangrove planting and traditional uses (Bodero and Robadue, 1995). In British Columbia, the Ministry of Agriculture, Fisheries and Food, proposed that areas demonstrating high capability for aquaculture of 2 or more species and lying within land-use areas designated as high intensity areas should be defined as aquaculture priority area (APA) (Truscott, 1994). In the APA, other uses would be allowed if demonstrably compatible with aquaculture. In areas designated as lower intensity land-use, aquaculture significant areas (ASA) and aquaculture interest areas (AIA) would be defined as sites of high capacity for one species, sites not yet assessed, or sites where potential exists for species not yet commercially cultivated. All zones would be subject to management designed to protect environmental quality, biological diversity, critical wildlife and fish habitat, as well as cultural and recreational features. Management would use environmental monitoring and progressive refinement of predictive modelling to develop intensity of resource-use up to maximum sustainable levels (i.e., consistent with the carrying or assimilative capacity). Targets for implementation of APA and ASA would be reviewed at regular intervals to accommodate improved assessment capability, including development of new methods of culture and new species.

2.11.5 Strengths and weaknesses

The strength of zoning lies in its simplicity, its clarity, and its potential in terms of streamlining procedures. For example, once a zone is established and objectives defined, then developments that meet the objectives and general conditions for the zone may need no further assessment (such as EIA). What is allowed and what is not allowed is clear, and developers can plan accordingly.

Its weakness lies in its rigidity. No zone is perfect, assessment may have been inadequate, boundaries are frequently arbitrary, and conditions may change. There may exist small pockets of high potential for aquaculture, which were not recognised in the resource assessment process, are not part of an aquaculture zone, and which are therefore prevented or subject to severe regulation. Furthermore, it may actually be undesirable to encourage a concentration of aquaculture in one particular area, however suitable it may be, because of the increased risk of disease spread.

2.11.6 Recommendations

1. A strategic planning process based on zoning is a useful first step towards more integrated coastal management;
2. A regional coastal zoning scheme may be used to identify areas potentially suitable or incompatible with coastal aquaculture;
3. Aquaculturists, as stakeholders, should be involved in decision processes related to zoning;
4. The cumulative impact of individual aquaculture projects must be addressed; zones provide a workable framework for such an analysis;
5. Where zoning schemes are used as a component of coastal management, decisions on site selection for aquaculture should be related to such schemes.

2.12 Planning instruments: incentives and constraints

The implementation of any kind of strategic plan requires some form of intervention. A set of incentives and constraints (planning instruments) must be developed to encourage activities most likely to meet strategic objectives and specific targets (whether or not they relate to specific zones) and to discourage those that do not. These instruments may be classified as economic, administrative (Whitmarsh *et al.* , 1993), and institutional (OECD,1989).

Economic approaches recognise that market failure, brought about by unrestricted access to un-priced resources, is a major cause of problems within the coastal zone. The resultant intensification of the use of the coastal zone leads to the generation of externality effects (e.g. pollution). The economic approach attempts to "internalise" these externalities, with the ultimate aim of attempting to allocate resources in the most socially efficient manner.

Administrative approaches, by contrast, do not explicitly recognise the problem of market failure, rather they tend to adopt "command and control" mechanisms to coastal management. Typically, a regulatory authority would make decisions on which activities are allowed to take place in the coastal zone, including the nature of participating organisations, and the extent and nature of the operations. Such decisions may be preceded by public discussion with interested groups, and may be accompanied by educational programmes in support of the aims and objectives of the policy.

In most countries, if not all, there is a firm tradition of command and control, with significant bureaucratic processes, and resistance to economic instruments, which are often seen as giving too much leeway. On the other hand, administrative approaches can become ineffective and burdensome. There is a general feeling with a growing number of users and greater intensity of usage of the coastal zone, that economic approaches offer an effective and powerful option for the future.

The two approaches are not completely interchangeable, since certain problems can only be resolved by the use of particular techniques, such as the sale or allocation of rights to land or water use. If the rights are non-tradable this is primarily an administrative or regulatory approach; if they are tradable this becomes an economic approach.

It is important to recognise the strengths and weaknesses of the two approaches, and the actual extent to which they are employed. These have been reviewed in Part 1, and also by OECD (1989) in the case of environmental protection. To date there is relatively little experience of the application of economic approaches to aquaculture development planning.

2.12.1 Administrative instruments

Education and communication

The explanation and justification of management plans and particular management provisions should be key elements in the development of any integrated management plan. An ICM initiative in Ecuador (Robadue,1995) placed great emphasis on communicating the rationale for any regulatory measures, to the extent of developing manuals to explain and justify particular measures. Clearly, stakeholder participation in the drawing up of regulations will greatly facilitate this process. The effective communication and exchange of information is also major tool in conflict resolution.

Infrastructure

The quality of infrastructure may be a major factor in the success or failure of aquaculture, especially in developing countries, and is commonly under-emphasised in site selection. Infrastructure may be used as a tool to directly improve productivity, product quality, and farm gate value, as well as to reduce environmental impacts.

Sea-water irrigation and waste-water treatment

Many of the problems associated with coastal aquaculture development in developing countries are related to poor water supply and poor wastewater disposal. Although large scale operators may be able to invest in appropriate infrastructure directly, small scale and poor operators are usually dependent on existing canals and water supplies. The result is a mixing of influent and effluent water supplies between a large number of farms, along with the exchange of effluent, chemicals and disease. Although associations of small farmers may be able to develop their own infrastructure and/or water management schemes, this is extremely difficult, and government intervention is normally required. Once in place, there are strong arguments for user charges and taxes to cover the costs of such infrastructure. In the case of shrimp farming the increased revenue resulting from better water quality and less disease is likely to easily cover the infrastructure costs. It may also be possible to develop product quality or “green” certification and labelling directly associated with a particular scheme and its constituent farmers. Thailand is actively developing such schemes at the present time.

Communications, markets and processing

The farm-gate value of any aquaculture product will be linked to the ease of access to lucrative markets. Any interventions which result in improved communications, closer markets and processing facilities, will stimulate aquaculture. This may be used strategically by governments to attract operators away from areas or zones where aquaculture is considered undesirable, to those areas where it is a specific development objective.

Regulatory approaches

Regulation has been commonly used in an attempt to manage the development of aquaculture and its impacts. This has succeeded in many instances, especially in developed countries, but has a rather poor record in developing countries where the enforcement of regulation may be particularly difficult.

Regulation may include any or all of the following:

- some form of registration to facilitate or provide a framework for further intervention and regulation;

- restrictions on location. For example some zoning schemes may explicitly bar certain types of development or activity in particular areas;
- restrictions on the importation and/or transfer of cultured species
- prohibition of specific activities, materials or technologies;
- requirements for specific activities, technology or design;
- effluent standards;
- receiving water standards.

These may be stand-alone regulations or may be directly linked to registration, licensing or the issue of permits.

Experience review

Shrimp farm registration has been a success in Thailand, in the sense that most farms are registered. This is due to its relation with free technical services from government agencies and the district fisheries office (the authorised office), which is usually located in culture areas for the convenience of farmers.

Regulation of routine effluent discharge quality is difficult if not impossible to implement for large numbers of small operators. In practice routine effluents from aquaculture systems are in any case of relatively high quality and regulation is not usually necessary.

Government regulation of sludge disposal is also almost impossible. However, in some areas of Thailand, groups of farmers are self-policing in this regard, since they need to avoid causing severe water quality problems for each other.

Size thresholds for the application of regulations are problematic. In Thailand, for example, the vast majority of farms are less than 8 hectares, so that some important regulations do not apply to most shrimp farming. On the other hand, enforcement would not be feasible for a large number of small farms. Clearly an alternative approach is required to influence the behaviour of small farmers.

Box 2.8 Regulation of shrimp farming in Thailand

In Thailand regulations for marine shrimp farming were announced by the Ministry of Agriculture and Cooperatives in 1991 under the Fisheries Act of 1947. The regulations included the following:

Shrimp farmers must *register* with the District Fisheries Office; such registration must be renewed every year.

To minimize environmental impact:
- Shrimp farms over 8 ha must have a sedimentation pond not less than 10% of the culture area; and BOD of discharged water should not exceed 10mg/l;
- Every farm must have a sludge disposal area for storage of pond sludge; and the sludge and slurry must not be released into any public area or agricultural land
- More recently the operation of shrimp farms in freshwater areas has been banned due to concerns over saltwater intrusion into agricultural land

Conclusions and recommendations

1. farmers understanding of, and co-operation with regulations can be enhanced through appropriate communication and training;
2. regulation is likely to be more successful where farmers or their representatives have been closely involved in their design;
3. successful enforcement can be facilitated via farm co-operative areas or farmer associations;
4. regulations should be simple and easy for small scale farmers to practice;
5. preparation of technical advice on best farm management practice should be distributed together with regulations.

Codes of practice for farm management (Best Management Practices)

As discussed above, many regulations are difficult to implement in practice, and may lead to an attitude of limited responsibility in practice. Where the rationale for regulation is clear, and particularly when it relates to the interests of farmers themselves, every effort should be made to promote self-regulation through codes of practice. These may be reinforced through peer pressure, and in some cases actually enforced by associations of farmers themselves.

Codes of practice, including best management practice may be used as a basis for certification and quality labelling (see Section 2.12.3).

The following is proposed as a set of basic of criteria for success of best management practice:

- high survival rate;
- low FCR (Feed Conversion Ratio);
- low waste discharge to the wider environment;
- high rate of return or profitability.

In the case of coastal pond culture, success can be promoted through the following (generic) best management practice:

- good site selection (e.g. in terms of soil quality, elevation, distance from prime mangrove areas and water pollution sources);
- well trained and experienced labour;
- high feed quality;
- efficient feeding practices;
- skilled water quality management;
- pond soil management to maximize water quality and minimize sludge discharge;
- membership of a co-operative or farmer association.

These would need to be developed in detail for specific locations and circumstances.

