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ANALYSIS

Integrated environmental management of the oceans

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Abstract

The application of integrated environmental management (IEM) as an analytical framework and general methodology to support ocean governance is suggested in this paper. IEM is described as an adaptive process, which has to consider interactively problem assessment, policy priorities, the formulation of policies and their implementation in adequate measures, taking into account the multiple perspectives of the stakeholders involved. Relevant issues related to the accomplishment of IEM tasks for marine environments are discussed and some directions for further research are identified. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Oceans governance; Integrated oceans management

1. Introduction

Ocean environmental management has become an important issue because of continued ocean pollution and resource extraction, in spite of some notable successes in reducing them. The environmental management of the oceans is an urgent task since they are an increasingly important resource for the sustenance of life on Earth, and yet have been regarded as an unlimited dumping ground for waste produced by human activities. The world's oceans are vast (both in surface and in volume) and extremely sensitive. Radical changes in the oceans' chemical, thermal and physical balance can cause great damage, not only to the biological, chemical and physical activities, but also to the Earth's atmosphere and inner crust which are also affected by the oceans (Frankel, 1995).

The concept of integrated environmental management (IEM) emerged as an alternative to the traditional sectoral approach to environmental problems that prevailed during the 1970s, which has resulted in inefficient procedures and contributed to the creation of new environmental problems, mainly due to difficulties in policy coordination. IEM aims at conciliating socioeconomic development objectives with the preservation of environmental quality and ecological functions through the adoption of policy in-

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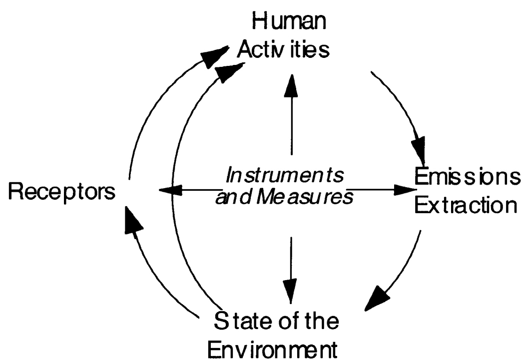

Fig. 1. Integrated environmental management.

struments and measures (Antunes et al., 1996). IEM thus intends to balance socioeconomic, technological and ecological forces in resource allocation processes in order to achieve sustainable development and preserve the maximum evolutionary potential of the biosphere.

IEM can be applied to different levels of analysis, including problems that occur on a local, regional (watershed), continental and global scale. Small-scale problems are usually easier to tackle since the distance (in time and space) between the causes of the problems and the effects are relatively small, and the number of actors involved is usually low. On the other hand, the distance between cause and effect for problems on a broader scale (continental and global) is frequently larger, and therefore they are more difficult to perceive and to solve (Maas, 1991). In addition, problems on a broader scale have a higher number of actors involved, and their solution often implies negotiations between interested parties and the adoption of cooperative solutions.

IEM has considered mainly land-based environmental problems at the national and European

