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Viewpoint

Observations on the implementation of ecosystem-based management: Experiences on Canada's east and west coasts

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Abstract

The proclamation of the Canada's Ocean Act in 1997 announced Canada's intention to adopt a holistic approach to the management of its aquatic ecosystems, one in which the impacts of the activities of diverse oceans industries would be considered as part of an integrated framework. Since then, there have been a number of initiatives undertaken to explore the structure and function of this new approach. These include not only the objectives of management, both at the conceptual and operational levels, but also issues relating to assessment, regulations and governance. They thus span the full complexity of what is termed 'integrated management'. The progress made and the lessons learned that are summarized in this paper will be of general interest to those engaged in the management of ocean activities.

Keywords: Ocean activity; Marine environment; Oceans Act; Integrated management; Ecosystem-based management

1. Introduction

There is an emerging paradigm shift in ocean management, exemplified by explicit consideration of the impacts of all ocean sectors on the marine environment, both separately and in aggregate (Sinclair and Vladimarsson, 2003). This comes from an increasing awareness of the cumulative impacts of industry activities on the ecosystem (Jennings and Kaiser, 1998; Kaiser and de Groot, 2000) and the need to take a holistic or integrated management (IM) approach to ensure the sustainability of marine ecosystems (Anon., 1999a; Kabuta and Laane, 2003; Link, 2002). The roots of this new paradigm can be found in the 1992 UN Conference on Environment and Development (UNCED), which highlighted the need to consider resource management in a broader biological, socio-economic and institutional context. This led to follow-up conferences and conventions (e.g. 1993 Convention on Biological Diversity, 1995 Agreement for the implementation of provisions of the UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFA), and 1995 FAO Code of Conduct for Responsible Fisheries), the intents of which nations are now struggling to implement.

In Canada, the *Fisheries Act*, first enacted in 1857, has been a prime legislative vehicle governing ocean usage, particularly fishing. While it is periodically revised (most recently in 1991), the focus of the Act has been the conservation and protection of commercially exploited species and their habitats. Responding to both international legislative changes, as well as concerns for the impacts of human activities on its marine ecosystems, Canada enacted the *Oceans Act* in 1997. This Act outlined a new approach to managing oceans and their resources based on the premise that oceans must be managed as a collaborative effort amongst all stakeholders that use the oceans, and that new management tools and approaches are required. While fishery management plans under the *Fisheries Act* continue to focus on target species, the *Oceans Act* has changed the legislative basis for management and now requires consideration of the impacts of all human activities on Canada's ecosystems in marine resource management plans.

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When the *Oceans Act* was proclaimed in 1997, there was little concept in Canada as to what IM meant in practical terms. Much of the dialogue had been at a higher policy level with little linkage to implementation. Since then, through a number of initiatives, Canada's approach to IM has begun to emerge. In 1998, pilot projects on both the east (Eastern Scotian Shelf IM or ESSIM) and west (Central Coast IM or CCIM) coasts were initiated to test implementation of IM. To guide these and IM projects that have been initiated since then, a national workshop was convened in 2001 (herein termed the Sidney workshop) to outline the set of required conservation objectives. The results of this workshop were then taken to Canada's coasts to test how IM could be practically implemented. Through this testing process, many lessons were learned about how best to implement IM. In this paper, we provide a perspective on integrated management, based on these experiences. While many of the concepts are still in development (for instance, see DFO (2005a) for some recent developments), it is hoped that this contribution will provide general guidance for those currently developing or contemplating adoption of an IM system and stimulate further discussion and debate on this complex topic.

2. An overview of integrated management

When discussing IM, it is important to have a clear, common understanding of its elements (e.g., protected areas, fishery regulations, nature of ecosystem monitoring, etc.) and how these elements are interrelated. For example, some consider as a major objective the zonation of ecosystems for permitted impacts through the establishment of Marine Protected Areas (MPAs), while others see MPAs as simply one of a suite of regulatory tools to achieve overall IM objectives. In this paper, we consider activities undertaken as part of management (functions) separate from the organization of how management is achieved (structures) (O'Boyle, 1993). Functions involve both goal setting (what one hopes to achieve, i.e. objective definition) and control activities (how goals are achieved), the latter involving both regulation of human activity and the monitoring and assessment of the scale and nature of impacts. Structures include what it is that is being managed (e.g. determination of ecosystem boundaries) and the organization of mandated management institutions (decision-makers and technical bodies). Much of this paper is focused on IM functions, particularly the determination of objectives, with some consideration of IM structure.