Experience review

Codes of practice and management guidelines are well established for some aquaculture industries and are attracting interest world-wide (e.g. FAO Fisheries Department, 1997; Huntington and Dixon 1997; GAA, 1998; FAO, 1998, 1999). Implementation and compliance tends to be high for large scale operations, since these have the skills and resources to implement, and because they are subject to greater scrutiny and regulation. Small and medium scale farmers may lack the knowledge, skills, resources and incentive to comply with such codes.

Some codes developed at higher (e.g. national) levels may be very difficult to implement at a local level, especially by small farmers. For example, while a farmer with 10 hectares may find the loss of two hectares for effluent treatment acceptable, a small farmer with only one hectare might find the loss of 20% of his production area unacceptable. Furthermore, depending on technology, management and local environmental conditions, such a practice may be unnecessary to meet environmental objectives.

Conclusions

It is very difficult to set anything other than very general codes of practice at international, national or regional level. Indeed, it is arguable that only *principles of operation* should be established at these higher levels. Technology, scale of enterprise and local social and environmental conditions are enormously diverse. More locally appropriate codes of practice need to be developed. Ideally these would refer to specific zones with particular environmental objectives and standards, as defined in the planning process.

Farmer associations and/or operation within a designated zone, may provide a framework for the dissemination and exchange of information relating to good practice, and could also form the basis for the development of linked marketing schemes, which might provide a financial incentive for compliance (2.12.3).

Recommendations

1. Codes of practice set at international or national levels should be framed around objectives and principles of operation rather than detailed prescriptions;
2. More detailed and practical codes of practice should be developed at local/district level, preferably in relation to a specific zone with defined development and environmental objectives and targets (ideally also with an environmental capacity assessment);

3. All farmers should be encouraged to be members of an aquaculture association or producer group;
4. Farmers should have easy access to high quality technical advisory material on best management practice, design and technology.

2.12.2 Economic instruments

In recent years, increasing dissatisfaction with administrative approaches to environmental management in the coastal zone has led to widespread interest in economic approaches (Garrod and Whitmarsh, 1994). Administrative approaches are now often viewed as providing little more than the legislative framework for control, and the regulatory instruments themselves are often seen as ineffective. Attempts at regulating aquaculture through administrative means have failed in many developing countries, and have been strongly resisted in developed countries.

Economic (market-based) instruments typically "...affect estimates of costs and benefits of alternative actions open to economic agents, with the effect of influencing decision-making and behaviour in such a way that alternatives are chosen that lead to an environmentally more desirable situation than in the absence of the instrument. Economic instruments, as opposed to direct regulations, leave actors free to respond to certain stimuli in a way they themselves think more beneficial" (OECD, 1989).

Economic instruments have been widely studied with respect to pollution control in coastal areas, and there are important lessons for their more widespread use in the regulation of activities such as aquaculture in a broad sense (e.g. to influence production levels, industry structure etc).

For pollution control, OECD (1989) has classified economic instruments into 5 types:

1. Charges;
2. Subsidies;
3. Deposit refund systems;
4. Market creation;
5. Financial incentives;

Charges

Charges can be considered as the "price" for pollution, with both incentive and redistributive impacts. *Effluent charges* include, for example, a charge per kg of nitrogen released to the environment, or a charge per unit volume of effluent. *Product charges* include, for example, taxes on polluting inputs such as phosphorus in feeds. In Norway and Sweden fertilisers and pesticides are taxed for this reason. *Administrative charges* include permit fees related to design or operation parameters – with a higher fee for higher effluents, or higher permit fees to pay for environmental regulation. For example, in Norway license fees have been used to fund sector environmental assessment. *User charges* may be levied for access to, or use of, seawater irrigation systems, or waste treatment. *Tax concessions* may be made for using particular sites or technologies.

The overall impact is to enter the cost of pollution into private cost-benefit calculations. Differential charges according to location may be used to influence siting. Charges or taxes levied may also be used for environmental improvements – such as water supply or wastewater treatment.

The effectiveness of product charges depends the relative cost of the product as part of overall operating costs, and the price and availability of substitutes. For example, feed is often a very high cost in aquaculture, and low pollution diets can be produced. A charge or tax levied on polluting feeds is therefore likely to have a significant effect.

Setting the level for these charges can be very difficult. Too low will have insignificant effect; too high may cripple the industry. Rough estimates must be made and the effect monitored closely, before adjusting to achieve the desired mix of objectives.

Subsidies

Subsidies are a form of financial assistance (e.g. grants, soft loans, tax allowances) which act as an incentive for polluters to alter their behaviour, or which are given to firms facing problems in complying with imposed standards. Subsidies may be provided for specific environment friendly technology or practice, or to siting in preferred zones. The provision of infrastructure is a common example of subsidy, and this may be used to reduce environmental impact. An example is government or aid funded seawater irrigation systems.

Although subsidies have been provided to aquaculture in many parts of the world they have rarely been linked to environmental management in practice.

The main weakness of subsidy is that it implies a net cost to government. Ideally therefore any subsidy should be matched by a tax (for example on a polluting product). A second weakness is that it provides no incentive for innovation, or reduced inputs.

Deposit refund systems

In this case a surcharge may be laid on the price of potentially polluting products or activities. When pollution is avoided by returning (recycling) these products or its residuals to a collection system, a refund of the surcharge is made. Alternatively a deposit or *bond* may be required prior to developing a site, especially in environmentally sensitive areas. If and when the operation closes, the site must be fully restored to previous use or value if the bond is to be returned (for example by removing or breaking pond dykes and replanting mangrove). Bonds or deposits may also be applied to operations. In this case the bond is only returned once a water treatment system is operational, or where there is demonstrated use of low pollution diets, or demonstrated low pollution load.

Bonds offer an incentive to minimise the cost of environmental protection and are therefore likely to stimulate innovation.

Market creation

Markets are created where actors might buy rights for actual or potential pollution, or where they sell their "pollution rights" or their process residuals. This approach could be applied to environmental capacity, a portion of which, for a particular estuary, lagoon or bay, could be sold or allocated for aquaculture, and subsequently traded freely. In theory, operators will buy permits until the price of the permit rises to equal the cost of treatment for the same amount of pollution. This provides a strong incentive to improve operation/technology: those without good technology/management will be unable to afford the larger permit required. This approach has many advantages in so far as it is cost effective (the cost associated with pollution and its treatment is set by the market), it generates revenue, and allows continuing economic growth without increased pollution. Emissions trading relating to heavy industry has been very effective in the USA and has resulted in substantial cost savings.

However, there are problems with this approach for aquaculture, especially in relation to small-scale operations. As for more regulatory approaches, there needs to be some means of policing to ensure that operators are keeping within their permit/allocation. One possible approach is to use feed records (cross-checked between the operator and the supplier). Another is to restrict a permit to only a part of operations. For example, in the case of pond culture, checking might be restricted to the time of harvest, when the bulk of any pollution is likely to take place. It is also essential to be able to track changes in ownership, and this requires significant administration, especially for small permits.

There are also generic problems with permit trading, including manipulation by powerful operators. For example, they may purchase a large number of permits (more than they need) while the price is low, so that there is then little need to improve technology and performance. If permits are originally allocated free of charge, there may be widespread profit taking. In other words these approaches suffer from some of the classic inadequacies of free markets, and some control may be required.

Financial incentives

This type may also be considered as legal instruments: non-compliance is "punished" either *ex ante* (by requiring a payment returnable upon compliance) or *ex post* (by charging a fine when non-compliance occurs). A variation of this is **liability insurance,** where polluters are made legally liable for damage (for example to fish nursery grounds). This will encourage the establishment of insurance schemes, the premium of which will be related to the risks of environmental damage caused by the operator, offering an incentive for improved design, technology and management.

In practice this is only likely to be effective in the case of relatively extreme environmental impacts, and is less suitable for the more subtle and diffuse impacts associated with most agriculture and aquaculture. Proof is notoriously difficult in the case of environmental impact. It would be very difficult to prove, for example, that steady low level pollution, or the occasional dose of chemicals, had been the cause of a failure of recruitment to a fishery. It would also be difficult to prove that it was not. If the burden of proof were to be laid on the fish farmer (in line with the precautionary principle and the polluter pays principle), this would probably result in most aquaculture being stopped. If the burden of proof were to lie with the complaintive, there would be few if any convictions, although the number might increase if legal aid were provided for such claims (as is the case for example in some States in Australia).

Liability is likely to work best where the risk is high but the information poor. It may be linked to a performance bond (i.e. if the bond is drawn on for damages).

Experience

The main examples of economic approaches to aquaculture have been positive incentives - grants and subsidies to encourage the development of aquaculture, especially in remoter or less developed regions. Grants, subsidies and low interest loans played a significant role in the rapid development of salmon culture in Scotland and Norway in the 80’s, and fin-fish culture in the Mediterranean in the ‘90s.

There are rather few examples of the use of such instruments to regulate the impacts of aquaculture on the environment or other resource users. The use of deposit refund systems, or restoration bonds tied to the issue of licenses or lease of land has been proposed (for example in India) as a means of ensuring that shrimp farming does not lead to lasting environmental damage, but it is too early to assess the success of such schemes in practice.

Pollution charges have been widely applied in the USA and Europe, and coupled with specific regulations they have almost eliminated pollution from freshwater aquaculture in Denmark. However, in this case they have significantly constrained the development of the industry.

Legal liability on the part of fish farmers for environmental damage is in place in several countries, including Korea and Australia.

Strengths and weaknesses

Strengths:

- implementation of the *polluter/user pays principle*: polluter or user pays in proportion to amount of pollution or full social and environmental costs of resource use;
- less need for “enforcement” in some of its forms;
- usually offers an incentive for innovation (since less pollution = lower cost);
- flexibility and efficiency in economic terms;
- may not need information on operation or discharge from individual farms (particularly important for non-point sources such as cages);
- partly addresses cumulative problems;
- generates government revenue for environmental management.