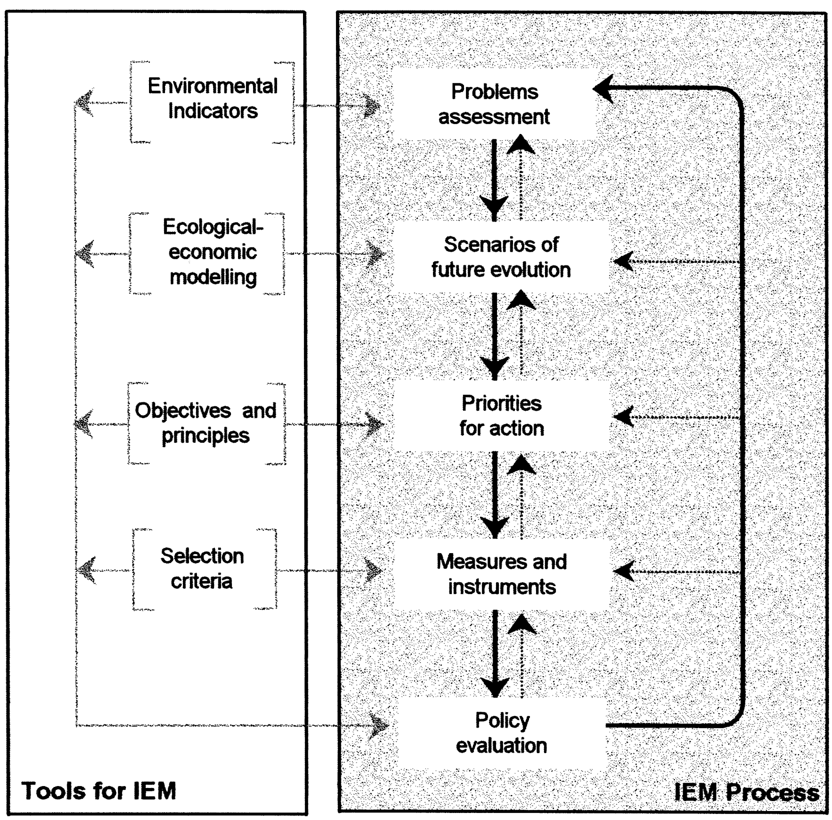

Fig. 2. Steps in the IEM process.

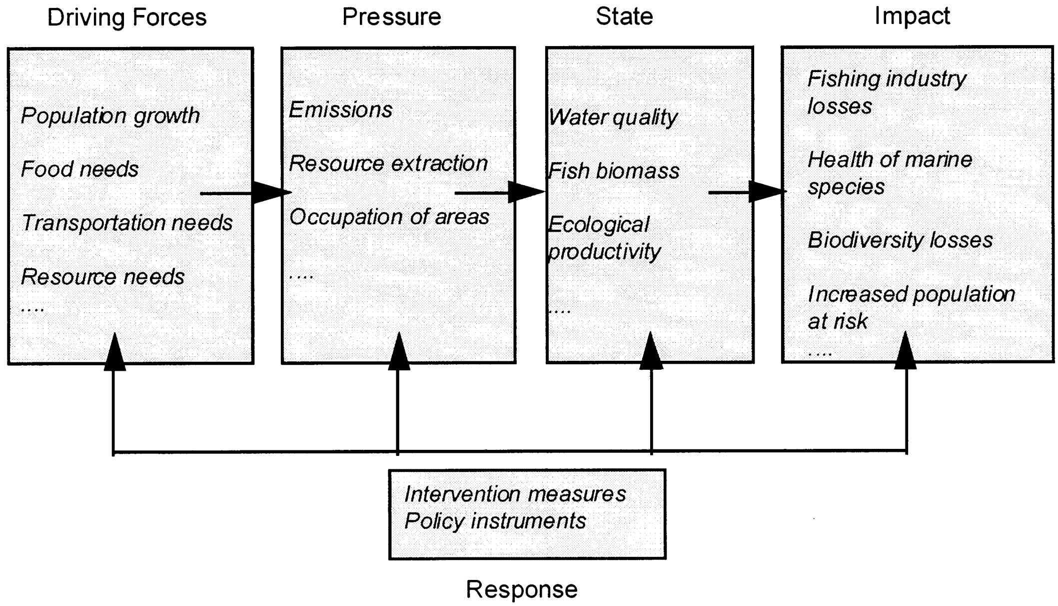

Fig. 3. DPSIR framework for integrated environmental assessment.

levels. Several authors have also suggested the application of IEM to coastal zones, introducing the concept of integrated coastal zone management (ICZM) (Turner and Adger, 1996). ICZM is a continuous planning process in which interested parties, stakeholders and regulators reach general agreement on the best mix of conservation, sustainable resource use and economic development for coastal areas (Fisheries and Oceans Canada, 1998).

We suggest that the adoption of IEM principles and methodology, taking into account the scales of analysis at which oceans problems occur, can provide relevant guidance for the development of sustainable oceans governance, providing a robust and analytically sound framework for management.

2. Integrated environmental management process

IEM is a complex process which involves the study of the complete environmental cycle associated with each environmental problem. This cycle includes resource extraction (e.g. fishing) and generation of emissions (e.g. toxins release) by socioeconomic activities, the evaluation of their effects on natural resources and environmental quality, and the impacts on ecosystem functions and human welfare. These, in turn, can limit the development of human activities and create the need for policy response (Fig. 1).