IM is relatively new and as such, is experiencing a rapid growth in terminology and jargon, a consequence of different individuals looking at the same element from different perspectives. Definitions used in this paper are based on those of Jamieson et al. (2001) with enhancements of these as required. A comparison of these terms with those from recent review papers, chosen as being exemplary of some current thinking, is provided in Table 1. This comparison illustrates that while there is agreement with some definitions, e.g. for indicator and reference points due to common referencing of early influential papers (e.g., Caddy and Mahon, 1995), for other terms, significant definition differences exist, especially evident for terms relating to IM objectives. These differences illustrate the on-going development of the discipline.

3. Functions of integrated management

3.1. The objectives of integrated management

Different ocean industries (e.g. fisheries, oil and gas development, aquaculture, recreational tourism, etc.) have historically defined objectives in terms that predominantly relate to their own specific activities. This has resulted in a suite of different objectives for those industries impacting the common marine ecosystem. For example, oil and gas development has predominantly focused on preventing pollution, and has paid less attention to impacts on species resulting from increased human activity in the drilled areas, such as possible alteration of habitat. Similarly, fisheries have typically focused on impacts on commercial species, with typically less consideration of impacts on non-exploited species, e.g. deep-water corals. One of the main intents of integrated management is harmonization of the activities of various ocean industries to achieve commonly defined and accepted management goals. Working towards development of common objectives puts all ocean industries on the "same rules" basis. However, while the concept of integrated management is not new, few management systems appear to have accepted objectives that are broadly reflective of the general public's desire for effective renewable resource conservation, i.e., for all ocean uses. Walmsley (2005), in a recent global review of IM systems, noted that most accepted management objectives focus solely on fisheries and do not take into consideration other marine resources or uses. Of the 21 IM initiatives reviewed, only eight had either defined objectives or were in the process of developing objectives and associated indicators to monitor performance for IM. Indeed, the development of IM objectives with their associated indicators is generally considered a difficult task, with still much uncertainly on application and how to proceed.

There is an emerging consensus that management goals need to be considered at two levels: the conceptual and the operational (Jamieson et al., 2001; Sainsbury and Sumaila, 2003). Conceptual objectives are stated in broad, general terms intended to be understandable to a general audience and valid for long time periods (O'Boyle, 1993). Jamieson et al. (2001) use the term 'conceptual' in this broad sense, which would include policy statements by a government or organization. This is different from this term's usage by FAO (2003) and Sainsbury and Sumaila (2003), who differentiate between 'principles/policy goals' and 'conceptual objectives'. We prefer the broader definition because, as will become evident