Weaknesses:

- effects not so predictable as regulatory approaches;
- may need sophisticated institutions (to monitor, enforce; adjust, adapt etc);
- not popular with government agencies - less control;
- not popular with industry - extra costs.

Conclusions

Economic approaches have many attractive features, including the prospect of paying for monitoring and compliance, and in many cases the provision of strong incentives for innovation in terms of less environmentally damaging technology. However, especially in the case of small scale operations, most of them do not overcome the problems of compliance, and implementation may be at least as complex as for regulatory measures.

Both the flexibility aimed at by economic approaches and the certainty of effectiveness sought by direct regulation, might be realised by an open-minded approach to the creative search for new instruments for environmental policy, or new combinations of existing instruments (Soley *et al.,* 1992; OECD, 1989).

Recommendations

1. Economic approaches deserve more attention as possible approaches to the planning and management of aquaculture, probably in combination with regulatory and market approaches;
2. Farmer groups or associations may allow for more effective application to small farmers.

2.12.3 Markets and labelling

There is currently significant interest in the possibility of tying best practice or codes of practice (siting, design, technology, operation/management) to labelling schemes, on the assumption that some consumers will pay a premium for environmentally friendly goods. This will then serve as a major incentive to adhere to codes of practice. Impartial certification (i.e. certification by a body without a financial interest in the outcome) is required, and this is more or less difficult and costly dependent upon the degree of variation in the technology and the complexity of the marketing and distribution networks. A key requirement is that the location of production must be known. Furthermore there must be solid consumer trust in the process if the product is to command a significant premium. Detailed discussion of the role of labelling in the promotion of sustainable shrimp farming can be found in Clay (1996, 1997).

Products such as shrimp, other crustaceans, and high quality finfish are particularly suited to such schemes, since they are already marketed as quality products, subject to existing quality classifications, to discerning consumers.

Many such schemes have been launched in respect of "sustainable forestry", and initiatives are also underway to apply them to fisheries. Initiatives are underway in Thailand at the present time to link the establishment of seawater irrigation schemes for aquaculture with ISO14000 certification. The government hopes that the higher value of a certified product may be (partially) taxed to provide funds for investment in further infrastructure designed to improve the sustainability of aquaculture.

One problem with these initiatives is that the benefits may accrue largely to the wholesaler or retailer rather than the producer, and directly linking farm gate price to environmental management will not be easy.

Quality labelling and environmental standards may in some cases work against small scale producers. While vertically integrated corporate aquaculture can control and certify both management practice and quality at almost all stages of production and marketing, this becomes far more difficult and costly for small scale producers. Furthermore, the environmental standards may be more difficult to meet. If, for example, western importers were to require a guarantee that shrimp were not produced in mangrove areas to allow them to apply an environmental friendly label to their product, this would automatically exclude the poorest producers in Asia. Many poor families farm in mangrove areas for lack of available land elsewhere, or because of the prohibitive costs of pumping water to areas above the tidal range.

A possible solution is to use a graduated labelling scheme, where producers may be awarded "stars" for different kinds of quality or environmental benefit (e.g. low or zero food input; low or zero fish meal input; zero destruction of prime mangrove within a certain distance from creeks etc.). Consumers themselves can balance their choice with their personal social and environmental priorities.

Associations of small farmers are likely to be able to exploit the potential of labelling schemes far more effectively than individual farmers.

Strengths

- offers a simple financial incentive for improved environmental performance;
- may be linked to codes of practice, zoning, existence of ICM;
- works through steady pressure rather than a sudden blow to producers, and can be "graduated" (e.g. star system) to allow for steady improvement;
- will ultimately reflect the environmental values of consumers rather than regulators.

Weaknesses

- certification will usually be more difficult and costly for smaller and more isolated producers – who may already be at a disadvantage in terms of ability to comply (e.g. with siting requirements);
- a significant part of the premium may go to the wholesaler, thus reducing the incentive for the producer;
- the certification criteria will reflect the environmental and social values of consumers (who may live on the other side of the world) rather than local people.

Conclusions and recommendations:

1. quality and "green" labelling schemes associated with codes of practice offer considerable potential in terms of encouraging farmers to farm in certain areas or operate in particular ways;
2. ideally such schemes should be "graduated", offering flexibility and a variety of standards, suited both to different consumer values, and also to the ability of farmers to comply;
3. associations of farmers should be encouraged, to facilitate access to such schemes by small farmers;
4. the criteria for certification should be drawn up in consultation with local people as well as consumers, NGO's, industry representatives etc

2.13 Monitoring and feedback

As has been discussed in earlier Sections of this report, development of aquaculture should take place within a management framework designed to minimise adverse impacts on the environment, both human and natural. Developing such a framework depends on prediction of significant potential effects at scales appropriate to the scale of the proposed aquacultural activity. These predictions are inevitably subject to uncertainty. Monitoring is, therefore, an integral part of the regulatory process, and its main objective is to verify that changes associated with aquaculture are within the predetermined, acceptable limits.

Monitoring is of limited use if it is not linked to a pre-determined management response in the event that the monitored variables are found to lie outside their acceptable limits. There should be ***a priori*** agreement about the action that will be taken if impacts exceed predicted levels. As Cairns and Dickson (1995) have pointed out, any useful definition of the term 'monitoring' must include an explicitly-stated management action if the data fall outside previously-established limits. This action might take the form of a reduction (where monitoring indicates that environmental capacity has been exceeded) or increase (where capacity is under-utilised) in stocking density or number of farms (GESAMP, 1996a). Reduction could extend to temporary or permanent resting of the affected site. This feedback-loop from prediction to monitoring to management provides the mechanism for optimal use of resources. Data from monitoring also allows methods for predicting impacts to be refined for use in the future.

GESAMP (1996a) provides a detailed discussion of monitoring in the context of ecological impacts of coastal aquaculture wastes, and Schmitt and Osenberg (1996) provide guidance and discussion of principles of monitoring.

2.13.1 Ecological monitoring

General principles and aims of ecological monitoring and impact assessment are set out in several reviews, such as those of Green (1979) and Schmitt & Osenberg (1996). Detailed discussion of monitoring in the context of ecological impacts of aquaculture is provided by Barg (1992) and GESAMP (1996a and b), including examples of variables commonly measured in monitoring studies for aquacultural impacts, several examples of their use, and evaluation of their use in interpreting changes.

The role and value of ecological monitoring in relation to a management plan are described in Part 1. Ecological monitoring can also indicate trends in environmental quality and determine whether individual farms are meeting regulatory requirements (Barg, 1992).

Because monitoring programmes should aim to test specific predictions derived from the assessment of potential impacts, they should be adapted to the size, type and location of the aquaculture operation in question, and the sensitivity of the receiving environment. It is not, therefore, appropriate to recommend standard monitoring procedures, and the references cited above should be consulted for guidance on the design of monitoring programmes.

Design of monitoring studies should carefully consider the selection of appropriate reference sites (see GESAMP, 1996a), standardisation of sampling and analytical procedures and analysis and interpretation of the data, and the selection of appropriate and cost-effective variables to measure. Given the often large variability of natural systems, the design of a cost-effective monitoring programme requires ensuring that it has adequate statistical power to detect important differences or changes (e.g., Peterman, 1990; Fairweather, 1991; GESAMP, 1996a). There should be more than one reference site whenever possible. This important point derives from the fact that any two places may differ for a wide range of reasons, most of which may be unrelated to the presence or absence of a fish farm. Impacts of the farm may, therefore, be confounded or obscured by other, perhaps unmeasured, differences between the farm and reference sites (Underwood, 1992, 1993).

The causal link between aquacultural activity and environmental change is greatly strengthened by including a baseline survey although, in theory, impacts can be detected by monitoring and comparison of the impacted location and a sufficient number of reference locations after aquaculture has commenced (Glasby, 1997). By providing data on conditions prior to the start of aquaculture, a baseline survey allows the coincidence of aquaculture and the onset of environmental change to be established, and obscuring effects of natural variation among farm and reference sites to be reduced (Glasby, 1997). Baseline data also provide information for use in the design of the monitoring study.

A general discussion of the selection of variables for monitoring is given by Keough and Quinn (1991). Examples of variables commonly measured in monitoring studies for aquacultural impacts, including several examples of their use, and evaluation of their value in interpreting changes are given by Barg (1992) and GESAMP (1996a, Table III). They may include concentrations and rates of output of contaminants, the extent and rate of physical modification of the environment, and changes in targets exposed to these changes, such as natural populations or communities of plants or animals. Barg (1992) points out that it is important to distinguish between output and consumption by aquaculture and their related ecological effects. The former are potential, but not necessarily actual, mechanisms for the ecological impacts that should be the real area of concern.

2.13.2 Social and economic monitoring

Many economic, social and welfare indicators are routinely collected by government agencies and local government as routine input to policy decisions. These may include such indicators as employment, GDP, per capita product, education, health, health and education provision, average wage etc. Coupled with specific data on the financial and economic profiles of particular enterprises or user groups, monitoring and assessment is relatively straightforward. Monitoring issues such as conflict is more difficult, and can only be assessed on the basis of long-term consultation and participation.

Local and provincial government commonly has expertise in social and economic monitoring, and existing capacity should be strengthened rather than substituted under any new initiative.

2.13.3 Conclusions and recommendations

1. Strategic coastal planning depends on assessing or predicting the impact of any development or activity, in social, economic or environmental terms. These assessments are inherently inaccurate or uncertain. Monitoring and feedback is required to refine the assessments and improve the quality of the interventions;
2. To be of any value, monitoring must be linked to a pre-determined management response in the event that the monitored variables are found to lie outside their acceptable limits.
3. Monitoring programmes should aim to test specific predictions derived from the assessment of potential impacts, and they should be adapted to the size, type and location of the aquaculture operation in question and the sensitivity of the receiving environment.
4. Given the often large variability of natural systems, the design of a cost-effective monitoring programme requires that it has adequate statistical power to detect important differences or changes.