IEM is, therefore, an adaptive process which has to consider interactively problem assessment, policy priorities, and the formulation and implementation of policies through adequate instruments and measures, taking into account the multiple perspectives of the stakeholders involved (Santos et al., 1991). Integrated environmental management implies the accomplishment of several tasks, namely:

1. Problem identification and assessment;
2. Modeling and formulation of scenarios of possible environmental change;
3. Identification of priority issues and establishment of targets for environmental policy;
4. Search and evaluation of policy alternatives, including environmental management instruments and measures which best meet objectives;
5. Implementation and evaluation of policy performance.

Table 1
Integrated environmental assessment of oceans[a]

Problem	Driving forces	Pressure	State	Impact
Over fishing	Population growth Food needs	Fish catches	Stock depletion Ecosystem changes	Decrease in capture per unit of effort Ecological effects
Contamination from land-based activities	Urban and industrial development Agriculture, aquaculture Resources needs	Emissions from land-based activities Resource extraction	Water quality indicators Eutrophication Sediments toxicity Biological indicators	Health effects in marine species Human health Damage to wetlands and other coastal ecosystems Tourism and recreation losses
Dumping at sea	Urban and industrial development Port activities	Waste dumping Resource extraction	Water quality Sediments toxicity Biological indicators	Health effects in marine species Human health
Oil spills (accidental and operational)	Need for transportation Resources needs Port activities	Release of toxins	Water quality indicators	Health effects in marine species Damage to coastal areas
Destruction of coastal ecosystems	Urban and industrial development Port activities Need for tourism/recreation Resource needs	Occupation of areas Emissions Dredging Overcrowding Destructive fishing techniques	Water quality indicators Changes in water motion Ecological productivity Health of key coastal ecosystems (wetlands, mangroves, and coral reefs)	Biodiversity losses Changes in biological productivity Increased vulnerability Fishing industry losses Coastal erosion Disturbance in sediment flow and siltation
Coastal dynamics	Urban and industrial development Need for tourism/recreation	Occupation of areas Dredging Channelisation Coast protection works	Beach and bottom erosion Disturbance in sediment flow and siltation	Land, property and infrastructures losses Flooding of low-lying areas Increased vulnerability
Climate change	Population growth Urban and industrial development Need for transportation Resource needs	CO_2; CFCs and other; GHG emissions	Average temperature Sea level rise Saltwater intrusion in freshwater Storminess Coastal erosion rates	Changes in biological productivity Increased populations at risk Land, property and infrastructures losses Flooding of low-lying areas

[a] This table describes some underlying causes of marine environmental problems, but does not consider marine resource related market failures which shape the 'intensity' of the pressures on the environment, such as ill-defined property rights, as well as factors related to the behavior of the actors.

Table 2
Measures and instruments for sustainable oceans governance

Problem	Measures	Command and control	Economic instruments	Information/voluntary
Over fishing	Reduce fishing effort Technology to reduce by-catch Marine protected areas Aquaculture	Total allowable catch (TAC) Mesh regulations Closed areas regulations Days at sea (DAS)	Share-based fisheries Incentives for fleet reduction Incentives to aquaculture Tax catches/fishing effort	Eco-label for fish products Increased awareness
Contamination from land-based activities	Effluent treatment Waste treatment/disposal Non-point source pollution control Improved production processes Improved resource efficiency Reduce agricultural inputs	Emissions standards Prohibitions for waste dumping Technological standards Regulations for agricultural practices	Emissions and product taxes/charges Transferable Discharge permits Subventions Liability systems	Information about quality (e.g. blue flag) Eco-label Environmental Audits Voluntary agreements/ covenants
Dumping at sea	Waste treatment facilities Clean-up	Prohibitions	Environmental assurance bonding systems Liability systems	Environmental audits
Oil spills (accidental and operational)	Reduce risk of accident Clean-up Restoration Waste oil treatment facilities	Safety requirements for tankers (e.g. double hull tankers) Definition of navigation routes Increased limit of responsibility of ship owners	Environmental assurance bonding systems Liability systems	Provision of information for the safe navigation of ships
Destruction of coastal ecosystems	Marine and coastal parks- Public provision Restoration Protection Reduce occupation/use	Limited access to resources Coastal zones management plans Zoning	Transferable development rights Visit/diving fees *Taxes de séjour* for tourists	Eco-label for tourism resorts
Coastal erosion	Coast protection works Restoration Land use planning in coastal areas	Zoning Limited access to resources	Resource extraction taxes	
Climate change	GHG emissions reduction Energy efficiency Renewable energy Retreat Protection	Emission standards Technological standards	Carbon tax Tradable emission reduction targets Incentives to energy saving equipment	Eco-label for energy efficient products

Fig. 2 illustrates the IEM process indicating also the major tools that can be used in the several stages. In the following sections we willbriefly discuss for each of these steps major issues related to the application of IEM for oceans.