Table 1
Definitions related to integrated management

Term	Definition			
	Jamieson et al. (2001)	FAO (2003)	FAO (1999), Garcia and Staples (2000b)	Sainsbury and Sumaila (2003)
Conceptual, or qualitative, objective	General statements that are uniformly accepted by all stakeholders as desirable. They are specific enough that everyone will interpret them the same way, but do not specify how they will be measured	*Policy goal*: high-level policy objective relating to fish resources, ecosystems (e.g. biodiversity), economics and social benefits, usually at a specified regional or national level	A purpose to be achieved within the overall principles of sustainable development. Objectives are often hierarchical, referring to specific scales within the system. Objectives encompass all the dimensions and relevant criteria of sustainable development	*Principle*: a high-level statement of ‘how things should be’
		Broad fishery objective: statement of what harvesting a particular resource attempts to achieve in terms of the fish resources and in terms of ecological, economic and social objectives		*Conceptual objective:* a high-level statement of what is to be attained
Operational objective	Objective that has a direct and practical interpretation in the context of (fisheries) management and against which performance can be evaluated quantitatively. A specific statement that consists of a verb (e.g., maintain), a specific measurable indicator (e.g., estimated biomass), and a reference point (e.g., 50,000 t), thus allowing an action statement for management (e.g., maintain estimated biomass of a given forage species greater than 20,000 t biomass)	A specific objective that can be achieved through the application of a management measure		An objective that has a direct and practical interpretation, usually for a component
Dimension	Themes of sustainable development e.g. ecological, economic, social and institutional dimensions		The classes used to describe a system. Examples include: i) ecological, economic, social and institutional; ii) pressure-state-response; iii) human and environmental; and iv) operations, management, research, aquaculture and coastal zone management	
Component	Broad features of the immediately preceding conceptual objective, e.g., biodiversity, productivity and physical/chemical features would be components of “conservation of species and habitats”			A major issue of relevance within a conceptual objective
Characteristic	Biological property of the ecosystem, separate from our measurement of it. For instance, recruitment is a characteristic of a fish population. Survey age one numbers per tow might be an associated indicator		*Criterion:* an attribute of the sustainability information system in relation to which indicators and reference points may be elaborated. For example, spawning biomass is a criterion related to the well-being of the stock	
Indicator	Quantity that can be measured and be used to track changes over time with respect to an operational objective. Measurable part or process (property) of a system (e.g., average weight of age 5 individuals of a species)	A variable that can be monitored in a system, e.g. a fishery to give a measure of the state of the system at any given time. Each indicator should be linked to one or more reference points and used to track the state of the fishery in relation to those reference points	A variable, pointer, an index related to a criterion. Its fluctuations reveal the variations in those key attributes of sustainability in the ecosystem, the fishery resource or the sector and social well-being. The position and trends of the indicator in relation to the reference points or values indicate the present state and dynamics of the system	Something that is measured (not necessarily numerically) and used to track an operational objective. An indicator that does not relate to an operational objective is not useful in this context
Reference point	Value of an indicator corresponding to a management target or threshold	A benchmark against which to assess the performance of management in achieving an operational objective, corresponding to a state considered to be desirable (target reference point) or undesirable and requiring immediate action (limit reference point)	Indicates a particular state of a fisheries indicator corresponding to a situation considered as desirable (target reference point) or undesirable and requiring immediate action (limit reference point)	A ‘benchmark’ value of an indicator, usually in relation to the operational objective, such as desired targets, undesirable limits or triggers for specified management purposes. A target reference point could serve as an operational objective
Target reference point	An indicator reference point that is trying to be achieved (e.g., an estimated biomass of 30,000 t)	See reference point	See reference point	See reference point
Limit reference point	An indicator reference point that if crossed results in the implementation of a management action (e.g., if the estimated biomass falls below 10,000 t, the fishery is closed)	See reference point	See reference point	See reference point

below, there is a continuum of conceptual objectives from the high level down to the specific level, which makes debate on what is policy or not unproductive.

Given that they are broad statements, conceptual objectives can be interpreted differently from different perspectives. They lack the specificity to be operational, i.e., result in a particular management action based upon the degree of divergence of a measurable indicator from a pre-determined reference point. Operational objectives are the strategies by which conceptual objectives are implemented. They make the link between the conceptual and management control. Jamieson et al. (2001) considered that an operational objective consists of a verb (e.g., maintain), a specific measurable indicator (e.g., biomass from a population analysis), and a reference point (e.g., 50,000 t), thus allowing an action statement for management (e.g., maintain biomass of a given forage species greater than 50,000 t biomass). While others might differ on the details of what defines an operational objective (e.g., Sainsbury and Sumaila, 2003; FAO, 2003), there is consensus on the need to associate indicators and reference points with operational objectives.

Where there is not consensus and where work is required is how to link the conceptual and operational objectives. Sainsbury and Sumaila (2003) advocated defining the components being managed based upon the relevant conceptual objectives. Each of these components is elaborated further into a tree of sub-components, with branching to whatever level is considered necessary, through a participatory and open process. Once the tree is defined, operational objectives are then be established for the end points of each branch of the tree.

Jamieson et al. (2001) also considered components associated with preceding conceptual objectives. For example, they state that biodiversity, productivity and physical/chemical properties are components of the "conservation of species and habitats" conceptual objective. Under each of these components, there are sub-components; for example, under diversity, there are community, species and population sub-components. Through a process termed 'unpacking', lower-level conceptual objectives are then associated with these sub-components, producing a 'conceptual objectives' tree (Fig. 1). The process of unpacking each conceptual objective continues in increasingly more detail, adding specificity to the initial conceptual objective and stopping when an operational objective for that chain of conceptual objectives can be stated, i.e., the point when a useable measurable indicator and reference point be associated with the particular objective.