2.14 References

Ackefors, H. & Enell, M., 1994. The release of nutrients and organic matter from aquaculture systems in Nordic countries. J.Appl.Ichthyol., 10:225-41

ADB (Asian Development Bank), 1991. Environmental evaluation of coastal zone projects: methods and approaches. ADB Environ.Pap. , (8):72 pp.

ADB/NACA, 1996. Aquaculture sustainability action plan. Regional study and Workshop on aquaculture sustainability and the environment (RETA 5534). Manila, Asian Development Bank; and Bangkok, Network of Aquaculture Centres in Asia-Pacific: 21 pp.

Aguilar-Manjarrez, J. & Ross, L.G., 1995. Geographical information systems (GIS); environmental models for aquaculture development in Sinaloa State, Mexico. Aquacult.Int., 3(2):103-115

Ali, C., Ross, L.G. & Beveridge, M.C.M., 1991. Microcomputer spreadsheets for the implementation of geographic information systems in aquaculture: a case study on carp in Pakistan. Aquaculture, 92:199-205

Angel, D.L., Krost, P. & Gordin, H., 1995. Benthic implications of net cage aquaculture in the oligotrophic Gulf of Aqaba. In Rosenthal, H., Moav, B. & Gordin, H. (eds). Improving the knowledge base in modern aquaculture. Proceedings of the Fifth German-Israeli Status Seminar of the German-Israeli Cooperation Programme in Aquaculture Research. Jerusalem, Israel, 18 July 1994. Spec.Publ.Eur.Aquacult.Soc., (25):129-173

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

Bacher, C., 1991. Etude de l'impact du stock d'huîtres et des mollusques compétiteurs sur les performances de croissance de Crassostrea gigas, à l'aide d'un modele de croissance. ICES Mar.Sci.Symp., (192):41-47

Bacher, C., Héral, M., Deslous-Paoli, J.M. & Razet, D., 1991. Modèle énergétique uniboite de la croissance des huîtres (Crassostrea gigas) dans le basin de Marennes-Oléron. Can.J.Fish.Aquat.Sci./ J.Can.Sci. Halieut.Aquat., 43:391-404

Barg, U.C., 1992. Guidelines for the promotion of environmental management of coastal aquaculture development (based on a review of selected experiences and concepts). FAO Fish.Tech.Pap., (328):122 pp. (issued also in French and Spanish)

Beveridge, M.C.M., 1996. Cage aquaculture. Oxford, UK, Fishing News Books, 2nd ed. 346 pp.

Beveridge, M.C.M., Ross, L.G. & Mendoza, E.A.Q M., 1994. Environment, site selection and planning: the role of Geographic Information Systems in aquaculture. In Proceedings of the IFS Workshop on ecology of marine aquaculture. Osorno, Chile, 18-23 November 1991. Stockholm, Sweden, International Foundation for Science, pp. 26-47

Bjorndal, T., 1990. The economics of salmon aquaculture. Oxford, UK, Fishing News Books, 128 pp.

Bodero, A. & Robadue, D., 1995. Strategies for managing mangrove ecosystems. Coast.Resour.Cent.Tech.Rep. Univ.R.I., (2088):41-70

Bohra, A., 1996. Application of multi-temporal remote sensing data and GIS techniques for evaluating the impact of modern shrimp farming in the coastal zone in Chantaburi Province, Thailand. Pathumthani, Thailand, Asian Institute of Technology (AIT)

Boyd, C.E., 1995. Bottom soils, sediment and pond aquaculture. New York, Chapman & Hall, 348 pp.

Brent, R., 1996. Applied cost benefit analysis. Cheltenham, Gloucestershire and Leeds, UK, Edward Elgar Publishers, 360 pp.

Briggs, M.R.P. & Funge-Smith, S.J., 1994. A nutrient budget for some intensive fish ponds in Thailand. Aquacult.Fish.Manage., 10:789-811

Brown, J.R., Gowen, R.J. & McLusky, D.S., 1987. The effects of salmon farming on the benthos of a Scottish sea loch. J.Exp.Mar.Biol.Ecol.,109:39-51

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

Cairns, J. & Dickson, K.L., 1995. Ecological hazard/risk assessment: lessons learned and new directions. Hydrobiologia, 312: 87-92

Campbell, J., 1996. Participatory and integrated policy: a field guide for policy formulation in small scale fisheries. Exeter UK, Integrated Marine Management Ltd.

Campbell, J. & Townsley, P., 1996. Participatory and integrated policy: a framework for small scale fisheries in sub-Saharan Africa. Exeter UK, Integrated Marine Management Ltd.

Carver, C. E. A. & Mallet, A.L., 1990. Estimating the carrying capacity of a coastal inlet for mussel culture. Aquaculture, 88:39-53

Chamberlain, G.W., 1997. Sustainability of world shrimp farming. In Pikitch, E.L., Huppert, D.D. & Sissenwine, M.P. (eds). Global trends: fisheries management. Symp.Am.Fish.Soc., (20):195-209

Chaston, I., 1989. Marketing in fisheries and aquaculture. Oxford, UK, Fishing News Books, 144 pp.

Chua T.-E., 1997. Sustainable aquaculture and integrated coastal management. In Bardach, J.E. (ed), Sustainable aquaculture. New York, John Wiley and Sons, pp. 177-99

Chua, T.-E., Paw, J.N., & Guarin, F.Y., 1989. The environmental impact of aquaculture and the effects of pollution on coastal aquaculture development in Southeast Asia. Mar.Pollut.Bull., 20(7):335-43

Chuenpagdee, R., 1996. Damage schedule - an alternative approach for valuation of coastal resources. Naga, 19(4):13-15

Clay, J W., 1996. Market potentials for redressing the environmental impact of wild-captured and pond-produced shrimp. Washington DC, World Wildlife Fund

Clay, J.W., 1997. Toward sustainable shrimp culture. World Aquacult., 28(3):32-37

Costanza, R. et al., 1997. The value of the world's ecosystem services and natural capital. Nature (Lond.), 387:253-260

Cross, S.F. & Kingzett, B.C., 1992. Biophysical criteria for shellfish culture in British Columbia: a site capability evaluation system. Victoria, British Columbia, MAFF Aquaculture and Commercial Fisheries Branch

Danish Hydraulic Institute. http:/www.dhi.dk/index.htm

de la Cruz, C., 1995. Brackishwater integrated farming systems in Southeast Asia. In: Bagarinao, T.U. & Flores E.E.C. (eds). Towards sustainable aquaculture in Southeast Asia. Proceedings of the Seminar Workshop on aquaculture development in Southeast Asia. Iloilo City, 26-28 July 1994. Iloilo City, the Philippines, SEAFDEC Aquaculture Department, pp. 23-26

Dinwoody, C. & Teal, F., 1996. Principles of cost benefit analysis for developing countries. Cambridge, UK, Cambridge University Press, 302 pp.

Dixon, J. & Scura, L., 1994. Economic analysis of environmental impacts. London, Earthscan (Kogan Page) 224 pp.

EAO (Environmental Assessment Office), 1997a. Salmon aquaculture review. Vol. 3. Technical advisory team discussion papers. Victoria, British Columbia Environmental Assessment Office

EAO (Environmental Assessment Office), 1997b. Salmon aquaculture review. Final report. Vol. 3. Part D. Victoria, British Columbia Environmental Assessment Office. http://www.eao.gov.bc.ca/project/aquacult/salmon/report/toc.htm

Fairweather, P.G., 1991. Statistical power and design requirements for environmental monitoring. Austr.J.Mar.Freshwat.Res., 42:555-567

FAO, 1994. Mangrove forest management guidelines. FAO For.Pap., (117):319 pp. (issued also in Spanish)

FAO, 1998. Report of the Bangkok FAO Technical Consultation on policies for sustainable shrimp culture. Bangkok, Thailand, 8-11 December 1997. Informe de la Consulta Técnica FAO/Bangkok sobre politicas por el cultivo sostenible del camerón. Bangkok, Tailandia, 8-11 de diciembre de 1997. FAO Fish.Rep./FAO Inf.Pesca, (572):31 pp.

FAO, 1999. Papers presented at the Bangkok FAO Technical Consultation on policies for sustainable shrimp culture. Bangkok, Thailand, 8-11 December 1997. Documentos presentados a la Consulta Técnica FAO Bangkok sobre politicas para el cultivo sostenible del camarón. Bangkok, Tailandia, 8-11 de diciembre de 1997. FAO Fish.Rep./FAO Inf.Pesca, (572) Suppl./Supl. 266 pp.

FAO Fisheries Department, 1997. Aquaculture development. FAO Tech. Guidel.Responsible Fisheries, (5):40 pp. (issued also in French and Spanish)

FAO/NACA, 1995. Report on a Regional Study and Workshop on the environmental assessment and management of aquaculture development (TCP/RAS/2253). Bangkok, Network of Aquaculture Centres in Asia-Pacific. NACA Environ.Dev.Ser., (1):492 p.

Findlay, R.H. and Watling, L., 1994. Towards a process level model to predict the effects of salmon net-pen aquaculture on the benthos. Can.Tech.Rep.Fish.Aquat.Sci., (1949):47-77

Findlay, R.H. & Watling, L., 1997. Prediction of benthic impact of salmon net-pens based on the balance of benthic oxygen supply and demand. Mar.Ecol.Progr.Ser., 155: 147-157

Findlay, R. H., Watling, L. & Mayer, L.M., 1995. Environmental impact of salmon net-pen culture on marine benthic communities in Maine: a case study. Estuaries, 18(1A):145-179

Fréchette, M., Booth, D.A., Myrand, B. & Bérard, H., 1991. Variability and transport of organic seston near a mussel aquaculture site. ICES Mar. Sci.Symp., (192):24-32

Garrod, B. & Whitmarsh, D., 1994. Economic approaches to the control of pollution in the marine environment. CEMARE Res.Pap. Univ. Portsmouth, (75):13 pp.