IEM is essentially adaptive, involving a continuous learning process that cannot be separated into research, design and implementation stages (Walters, 1986). A stage of equilibrium involving full knowledge and optimal allocation of coastal and marine resources will probably never be reached. In this context, the stages mentioned above are not performed in a linear one-time sequence; instead they are all performed simultaneously in a continuous process of identification–design–implementation–evaluation and revision.

The involvement of stakeholders at stages and the establishment of adequate governance institutions are essential for the success of the IEM approach. These issues will be discussed in Section 8.

3. Problem identification/assessment

The first stage in IEM is the identification/assessment of current and future environmental problems. This stage is generally referred to as integrated assessment, and it can be defined as, "the interdisciplinary process of identification, analysis and appraisal of all relevant natural and human processes and their interactions, which determine both the current and future state of environmental quality and resources at appropriate spatial and temporal scales. It facilitates the framing, implementation and evaluation of policies promoting sustainable development" (Quinn et al., 1995).

We consider that the driving forces–pressure–state–impact–response (DPSIR) framework, adopted in several integrated assessments (RIVM, 1995, 1997), can be successfully applied to oceans management.

Driving forces, i.e. underlying causes of environmental problems, refer to the needs of individuals and institutions which lead to activities that exert pressures on the environment (e.g. emissions to water, resource use). For example, the human need for food is a driving force that motivates fishing that implies the harvest of fish resources. The 'intensity' of the pressure depends on the nature and extension of the driving forces and also on other factors which shape human interactions with ecological systems, such as ill-defined property rights and other market failures, as well as the behavior of the actors involved.

These pressures modify the state of the environment (e.g. changes in water quality, fish populations), and these modifications may have an impact on ecosystems and on human well-being. Undesirable impacts lead to a response from society that results in the formulation of an environmental policy. The policy responses lead to changes in the DPSI chain. Depending on the results achieved, further responses are formulated (RIVM, 1995). Fig. 3 shows the general model of the DPSIR framework.

This framework is an extension of the Pressure–State–Response model previously adopted by OECD, UNEP and LOICZ.[1] This framework is useful because it leads both scientists and policy makers to think in terms of causality chains. The drawback is that the suggested linear relationships might obscure the more complex relationships in ecosystems and the interactions among sub-systems (e.g. socioeconomic and ecological) (UNEP/RIVM, 1994).

The identification and assessment of problems related to oceans sustainable management requires therefore the definition of a set of indicators aimed at the different parts of this framework. Among other things, these indicators should be (OECD, 1998):

1. Policy relevant and useful,
2. Responsive to changes in the marine environment to allow monitoring signs of ecosystems change,
3. Able to show trends over time and to establish comparisons among regions,
4. Simple and easy to interpret,
5. Related to the different stakeholders perspectives,
6. Easily available at a reasonable cost/benefit ratio.

Table 1 proposes a possible set of indicators for some of the current problems associated with

[1] Land-ocean interactions in the coastal zone (IGBP core project).

oceans, applying the DPSIR framework. The Response stage will be analysed in Section 6, which addresses the instruments and measures for ocean management.

A more in-depth analysis of Table 1 shows the difficulties that arise in the application of the DPSIR framework to complex environmental problems, such as the case of marine resources. These difficulties can be due to several factors such as:
1. Several causes contributing to a single effect;
2. Multiple effects resulting from a single pressure;
3. Interrelations among ecosystem components;
4. Indirect, synergistic or cumulative effects.

However, this framework provides a basis for identification of information needs and for problem assessment.

Many of the identified oceans' problems are relevant at several scales. For instance, destruction of coastal ecosystems has obvious effects at the local and regional levels but can also have an impact at a higher level when it affects global fishery resources.

The development of monitoring systems capable of providing information on marine ecosystems, and their response to pressures generated by human activities, is essential to improve ocean governance. Therefore, the definition of a set of indicators aimed at monitoring the different stages of the DPSIR chain is urgently needed, in spite of the referred to difficulties.