Unpacking is facilitated by considering at each step the 'characteristic' of the ecosystem component under consideration. A characteristic (the criterion of Garcia and Staples, 2000b) is an attribute of the ecosystem component (e.g. spawning biomass), irrespective of our ability to measure it, a concept derived from Halliday and Mohn (2001). Consideration of the characteristic forces individuals involved in the process to clearly state what it is about the ecosystem that is important to conservation. It also provides the basis for identifying the measurable indicator for the ecosystem component in question. We suggest that the characteristic be formally incorporated into the final accepted conceptual sub-objective (one step before definition of the operational objective). An illustration of the unpacking process, from initial conceptual objective through the conceptual sub-objectives to the final operational objective, as well as the use of the component's characteristic in it, is given in Fig. 2.

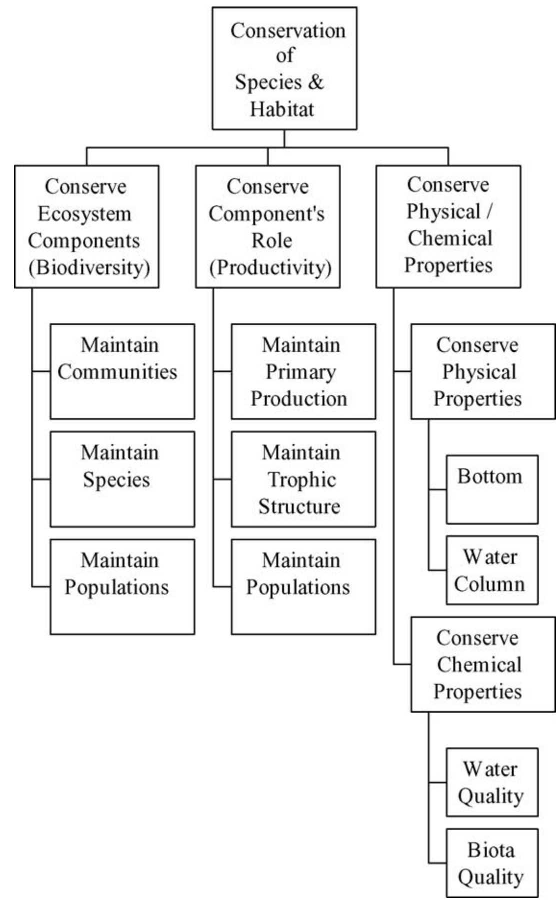

Fig. 1. Conceptual objectives tree for the environmental dimension of integrated management in Canada (from Jamieson et al., 2001).

A variety of terms, all with the same meaning, have been used for operational objectives by different organizations, even within Canada, which has created some confusion. For example, the term 'strategy' has been used synonymously with 'sub-objective' (Anon., 2002c), without specifying whether it is at an operational level or not; Canada's Oceans Strategy (Anon., 2002a,b) refers to Marine Environmental Quality objectives, which appear to be synonymous with the meaning of operational objective used here.

It is important to note that unpacking starts with an objectives' tree and elaborates each branch further to meet specific operational needs. Different conceptual objectives might be unpacked to different extents or levels, and the level at which

Unpacking of Conceptual Objective	Characteristic	Indicator	Operational Objective (Consists of Verb, Indicator and Reference Point)
• Conserve each component of ecosystem so that it can play its historical role in foodweb			
○ Maintain Production of Forage Species supporting Food Chain in IM Area			
▪ Maintain Herring Population Biomass above Minimum level	Herring Population Biomass	Age 3+ Biomass Estimate from Population Analysis (e.g. VPA)	Maintain Age 3+ Herring Population Biomass above 50,000t

Fig. 2. The link between conceptual objectives and operational objectives—the 'unpacking' process.

an associated operational objective is defined does not affect its importance relative to other determined operational objectives.

There are a number of advantages to the objectives tree and unpacking process described above. First, within any one branch of the tree, the process of 'unpacking' creates explicit linkages between qualitative conceptual and quantitative operational objectives used to guide management decision-making. Second, the relationship of one branch of the objectives' tree to another is clearly defined. It is thus possible to evaluate progress against objectives for each branch of the tree separately. This allows the possibility of setting priorities based on the relative importance of achieving different objectives in the overall suite of identified objectives. It should be remembered, though, that management performance can only be measured at the lowest, operational, level. Every level above this is not in the currency of something specifically measurable, and thus progress achieved at higher objectives' levels can only be "measured" qualitatively. Lastly, a nested unpacking sequence facilitates communication amongst, scientists, managers and stakeholders. As one proceeds through unpacking, the intent of the broad objective will ultimately be translated into management actions. For this reason, unpacking can be thought of as a probing of the conceptual objective to obtain consensus of its application in a local context. The link between the conceptual and operational objectives is explicitly maintained and is transparent to all. This communication function is particularly important in ecosystem-based management, where a common set of objectives is being utilized across a number of sectors of industry and society.