GEF/UNDP/IMO, 1996. Enhancing the success of integrated coastal management: good practices in the formulation, design and implementation of integrated coastal management initiatives. Quezon City, Philippines, GEF/UNDP/IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas and Coastal Management Center. MPP-EAS Tech.Rep., (2):32 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 1986. Environmental capacity. An approach to marine pollution prevention. Rep.Stud.GESAMP, (30):49p.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1991a. Reducing environmental impacts of coastal aquaculture. Rep.Stud.GESAMP, (47):35 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection),1996a. Monitoring the ecological effects of coastal aquaculture wastes. Rep.Stud.GESAMP, (57): 38 pp.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1996b. The contributions of science to integrated coastal management. Rep.Stud.GESAMP, (61):66 pp.

Gilbert, A.J. & Janssen, R., 1997. The use of environmental functions to evaluate management strategies for Pagbilao mangrove forest. IIED/CREED. Work. Pap. Ser. Inst. Environ.Stud.Vrije Univ.Neth., (15) Gittinger, J.P., 1982. Economic analysis of agricultural projects. Baltimore and London, Johns Hopkins University Press, 505 pp.

Glasby, T.M., 1997. Analysing data from post-impact studies using assymmetrical analyses of variance: a case study of epibiota on marinas. Aust. J.Ecol., 22: 448-459

Global Aquaculture Alliance (GAA). http://www.gaalliance.org/index.html

Gowen, R.J., Smith, D. & Silvert, W., 1994. Modelling the spatial distribution and loading of organic fish farm waste to the sea bed. In Hargrave, B.T. (ed.). Modelling benthic impacts of organic enrichment from marine aquaculture. Can.Tech.Rep.Fish.Aquat. Sci., (1949):19-30

Grant, J. et al., 1993. Perspectives on field studies and related biological models of bivalve growth and carrying capacity. In Dame, R. (ed.). Bivalve filter feeders in estuarine and coastal ecosystem processes. NATO Adv.Sci.Inst. Ser.G.Ecol.Sci., (33):371-420

Green, R.H., 1979. Sampling design and statistical methods for environmental biologists. Chichester, UK, Wiley Interscience, 257 pp.

Gren, I.-M. & Soderqvist, T., 1994. Economic valuation of wetlands: a survey. Beijer Int.Inst.Ecol.Econ.Discuss Pap.Ser. , (54)

Grigalunas, T.A. & Congar, R. (eds), 1995. Environmental economics for integrated coastal area management: valuation methods and policy instruments. UNEP Reg.Seas Rep.Stud., (164):165 pp.

Grimble, R. & Man Kwun Chan, 1995. Stakeholder analysis for natural resource management in developing countries. Nat.Resour. Forum, 19 (2) :113-124

Grimble, R. & Wellard, K., 1997. Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities. Agric.Syst.J., 55(2):173-193

Hambrey, J.B., 1993. Comparative economics of different land-use options in the mangrove forest area of North Sumatra Province. Report prepared for NESPP/ODA and Direktorat Jenderal Perikanan, Indonesia, by Nautilus Consultants, Edinburgh, 60 pp.

Hambrey, J.B., 1996. Comparative economics of land use options in mangrove. Aquacult.Asia, 1(2):10-15

Hambrey, J.B., 1998. Utilization of coastal resources for aquaculture. Paper presented at the Fifth Asian Fisheries Forum: International Conference on fisheries and food security beyond the year 2000, organized by the Asian Fisheries Society and the Aquatic Resources Research Institute, Chulalongkorn University, Chiang Mai, Thailand, 11-14 November 1998 (mimeo)

Hambrey, J.B., Phillips, M.J., Chowdhury, M.A.K. & Shivappa, R.B., 2000. Guidelines for the environmental assessment of coastal aquaculture development. An environmental assessment (EA) manual to assist governmental agencies, coastal aquaculture developers, non-governmental organisations (NGOs) and community organisations. Maputo, Mozambique, Secretariat for Eastern African Coastal Area Management (SEACAM) 213 pp.

Hanley, N. & Splash, C., 1998. Cost-benefit analysis and the environment. Cheltenham, Gloucestershire, and Leeds UK, Edward Elgar Publishing Ltd., 288 p.

Hargrave, B.T., 1994. A benthic enrichment index. Can.Tech.Rep.Fish. Aquat.Sci ./Rapp.Tech.Can.Sci. Halieut.Aquat., (1949):79-91

Hayek, B.F. & Boyd, C.E., 1994. Rating soil and water information for aquaculture. Aquacult.Eng., 13:115-28

Héral, M., 1993. Why carrying capacity models are useful tools for management of bivalve mollusc culture. In Dame, R.F. (ed.). Bivalve filter feeders in estuarine and coastal ecosystem processes. NATO Adv.Sci.Inst.Ser.G Ecol.Sci., (33):455-477

Herman, P.M.J. & Scholten, H., 1990. Can suspension-feeders stabilise estuarine ecosystems? In Trophic relationships in the marine environment. Proceedings of the Twentyfourth European Marine Biological Symposium, edited by Barnes, M. & Gibson, R.N. Aberdeen, Scotland, Aberdeen University Press, pp. 104-116

Hofmann, E.E. et al., 1994. Modelling oyster populations. 2. Adult size and reproductive effort. J.Shellfish Res., 13:165-182

Huguenin, J.E., 1997. The design, operations and economics of cage culture systems. Aquacult.Eng., 16:167-203

Huguenin, J.E. & Colt, J., 1989. Design and operating system for aquaculture seawater systems. Dev.Aquacult.Fish.Sci., 20:264 pp.

Huntington, T. & Dixon, H., 1997. A review of the environmental impact of aquaculture in Belize and guidelines for sustainable development. Final report by MacAlister Elliot Partners. Belize City, Government of Belize, GEF/UNDP

Johansson, P.-O., 1993. Cost-benefit analysis of environmental change. Cambridge UK, Cambridge University Press, 246 pp.

Kahn, J.R., 1998. The economic approach to environmental and natural resources. London, Dryden Press (Harcourt Publishers Ltd., a subsidiary of Harcourt International Ltd.), 540 pp.

Kapetsky, J.M., 1989. A geographic information system for aquaculture development in Johore State. Rome, FAO, Field document FI:TCP/MAL76754: 62 pp. (mimeo)

Kapetsky, J.M., Hill, J.M. & Worthy, I.D., 1988. A geographical information system for catfish farming development. Aquaculture, 68:311-320

Kapetsky, J.M., McGregor, L. & Nanne E.H., 1987. A geographical information system and satellite remote sensing to plan for aquaculture development: an FAO/UNDP/GRID cooperative study in Costa Rica. FAO Fish.Tech.Pap., (287):51 pp.

Kapetsky, J.M. & Travaglia, C., 1995. Geographical information systems and remote sensing: an overview of their present and potential applications in aquaculture. In Nambiar, K. & Singh, T. (eds). Aquaculture towards the twentyfirst century. Kuala Lumpur, INFOFISH, pp. 187-208

Kapetsky, J.M. et al., 1990. Where are the best opportunities for fish farming in Ghana? The Ghana aquaculture Geographical Information System as a decision-making tool. Rome, FAO, FI/TCP/GHA/0051 Field Technical Report 5: (mimeo)

Keough M.J. & Quinn, G.P., 1991. Causality and the choice of measurements for detecting human impacts in marine environments. Austr.J.Mar.Freshwat.Res., 42: 539-554

Knetsch, J.L., 1994. Environmental valuation: some problems of wrong questions and misleading answers. Environ.Values, 3:351-368

Levings, C.D., Ervik, A., Johannessen, P. & Aure, J., 1995. Ecological criteria used to help site fish farms in fjords. Estuaries, 18 (1A): 81-90.

Lootsma, F. A., 1999. Multi-criteria decision analysis via ratio and difference judgement: applied optimization. Dordrecht, Kluwer Academic Publishers Group, 300 pp.

McPadden, C.A., 1993. The Malacca Straits coastal environment and shrimp aquaculture in North Sumatra Province. NESPP/ODA in cooperation with Dinas Perikanan (N. Sumatra) and Directorate General of Fisheries, Indonesia. London, Department for International Development (DFID UK)

Meaden, G. J. & Kapetsky, J.M., 1991. Geographic Information Systems and remote sensing in inland fisheries and aquaculture. FAO Fish.Tech.Pap., (318):262 pp. (issued also in Spanish).

Miller, D.C., 1983. Handbook of research design and social measurement. New York, Longman. 4th ed.

NCC, 1989. Fishfarming and the safeguard of the natural marine environment of Scotland. Edinburgh UK, Nature Conservancy Council Scottish Headquarters

NORAD (Norwegian Agency for Development Cooperation), 1992. Environmental impact assessment of development aid projects: initial environmental assessment. 5. Aquaculture. Oslo, Norway. NORAD, 22 pp.

Odum, W.E., 1982. Environmental degradation and the tyranny of small decisions. BioScience, 32:728-729

OECD, 1989. Economic instruments for environmental protection. Paris, Organization for Economic Cooperation and Development, 130 pp.

Pearce, D.W. & Turner, R.K., 1990. Economics of natural resources and the environment. Hemel Hempstead, UK, Harvester Wheatsheaf, 377 pp.

Pearson, T. H. & Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr.Mar.Biol., 16:229-311

Peterman, R.M., 1990. Statistical power analysis can improve fisheries research and management. Can.J.Fish. Aquat.Sci./J.Can. Sci. Halieut.Aquat., 47(1):2-15

Phillips, M.J. & Barg, U., 1999. Experiences and opportunities in shrimp farming. In Svennevig, N., Reinertsen, H. & New, M. (eds). Sustainable aquaculture - food for the future. Proceedings of the Second International Symposium on sustainable aquaculture. Oslo, Norway, 2-5 November 1997. Rotterdam, Balkema, pp.43-72

Pido, M.D., Pomeroy, R.S., Carlos, M.B. & Garces, L.R., 1996. A handbook for rapid appraisal of fisheries management systems. (Version 1). ICLARM Educ.Ser. (116):85 pp.