4. Scenarios of future evolution

The second stage in IEM is to predict the expected evolution of marine and coastal systems under different socioeconomic scenarios, and the feedback effects of these environmental changes into human activities. In the case of oceans management this requires the development of integrated ecological–economic models, which take into account, on the ecological side, different physical, chemical and biological processes, and multiple species and their interactions, and on the socioeconomic side the various stakeholders involved and their points of view.

Major problems associated with the development of integrated ecological–economic models for ocean management are related to:
1. The need to include different time frames in the model to account both for short-term effects, such as population fluctuations and response, and for long-term cumulative effects, such as chronic effects on the health of marine species due to toxic releases;
2. In addition, different levels of analysis have to be considered due to the relevance of local, regional and global processes for oceans systems, and to the great distance between cause and effect which is frequently observed (e.g. migratory species, oceans transport);
3. Modeling of oceans transport movements has to be combined with ecological models considering major materials and energy flows for lower and higher trophic levels, and coupled with socioeconomic models;
4. The socioeconomic model must account for the different stakeholders' perspectives;
5. Difficulty in conciliating the time frame of the economic and ecological models—what is generally considered as a long-term economic model is a very short time frame to capture some ecological responses.

In summary, the major problems associated with this stage of ocean IEM relate to the fact that the interactive processes that control coupled physical–biological–chemical science of the oceans are not yet completely understood, although some knowledge already exists concerning the structures that constitute the physical circulation, motion and transport mechanisms in the oceans. In addition, the fundamental biological and chemical dynamics of the euphotic zone of the upper ocean are also already known. However, interdisciplinary research is needed to develop linked physical–biological–chemical models (Robinson, 1995), and to integrate the socioeconomic dimension.

5. Priorities and goal setting

The definition of priorities for action and the establishment of policy goals is a fundamental step of IEM. Although these tasks are common to all management processes, they are often performed without the definition of a specific methodology. We consider that the adoption of an explicit procedure, in which the criteria are clearly identified and accepted by the main actors involved, improves decision-making and enhances the acceptance of policy measures.

Policy priorities criteria should translate the basic principles of oceans governance, namely sustainability (including the ecological, economic and social dimensions) and precautionarity.

We propose a set of criteria for prioritising policy targets. Some of them are related to the fundamental principles of IEM, and others address different issues which can also influence the priority of a problem.

- Reversibility—problems that may lead to irreversible damage for ecosystems should receive high priority. The concept of critical load, which is defined as the maximum pollutant deposition (or utilisation of a resource) which does not entail irreversible ecosystem damage (Downing et al., 1993), can be useful to the definition of goals for oceans management, related with this criterion.
- Diversity (biological and cultural)—problems which may imply loss of diversity should also receive high priority. Diversity should be considered here in a broad sense, including both biological and cultural diversity.
- Ecosystem functions affected—problems that may pose a threat to key ecosystem functions (e.g. nursery, resources cycling) should also be considered as a policy priority.
- Economic value of the damage—economic value of the damage associated with the problem.
- Scale—scale of the problem—in general, larger scale problems should receive higher priority than small scale ones.
- Equity considerations—namely spatial, temporal and across populations and uses of resources affected.
- Human health and quality of life—problems threatening the health or basic needs of human populations should also receive high priority.
- Public opinion, judgement—public pressure can influence decision makers regarding the problems which are considered important by the populations.

This set of criteria does not intend to be comprehensive. On the other hand, some of the criteria presented may not be independent from each other (for instance, the evaluation of the economic value of the damage may already take into account effects on human health). Therefore, in each case, the criteria to be used should be selected considering the points of view of all interested parties, and taking into account the nature of the issues involved and the availability of information.

In some cases, information regarding a single criterion is sufficient to establish the priority of a problem. For example, a problem that causes irreversible damage to a specific ecosystem may be considered of high priority just for that fact. Other situations may occur in which to establish the priority of a problem, a combination of several criteria has to be considered.

In summary, the establishment of priorities requires the definition of a multi-criteria procedure involving the selection of relevant criteria, the definition of a metric allowing the evaluation of the problems in relation to those criteria and the establishment of an aggregation rule to establish the ordination of the problems priority.

The major objective of this exercise is to make clear the importance of the several problems identified in stage 1, assessed in economic, ecological and social terms, and to show the trade-offs among them, in order to help decision makers in setting priorities.