Pridmore, R.D. & Rutherford, J.C., 1992. Modelling phytoplankton abundance in a small enclosed bay used for salmon farming. Aquacult.Fish.Manage., 23:525-542

Raillard, O. & Menesguen, A., 1994. An ecosystem box model for estimating the carrying capacity of a macrotidal shellfish system. Mar.Ecol.Prog.Ser., (115):117-130

Rios, S., 1994. Decision theory and decision analysis: trends and challenges. Dordrecht, Kluwer Academic Publishers Group, 312 pp.

Robadue, D. (ed.), 1995. Eight years in Ecuador: the road to integrated coastal management. Coast.Resour.Cent.Tech.Rep.Univ.R.I., (2088):319 pp. http://crc.uri.edu.eccover.html

Rodhouse, P.G. & Roden, C.M., 1987. Carbon budget for a coastal inlet in relation to intensive cultivation of suspension-feeding bivalve molluscs. Mar. Ecol.Prog.Ser., (36):225-236

Rosenberg, R. & Loo, L.-O., 1983. Energy-flow in a Mytilus edulis culture in western Sweden. Aquaculture, 35:151-161

Ross, L.G., Mendoza, E.A.Q.M. & Beveridge, M.C.M., 1993. The application of Geographical Information Systems to site selection for coastal aquaculture: an example based on salmonid cage culture. Aquaculture,113:165-178

Rubino, M.C. & Wilson, C.A., 1993. Issues in aquaculture regulation. Bethesda, Maryland, USA, Bluewaters Inc. pursuant to the National Oceanic and Atmospheric Administration (NOAA) Award no. NA27FD0093-01A

Ruitenbeek H.J., 1992. Mangrove management, an economic analysis of management options with a focus on Bintuni Bay, Iryan Jaya. Paper prepared for the Environmental Management Development in Indonesia Project (EMDI) Jakarta. EMDI Environ.Rep.Dalhousie Univ.Halifax Can., (8):90 pp.

Schmitt, R.J. & Osenberg, C.W., 1996. Detecting ecological impacts: concepts and applications in coastal marine habitats. San Diego, Academic Press, 401 pp.

Scialabba, N. (ed.), 1998. Integrated coastal area management and agriculture, forestry and fisheries. FAO Guidelines. Rome, FAO, Environment and Natural Resources Service, 256 pp.

Shang Y.C., 1990. Aquaculture economic analysis: an introduction. Adv.World Aquacult., 2:211 pp.

Shaw, S.A., 1990. Marketing: a practical guide for fish farmers. Oxford UK, Fishing News Books/Blackwell Science in association with the Highlands and Islands Development Board, 112 pp.

Simpson, H.J. & Pedini, M., 1985. Brackishwater aquaculture in the tropics: the problem of acid sulphate soils. FAO Fish. Circ., (791):32 pp.

Smaal, A.C., 1991. The ecology and cultivation of mussels: new advances. Aquaculture, 94:245-261

Soley, N., Neiland, A. & Nowell, D., 1992. An economic approach to pollution control in aquaculture. Mar.Pollut.Bull., 28(3):170-178

Townsley, P., 1996. Rapid rural appraisal, participatory rural appraisal and aquaculture. FAO Fish.Tech.Pap., (358):109 pp.

Truscott, S.J., 1994. Capability studies for finfish and shellfish aquaculture as a prerequisite to coastal planning. In Wells, P.G. & Ricketts, P.J. (eds). Coastal zone Canada '94: cooperation in the coastal zone. Coastal Zone Canada Association Conference Proceedings. Dartmouth, Bedford Institute of Oceanography, Vol.1:1611-29

UN, 1989. Handbook on social indicators. New York, United Nations, Department of International Economics and Social Affairs, Statistical Office, Studies in methods (ST/ESA/STAT/SER.F.49)

Underwood, A.J., 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable world. J.Exp.Mar.Biol.Ecol., 161:145-178

Underwood, A.J., 1993. The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. Austr. J.Ecol., 18:99-116

UNEP, 1988. Environmental impact assessment: basic procedures for developing countries. Bangkok, Thailand, UNEP Regional Office for Asia and the Pacific, 16 pp.

UNEP, 1990. Environmental guidelines for fish farming. UNEP Environ.Manage.Guidel.,Nairobi, (19):50 pp.

UNEP Environment and Economics Unit (EEU), 1996a. Environmental impact assessment: issues, trends and practice. Prepared for the United Nations Environment Programme (UNEP) by Scott Wilson Resource Consultants (Ron Bisset) under the guidance and technical support of the UNEP International Working Group on EIA. Preliminary version, June 1996. Nairobi, UNEP Environment and Economics Unit, 96 p.

UNEP, 1996b. Environmental impact assessment: training resource manual. Prepared for the United Nations Environment Programme by the Environment Protection Agency, Canberra, Australia, under the guidance and technical support of the UNEP International Working Group on EIA. Preliminary version, June 1996. Nairobi, UNEP and Canberra, Australian Environment Protection Agency, 699 pp. (loose-leaved binder)

Washington State Department of Ecology,1986. Recommended interim guidelines for the management of salmon net-pen culture in Puget Sound. Shorelands Planning. Olympia, Washington State Department of Ecology, Report (87/5)

Washington State Department of Fisheries, 1990. Final programmatic environmental impact statement: fish culture in floating net-pens. Prepared by Parametrix Inc. Olympia, Washington State Department of Fisheries

Weber, K.E. & Tiwari, I.P., 1992. Research and survey format design: an introduction. Bangkok, Asian Institute of Technology, Division of Human Settlements Development, Reference Material (23)

Whitmarsh, D. et al., 1993. Fisheries in the context of coastal zone management. CEMARE Res. Pap.Univ.Portsmouth, (63):10 pp.

Wong, P.S., 1995. Hong Kong. In Report on a Regional Study and Workshop on the environmental assessment and management of aquaculture development (TCP/RAS/2253). Bangkok, Network of Aquaculture Centres in Asia-Pacific. NACA Environ.Aquacult.Dev.Ser., (1):113-139

Yoo, Kyung H. & Boyd, C.E., 1994. Hydrology and water supply for pond aquaculture. New York, Chapman & Hall, 483 pp.

2.15 Glossary

Selected Terms[24] are defined here in the sense that they are used in this report. They are described here to provide interested readers with additional explanations, comments or background information.

Command and control policy instruments
Policy measures that seek to directly control or restrict activities

Conservation
Protection, maintenance, rehabilitation, restoration and enhancement of populations and ecosystems.

Cost-benefit analysis
The identification and valuation of all the direct and indirect costs and benefits (financial, economic, social and environmental) associated with a particular action, project or programme. These costs and benefits can then be aggregated in the form of a benefit/cost ratio providing a simple decision criteria for decision makers. In practice it is extremely difficult to identify and value (in cash terms) all the costs and benefits, although economists use a range of tools to facilitate this process, and adjust values to allow for market imperfections.

Decision tree
A branched diagram starting from a single point which illustrates the possible consequences of different sets of sequential decisions or actions, taken under different external circumstances. Probabilities related to different outcomes may be assigned. Decision trees can be effective tools to aid discussions related to the possible long term effects of different decisions or sets of decisions.

Deposit refund system
A command and control policy instrument (see above) in which a surcharge is levied on the price of products leading to resource depletion or pollution which is then refunded if the product (or its residuals) are re-cycled.

Diversity
The number of different species, and their relative abundance, and the number of habitats existing in a particular area. Diversity is a measure of the complexity of an ecosystem, and often an indication of its relative age, measured in terms of the number of different plants and animal species (often called species richness) it contains, their distribution and the degree of genetic variability within each species. **Biodiversity** is the term used to designate the variety of life in all its forms, levels and combinations and includes ecosystem, species and genetic diversity.

Earth (Rio) Summit
The United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, 3-14 June 1992. Texts of agreements negotiated by more than 178 Governments at the Conference were Agenda 21 (the Programme of Action for Sustainable Development), the Rio Declaration on Environment and Development, and the Statement of Forest Principles. The Conference also presented the Conventions on Biological Diversity and Climate Change,

Economic policy instruments
Policy or planning instruments which create financial incentives for individuals to behave in specific ways, or increase/decrease their economic activity.

Ecosystem: A natural entity (or a system) with distinct structures and relationships that liaise biotic communities (of plants and animals) to each other and to their abiotic environment. The study of an ecosystem provides a methodological basis for complex synthesis between organisms and their environment.

Efficiency: In general, efficiency is the ratio of a system's output (or production) to input, as in the useful energy produced by a system compared to the energy put in the system. In ecology, it is the percentage of useful energy transferred from one trophic level to the next (as in the ratio of production of herbivores to that of primary producers). Used in the context of production, efficiency is the ratio of useful work performed to the total energy expended, thus avoiding waste generation. In the context of the allocation of resources, efficiency is the condition

---

[24] Sources:
United Nations, 1997. Glossary of Environment Statistics. Department for Economic and Social Information and Policy Analysis, Statistics Division. ST/ESA/STAT/SER.F./67. 83 p.
Scialabba, N. (ed.), 1998. Integrated coastal area management and agriculture, forestry and fisheries. FAO Guidelines. Environment and Natural Resources Service, FAO Rome. 256p. http://www.fao.org/docrep/W8440e/W8440e00.htm
FAO, 2001. FAO Fisheries Glossary. http://www.fao.org/fi/glossary/default.asp

which would make at least one person better off and no one worse off. This implies that some may get richer and others not improve their status.

Environmental capacity
A property of the environment and its ability to accommodate a particular activity or rate of an activity...without unacceptable impact" (GESAMP, 1986). In practice this may be measured as, for example, a specific quantity of nutrient or pollutant which can be assimilated by a lagoon system without exceeding a water quality standard.

Environmental economics
A set of tools and procedures that have been developed to assign a value, in monetary terms, to non-traded environmental goods and services.

Environmental Impact Assessment (EIA): A sequential set of activities designed to identify and predict the impacts of a proposed action on the biogeophysical environment and on man's health and well being, and to interpret and communicate information about the impacts, including mitigation measures that are likely to reduce impacts. **Sector environmental assessment** applies the process to a whole sector (such as aquaculture) with a view to identifying industry level mitigation measures, such as development zones and/or environmentally friendly technology and practices. **Integrated environmental assessment** applies this process across a range of activities for a specific region or area, with a view to identifying higher level (e.g. planning interventions) mitigation measures, and promoting a mix of activities which will minimise environmental impact while maximising socio-economic benefit.

Environmental quality standards (EQS)
Agreed standards for environmental quality. Typically these standards are set in relation water or air at national or international levels. However, it is desirable that they should also be set in relation to specific planning objectives and targets, and relating to specific natural resource systems. EQS are important for the determination of environmental capacity, and for measuring progress against planning objectives.

Externality(ies)
Social, economic and environmental benefits and costs which are not included in the market price of goods and services being produced. These costs are not born by those who occasion them, and benefits are not paid for by the recipients. Some economists suggest that externalities should be internalised, that is, they should be included in the accounting of those activities which generate them.

History line
A communication and synthesis tool sometimes used in participatory rural appraisal. During discussions between researchers and stakeholders (especially resource users), a line is drawn, against which key events of the past are indicated. In this way the sequence of events and their possible causal relations can be analysed.

Indicators
Indicators are defined as signals - of processes, inputs, outputs, effects, results, outcomes, impacts, etc - that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring and evaluation.

Institutions
Institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. Institutions can be formal (e.g. a government agency) or informal (e.g. socially transmitted conventions and codes of behaviour).

Institutional analysis
The analysis, in relation to a specific issue or problem, of relevant formal and informal institutions and their relationships, and the structure and procedures (e.g. decision making, implementing, review) of these institutions.

Integration
The process of bringing together separate components as a functional whole that involves co-ordination of interventions. In ICM, integration may take place at three levels, system, functional and policy. Systems integration refers to the physical, social and economic linkages of land and water uses and ensures that all relevant interactions and issues are considered. Functional integration ensures that programmes and projects are consistent with ICM goals and objectives; and policy integration ensures that management actions are consistent with other development and policy initiatives. **Vertical integration** refers to integration between local level and national or international activities and policies. **Horizontal integration** refers to integration between different sectors (such as fisheries and forestry).

Integrated Coastal Management.
In its ideal form this is a multi-sectoral planning and management process for a specified coastal area which takes account of impacts and interdependencies within and between sectors, through improved understanding of ecosystem functions and economic systems, and through the development of institutional capacity.

Key informant
An individual with exceptional knowledge related to a specific issue, or able to direct the researcher to other key sources of information.

Non-Governmental Organisation: Any organisation that is not a part of federal, provincial, territorial, or municipal government. Usually refers to non-profit organisations involved in development activities.

Non-compliance fees: “Additional” prices to be paid for not complying with environmental requirements to meet the social costs arising from environmental damages.

Objective: Expresses the object of an action or what is intended to be achieved. Any objective will include explicit statements against which progress can be measured, and identify which things are truly important and the way they inter-relate. Quantified objectives are referred to as targets.

Open access:
A situation in which access to a natural resource (e.g. a fishery or grazing) is free, unlimited and available to everyone. The situation arises either where no one is legally entitled to deny others access (e.g. many high seas fisheries) or where the owner or manager of the resource fails to control access.

Participatory (rural) appraisal (PRA)
An approach to understanding and exchanging views about social, cultural and resource use issues, as the basis for increased participation of ordinary people in the planning and decision making process. Key features of this approach are the use of a variety of tools and techniques (often graphic) to facilitate the exchange of information and opinion, and in particular to synthesise information about resource use, exchange and interactions

Performance bonds: Similar to a deposit refund system (see above), a bond is placed equal to the estimated social costs of possible environmental damage as a surety for complying with environmental requirements and is forfeit if these requirements are not met.

Plan: Amplification of a strategy showing the precise means by which objectives will be reached: the policy instruments to be employed; the financial and human resources required; and the time frame for implementation. *Rolling (plan):* the practice of preparing a plan for a number of years in annually sequentially less detail, revising the plan annually and maintaining the number of years covered by the plan.

Planning: The plotting of a course of action (involving executive action or enforcement) which is proposed to carry-out some proceeding, devising the relative positions and timing of a set of actions.

Planning instrument
A specific form of action designed to influence development activity. This might be regulatory (e.g. a production limit) or economic (e.g. a tax or bond).

Policy
The course of action for an undertaking adopted by a government, a person or another party. Instruments that exist to support policy and tools used to achieve policy objectives include some or all of the following: societal instruments, economic and command and control instruments, direct government involvement and institutional and organisational arrangements.

Polluter pays principle
The re-allocation of the social costs of environmental degradation by regulating to ensure that such costs are borne by the parties to the transaction rather than by society at large. The principle therefore internalises externalities (see externalities above). The price charged may be levied directly (e.g. as taxes on the process which generates pollution) or as purchase price of licences which entitle the holder to generate specific quantities of pollution.

Protected area
A geographically defined area which is designed and managed to achieve specific conservation objectives

Ranking
Arranging objectives, criteria, or activities in order of importance or value. When absolute cash or numeric values cannot be assigned to costs or benefits associated with any particular activity or course of action, ranking can be used to assign relative value, and in some cases to assign an imputed numeric value.

Rapid appraisal
A rapid assessment of social, economic, environmental and resource use issues through discussions and interviews with a range of “key informants” and randomly selected ordinary people. Some of the techniques typically used in participatory appraisal may be used in this process.

Socio-economic survey
Formal survey of social and economic conditions using sophisticated sampling techniques, questionnaires and/or formal and standardized interviews.

Stakeholders
The individuals and groups of individuals (including governmental and non-governmental institutions, traditional communities, universities, research institutions, development agencies and banks, donors, etc.) with an interest or claim (whether stated or implied) which has the potential of being impacted by or having an impact on a given project and its objectives. Stakeholder groups that have a direct or indirect "stake" can be at the household, community, local, regional, national, or international levels.

Stakeholder analysis
An approach to understanding a system through the identification of all key actors or stakeholders, and describing their specific interests, motivations, and associations relating to that system.

Strategy: A statement involving the projections of actions, including the direction of means, to achieve an objective.

Sustainable development: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland Report; WCED, 1987) or "..the management and the conservation of the natural resource base and the orientation of the technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human need for present and future generations. Such sustainable development in the agriculture, forestry and fishery sectors concerns land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable." (FAO Fisheries Department, 1997)

Technically driven
An activity which is driven by technical interests rather than actual need in relation to objectives.

Tradable permits
An economic policy instrument under which rights to discharge pollution or exploit resources can be exchanged or traded through either a free or a controlled "permit" market. Examples include Individual Transferable Quotas in fisheries, tradable depletion rights to mineral concessions, and marketable discharge permits for water-borne effluents.

Transect
A cross sectional diagram of a resource or economic system, with notes or symbols indicating physical features, vegetation, land use, and economic activity. Such diagrams are particularly useful for indicating resource use, flow and exchange.

Trade-off
The value of something which has to be given up in order to get something else which is desired (e.g., the environmental cost incurred to obtain economic development). Trade-off patterns between resources are determined by the different properties of a system, and their importance to different groups. The understanding of social dynamics and resource-use systems and the evaluation of related trade-offs, in terms of equity, productivity, resilience, and environmental stability, are useful to envision alternative development scenarios.

Venn diagram
Discrete or overlapping circles of differing sizes arranged in two dimensions to illustrate the nature of, and interactions between, institutions or social groups. Typically the relative sizes of circles are used to illustrate relative size or power of institutions or social groups; the degree of overlap illustrates the degree of interaction or the extent of overlapping interest; and the arrangement in space illustrates the overall pattern and strength of relationships between different groups. The diagrams may be developed with text or arrows to better illustrate the nature important interactions.

Zoning
The delineation of land or water areas with specific characteristics relevant to development activities. These zones may be used for information purposes (e.g. as an aid to site selection) or as a strategic planning tool, in which development or conservation objectives are defined for specific zones. These objectives may be promoted through the use of a range of planning instruments taylor-made for specific zones.

IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)

Groupe mixte d'experts OMI/FAO/UNESCO-COI/OMM/OMS/AIEA/ONU/PNUE chargé d'étudier les aspects scientifiques de la protection de l'environnement marin (GESAMP)

Grupo Mixto de Expertos OMI/FAO/UNESCO-COI/OMM/OMS/OIEA/Naciones Unidas/PNUMA sobre los Aspectos Científicos de la Protección del Medio Marino (GESAMP)

The following reports and studies have been published so far. They are available from any of the organizations sponsoring GESAMP

Reports and Studies GESAMP
ISSN 1020-4873

1.	Report of the seventh session, London, 24-30 April 1975. (1975). *Rep.Stud.GESAMP*, (1):pag.var. Available also in French, Spanish and Russian
2.	Review of harmful substances. (1976). *Rep.Stud.GESAMP*, (2): 80 p.
3.	Scientific criteria for the selection of sites for dumping of wastes into the sea. (1975). *Rep.Stud.GESAMP*, (3): 21 p. Available also in French, Spanish and Russian
4.	Report of the eighth session, Rome, 21-27 April 1976. (1976). *Rep.Stud.GESAMP*, (4): pag.var. Available also in French and Russian
5.	Principles for developing coastal water quality criteria. (1976). *Rep.Stud.GESAMP*, (5): 23 p.
6.	Impact of oil on the marine environment. (1977). *Rep.Stud.GESAMP*, (6): 250 p.
7.	Scientific aspects of pollution arising from the exploration and exploitation of the sea-bed. (1977). *Rep.Stud.GESAMP*, (7): 37 p.
8.	Report of the ninth session, New York, 7-11 March 1977. (1977). *Rep.Stud.GESAMP*, (8): 33 p. Available also in French and Russian
9.	Report of the tenth session, Paris, 29 May - 2 June 1978. (1978). *Rep.Stud.GESAMP*, (9): pag.var. Available also in French, Spanish and Russian
10.	Report of the eleventh session, Dubrovnik, 25-29 February 1980. (1980). *Rep.Stud.GESAMP*, (10): pag.var. Available also in French and Spanish
11.	Marine Pollution implications of coastal area development. (1980). *Rep.Stud.GESAMP*, (11): 114 p.
12.	Monitoring biological variables related to marine pollution. (1980). *Rep.Stud.GESAMP*, (12): 22 p. Available also in Russian
13.	Interchange of pollutants between the atmosphere and the oceans. (1980). *Rep.Stud.GESAMP*, (13): 55 p.