6. Measures and instruments for oceans management

Environmental policy is implemented through a set of measures and instruments addressing existing priority problems and aimed at the preservation of ecological systems. By measures we mean concrete actions which are implemented to address environmental problems. These measures can be directed to different stages of the DPSI chain and, therefore, we can consider the following:

1. Measures directed at the driving forces aimed, for instance, at reducing or replacing the consumption of less environmentally friendly products (e.g. reduction in consumption of a threatened fish species, aquaculture).
2. Measures aimed at reducing the pressures on environmental systems through end-of-pipe technologies or by the adoption of improved production processes and more efficient resource use.
3. Measures addressing the state of the environment aimed directly at ecological systems. For marine environments this applies to coastal ecosystem restoration or the introduction of juveniles to enhance recovery of a threatened fish stock.
4. Measures aimed at mitigating or attenuating environmental impacts. For instance, the Coastal Zone Management Subgroup of Intergovernmental Panel on Climate Change (IPCC, CZMS, 1994) considers retreat (the abandonment of land and structures in vulnerable areas and resettlement of population), and protection (of vulnerable areas, especially population centers, economic activities and natural resources) as possible measures in response to global change. Both of these measures are aimed at mitigating the impacts.

For each relevant environmental problem a set of measures has to be identified considering the points of the DPSI chain where intervention is more adequate and effective (e.g. environmental-effectiveness, cost-effectiveness).

Policy instruments are used to promote the adoption of measures by the agents in the problem chain. These instruments can establish what types of measures should be adopted (e.g. technological regulations). They can also establish the targets leaving the choice of how to achieve them to socioeconomic agents (e.g. emission standards) or they can simply send a signal (incentive/disincentive) to the agents (e.g. emission taxes, voluntary information). Usually environmental policy instruments are classified into command and control (CAC), economic and voluntary/information based.

Table 2 shows a preliminary list of environmental policy instruments which can be applied to promote the adoption of measures targeted at the major oceans problems identified in stage 1.

Instruments targeted to the assignment of property rights, such as fishing-right systems (Young, 1999) and transferable development rights (Panayotou, 1995) can play a very important role for oceans management since ill-defined property rights (or their absence) are associated with many of the problems identified in Table 1. In addition, the application of liability systems and environmental assurance bonding systems (Cornwell and Costanza, 1994) can contribute to the implementation of a precautionary approach to ocean management.

Several criteria have to be considered to define policy action through the choice of the best set of measures/instruments to be used for each problem. These can be grouped into performance and feasibility criteria, namely:

1. Performance criteria
   - 1.1. Economic efficiency—maximise the net benefit;
   - 1.2. Cost-effectiveness—maximise the benefit in a chosen indicator for a given expenditure or minimise the cost to attain a given objective;
   - 1.3. Environmental effectiveness—extent to which environmental objectives are met;
   - 1.4. Equity—refers to the allocation of gains and losses across the different agents, and in time and space. It is related to the perceived fairness of the policy.
   - 1.5. Response time—in some cases it is important to minimise the time needed to achieve the desired policy targets.
   - 1.6. Indirect effects—some measures/instruments aimed at an environmental problem can reduce (or increase) another one or create a new problem.
2. Implementation criteria
   - 2.1. Institutional setting, legal authority—there must be an institutional setting and legal framework to allow for the establishment of a governance regime.
   - 2.2. Enforceability—related to the ability to enforce and monitor compliance.
   - 2.3. Public and stakeholders acceptance—the measures/instruments must be acceptable to the public and actors in the process.

2.4. Technical and economical feasibility.
2.5. Opportunity for action.

While the criteria presented in Section 5 highlight the issues which should be considered to prioritise policy targets, these criteria are intended to help decision makers evaluate the tradeoffs of the various policy options.

The flexibility, compatibility with other sectoral/regional policies and adjustment capacity to uncertainty factors (e.g. macroeconomic conjuncture) should also be evaluated as implementation aspects.

One of the major difficulties in ocean governance is the lack of information/understanding about marine resources and processes and the threats they face. The design and implementation of marine resources monitoring systems and protocols is therefore a prioritary action to implement IEM and thus improve decision making processes. This information is also fundamental to raise awareness and judgement in the public about oceans, in order to press for action. In this context, research is also needed on how best to convey knowledge to the public, using empirical data from existing instruments (e.g. blue flags) and devising new information-based policy instruments.

Voluntary information instruments have been successfully implemented for land-based problems, and these can play an important role in the oceans management (e.g. the certification of fish products—such as is already in place for forest and timber certification).

7. Implementation and evaluation of policy performance

The next stage in the IEM process should be the implementation of the strategy defined in previous stages, through the application of the selected environmental policy instruments and measures, to achieve the goals and objectives defined.

The institutional setting is a key element in the design of a strategy to allow for the establishment of an oceans governance regime, particularly regarding such aspects as monitoring and enforcement, and co-operation between local, regional and global institutions. Consensus building among the parties involved is also very important to ensure the success of any policy, and to implement instruments which key stakeholders are not always willing to accept.

This implementation stage must also include the development of adequate mechanisms to monitor the performance of the adopted policy. This can be achieved through the development of a set of performance indicators for which information will be continuously gathered.

These performance indicators must include measures to evaluate progress in the solution of the problems identified in the assessment phase (and selected as a priority in the goals and priorities setting stage). In other words, these indicators should measure the efficacy of the adopted policy. These indicators can be essentially the same as those mentioned in Section 3.

However, other indicators have to be included aimed at the evaluation of management performance. These indicators are mainly targeted at the measures and instruments implemented (the response component of the DPSIR chain) and should assess policy implementation.

8. Stakeholder involvement and institutions for management

The development of new systems of oceans governance must be defined in ways that foster the participation and involvement of stakeholders (IWCO, 1998). The aim of ocean governance should be to create a climate of co-operation rather than confrontation among the interested parties. Significant global gains can be achieved through collaboration, and all stakeholders may be better off mainly in the long run.

IEM of the oceans is a process involving comprehensive assessment, setting of priorities and objectives, and the design and implementation of management strategies for coastal and marine systems and resources. IEM thus requires the integration of ecological, social, and economic perspectives as well as conflicting interests. This can be achieved balancing protection and conservation with multiple-use objectives. There are many stakeholders involved who often have conflicting objectives and overlapping responsibilities.

The application of IEM for ocean governance can contribute to overcoming some of these difficulties by providing a structured framework to accommodate the stakeholders' views. However, to achieve this IEM has to include the implementation of a process to facilitate full stakeholder involvement at all stages of decision making, referred to in the previous sections. For example, the adoption of mediated modeling techniques (van den Belt et al., 1999), where stakeholders participate in the formulation of a scoping model, can be useful to identify major problems and issues, to develop scenarios of evolution and to test alternative strategies for action within the IEM process.

IEM can also support the identification of the appropriate levels for governance. Currently, ocean governance is characterised by a set of sectoral institutions at each level (local, regional, national and international) in such a way that the information and responsibilities for management remain fragmented among different entities with conflicting objectives and priorities for action. There are ocean problems that currently involve several institutions with overlapping responsibilities (e.g. coastal areas). On the other hand, there are issues that are not tackled due to existing gaps in responsibility and jurisdiction (e.g. international waters).

The development of all IEM stages will foster understanding about current oceans problems, and the ecosystem functions and processes affected, thus enabling the identification of the most suited scale for action. According to the Lisbon 'scale-matching principle' (Costanza et al., 1998), these scales will be the ones that have the most relevant information, can respond quickly and efficiently and are able to integrate across boundaries. The design and structure of oceans governance institutions can therefore benefit from the adoption of an integrated approach to management.

9. Conclusions

IEM is suggested as a robust and analytically sound framework for the development of sustainable ocean governance, taking into account all the scales at which ocean problems occur. IEM is an adaptive process, which has to consider interactively problem assessment, policy priorities, the formulation of policies and their implementation in adequate measures, taking into account the multiple perspectives of the stakeholders involved.

Major issues which have to be dealt with in order to promote IEM of the oceans relate to (1) the definition of a set of indicators aimed at monitoring and assessing the different stages of the oceans problem chains; (2) the development of integrated ecological–economic models, considering multiple processes and multiple species on the ecological side, and multiple stakeholders and points of view on the socioeconomic side; and (3) the establishment of a set of criteria for prioritising policy targets.

For each priority environmental problem, an environmental management strategy needs to be formulated identifying the most adequate set of measures to apply, taking into account the stages where intervention is more effective. The management strategy also includes the design of policy instruments to promote the implementation of measures by the agents in the problem chain and the establishment of adequate governance institutions.

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