14. Report of the twelfth session, Geneva, 22-29 October 1981. (1981). *Rep.Stud.GESAMP*, (14): pag.var. Available also in French, Spanish and Russian

15. The review of the health of the oceans. (1982). *Rep.Stud.GESAMP*, (15): 108 p.

16. Scientific criteria for the selection of waste disposal sites at sea. (1982). *Rep.Stud.GESAMP*, (16): 60 p.

17. The evaluation of the hazards of harmful substances carried by ships. (1982). *Rep.Stud.GESAMP*, (17): pag.var.

18. Report of the thirteenth session, Geneva, 28 February - 4 March 1983. (1983). *Rep.Stud.GESAMP*, (18): 50 p. Available also in French, Spanish and Russian

19. An oceanographic model for the dispersion of wastes disposed of in the deep sea. (1983). *Rep.Stud.GESAMP*, (19): 182 p.

20. Marine pollution implications of ocean energy development. (1984). *Rep.Stud.GESAMP*, (20): 44 p.

21. Report of the fourteenth session, Vienna, 26-30 March 1984. (1984). *Rep.Stud.GESAMP*, (21): 42 p. Available also in French, Spanish and Russian

22. Review of potentially harmful substances. Cadmium, lead and tin. (1985). *Rep.Stud.GESAMP*, (22): 114 p.

23. Interchange of pollutants between the atmosphere and the oceans (part II). (1985). *Rep.Stud.GESAMP*, (23): 55 p.

24. Thermal discharges in the marine environment. (1984). *Rep.Stud. GESAMP*, (24): 44 p.

25. Report of the fifteenth session, New York, 25-29 March 1985. (1985). *Rep.Stud.GESAMP*, (25): 49 p. Available also in French, Spanish and Russian

26. Atmospheric transport of contaminants into the Mediterranean region. (1985). *Rep.Stud.GESAMP*, (26): 53 p.

27. Report of the sixteenth session, London, 17-21 March 1986. (1986). *Rep.Stud.GESAMP*, (27): 74 p. Available also in French, Spanish and Russian

28. Review of potentially harmful substances. Arsenic, mercury and selenium. (1986). *Rep.Stud.GESAMP*, (28): 172 p.

29. Review of potentially harmful substances. Organosilicon compounds (silanes and siloxanes). (1986). Published as *UNEP Reg.Seas Rep.Stud.*, (78): 24 p.

30. Environmental capacity. An approach to marine pollution prevention. (1986). *Rep.Stud.GESAMP*, (30): 49 p.
Adobe (.pdf) format (392K) (PDF)

31. Report of the seventeenth session, Rome, 30 March - 3 April 1987. (1987). *Rep.Stud.GESAMP*, (31): 36 p. Available also in French, Spanish and Russian

32. Land-sea boundary flux of contaminants: contributions from rivers. (1987). *Rep.Stud.GESAMP*, (32): 172 p.

33. Report on the eighteenth session, Paris, 11-15 April 1988. (1988). *Rep.Stud.GESAMP*, (33): 56 p. Available also in French, Spanish and Russian

34. Review of potentially harmful substances. Nutrients. (1990). *Rep.Stud.GESAMP*, (34): 40 p.

35. The evaluation of the hazards of harmful substances carried by ships: Revision of GESAMP Reports and Studies No. 17. (1989). *Rep.Stud. GESAMP*, (35): pag.var.

36. Pollutant modification of atmospheric and oceanic processes and climate: some aspects of the problem. (1989). *Rep.Stud.GESAMP*, (36): 35 p.

37. Report of the nineteenth session, Athens, 8-12 May 1989. (1989). *Rep.Stud.GESAMP*, (37): 47 p. Available also in French, Spanish and Russian

38. Atmospheric input of trace species to the world ocean. (1989). *Rep.Stud.GESAMP*, (38): 111 p.

39. The state of the marine environment. (1990). *Rep.Stud.GESAMP*, (39): 111 p. Available also in Spanish as *Inf.Estud.Progr.Mar.Reg. PNUMA*, (115): 87 p.

40. Long-term consequences of low-level marine contamination: An analytical approach. (1989). *Rep.Stud.GESAMP*, (40): 14 p.

41. Report of the twentieth session, Geneva, 7-11 May 1990. (1990). *Rep.Stud.GESAMP*, (41): 32 p. Available also in French, Spanish and Russian

42. Review of potentially harmful substances. Choosing priority organochlorines for marine hazard assessment. (1990). *Rep.Stud. GESAMP*, (42): 10 p.

43. Coastal modelling. (1991). *Rep.Stud.GESAMP*, (43): 187 p.

44. Report of the twenty-first session, London, 18-22 February 1991. (1991). *Rep.Stud.GESAMP*, (44): 53 p. Available also in French, Spanish and Russian

45. Global strategies for marine environmental protection. (1991). *Rep.Stud.GESAMP*, (45): 34 p.

45 Add.1 Global strategies for marine environmental protection: Can there be a common framework for managing radioactive and non-radioactive substances to protect the marine environment? (1992). *Rep.Stud. GESAMP*, (45, Add.1): 13 p.

46. Review of potentially harmful substances: Carcinogens. (1991). *Rep.Stud.GESAMP*, (46): 56 p.

47. Reducing environmental impacts of coastal aquaculture. (1991). *Rep.Stud.GESAMP*, (47): 35 p.

48. Global changes and the air-sea exchange of chemicals. (1991). *Rep.Stud.GESAMP*, (48): 69 p.

49. Report of the twenty-second session, Vienna, 9-13 February 1992. (1992). *Rep.Stud.GESAMP*, (49): 56 p. Available also in French, Spanish and Russian

50. Impact of oil and related chemicals and wastes on the marine environment. (1993). *Rep.Stud.GESAMP*, (50): 178 p.

51. Report of the twenty-third session, London, 19-23 April 1993. (1993). *Rep.Stud.GESAMP*, (51): 41 p. Available also in French, Spanish and Russian

52. Anthropogenic influences on sediment discharge to the coastal zone and environmental consequences. (1994). *Rep.Stud.GESAMP*, (52): 67 p.

53. Report of the twenty-fourth session, New York, 21-25 March 1994. (1994). *Rep.Stud.GESAMP*, (53): 56 p. Available also in French, Spanish and Russian

54. Guidelines for marine environmental assessments. (1994). *Rep.Stud. GESAMP*, (54): 28 p.

55. Biological indicators and their use in the measurement of the condition of the marine environment. (1995). *Rep.Stud.GESAMP*, (55): 56 p. Available also in Russian

56. Report of the twenty-fifth session, Rome, 24-28 April 1995. (1995). *Rep.Stud.GESAMP*, (56): 54 p. Available also in French, Spanish and Russian

57. Monitoring of ecological effects of coastal aquaculture wastes. (1996). *Rep.Stud.GESAMP*, (57): 45 p.

58. Opportunistic settlers and the problem of the ctenophore *Mnemiopsis leidyi* invasion in the Black Sea. (1997). *Rep.Stud.GESAMP*, (58): 84 p.

59. The sea-surface microlayer and its role in global change. (1995). *Rep.Stud.GESAMP*, (59): 76 p.

60. Report of the twenty-sixth session, Paris, 25-29 March 1996. (1996). *Rep.Stud.GESAMP*, (60): 29 p. Available also in French, Spanish and Russian

61. The contributions of science to integrated coastal management. (1996). *Rep.Stud.GESAMP*, (61): 66 p.
Adobe (.pdf) format (902K) (PDF)
La contribución de la ciencia al manejo costero integrado (1999). Inf.Estud.GESAMP, (61): 65 p.
Adobe (.pdf) format (486K) (PDF)

62. Marine biodiversity: patterns, threats and conservation needs. (1997). *Rep.Stud.GESAMP*, (62): 24 p.

63. Report of the twenty-seventh session, Nairobi, 14-18 April 1997. (1997). *Rep.Stud.GESAMP*, (63): 45 p. Available also in French, Spanish and Russian

64.	Hazard assessment of ship's cargoes: Review of GESAMP Reports and Studies No. 35. (in preparation). *Rep.Stud.GESAMP*, (64)
65.	Towards safe and effective use of chemicals in coastal aquaculture. (1997). *Rep.Stud.GESAMP*, (65): 40 p. Adobe (.pdf) format (902K) (PDF)
66.	Report of the twenty-eighth session, Geneva, 20-24 April 1998. (1998). *Rep.Stud.GESAMP*, (66): 44 p.
67.	Report of the twenty-ninth session, London, 23-26 August 1999. (1999). *Rep.Stud.GESAMP*, (67): 44 p.
68.	Planning and management for sustainable coastal aquaculture development. (2001). *Rep.Stud.GESAMP*, (68): 90 p. Adobe (.pdf) format (714KB) (PDF)
69.	Report of the thirtieth session, Monaco, 22-26 May 2000. (2000). *Rep.Stud.GESAMP*, (69): 68 p.
70.	A Sea of Troubles. (2001). *Rep.Stud.GESAMP*, (70): 35 p.
71.	Protecting the Oceans from Land-based Activities. (2001). *Rep.Stud.GESAMP*, (71): 162 p.
72.	Report of the thirty-first session, New York, 13-17 August 2001. (in preparation). *Rep.Stud.GESAMP*, (72):