We have described the process whereby operational objectives can be theoretically defined, but what should the high-level conceptual objectives (the objectives tree trunk) be? A logical starting point is the principle of sustainable development (Anon., 1987). Sustainable development consists of a number of dimensions—environmental, social, economic, institutional, community, cultural and so on (Charles et al., 2001; Garcia and Staples, 2000a; Pitcher et al., 1998). For this reason, Jamieson et al. (2001) considered the highest level of the objectives' tree as having two, broad, overarching goals:

- the conservation of species and habitats, including those other ecosystem components that may not be utilized directly by humans (environmental dimension) and
- the sustainability of human usage of environmental resources (dimensions of human activity).

Garcia et al. (2000) similarly considered the effects of fishing on an ecosystem as composed of two parts: (1) effects on humans, and (2) effects on the environment. Walmsley (2005) noted that few have explicitly articulated objectives related to the dimensions of human activity, with most so far focusing on the environmental dimension. We consider that the best management decisions come from consideration of the interrelationships amongst cultural, social, economic and ecosystem parameters. Community involvement and buy-in is more likely with the inclusion of social and economic indicators. Based on the few examples that are available (Anon., 2002c, 2003; Garcia et al., 2000), we compiled an overview (Table 2) of components that objectives on the dimensions of human activities might consider. These could be used as a

Table 2
Components in the social and cultural, economic and institutional dimensions of sustainable development

Social and cultural dimension
Community structure
Ocean access
Sharing
Resource allocation
Community behaviour, e.g. code of conduct
Best practices
Responsible use
Stewardship
Compliance
Safety and security
Economic dimension
Sector valuation
Economic costs/benefits
Employment
Sector resilience
Economic self-reliance
Pace of development
Institutional dimension
Management approach
Degree to which international, national, regional and local requirements/responsibilities met
Decision-making e.g. collaborative, inclusive, transparent
Adaptability
Responsiveness
Acceptability of management approach, e.g. co-management
Benefit for administrative cost
Achievement of management approach
Sufficiency of institutional resources, e.g. commitment
Compliance with system

Table 3
Conceptual objectives of the environmental dimension (from Jamieson et al., 2001)

To conserve enough components (ecosystems, species, populations, etc.) so as to maintain the natural resilience of the ecosystem
To maintain communities within bounds of natural variability
To maintain species within bounds of natural variability
To maintain populations within bounds of natural variability
To conserve each component of the ecosystem so that it can play its historic role in the foodweb (i.e., not cause any component of the ecosystem to be altered to such an extent that it ceases to play its historical role in a higher order component)
To maintain primary production within historic bounds of natural variability
To maintain trophic structure so that individual species/stage can play their historical role in the foodweb
To maintain mean generation times of populations within bounds of natural variability
To conserve the physical and chemical properties of the ecosystem
Conservation of physical properties of the ecosystem
To conserve critical landscape and bottomscape features
Toto conserve water column properties
Conservation of chemical properties of the ecosystem
To conserve water quality
To conserve biota quality

starting point for further development. Conceptual objectives would have to be developed, in partnership with stakeholders, for all these components. Recognizing that this is a very preliminary list to encourage further development, having an agreed conceptual objectives/components tree for all dimensions of sustainable development in the early stages of indicator development would help avoid confusion in later stages, and would facilitate effective achievement of IM.

While some IM projects (Sainsbury and Sumaila, 2003; Jamieson et al., 2003; Walmsley, 2005) consider objectives for conservation of biodiversity, productivity and habitats, others have focused on ecosystem-based fisheries management rather than the broad application of IM. For example, Gislason et al. (2000) discussed the maintenance of biodiversity (ecosystem, species and genetic), the maintenance of directly impacted species and ecologically dependent species, and the maintenance of trophic balance, all in a fisheries context. Similarly, Garcia et al. (2000) referred to primary commercial species, non-target species and other aspects (marine landscape, water quality and movement of organisms). Also, the initial proposal made at the Sidney workshop (Jamieson et al., 2001) for a conceptual objectives tree was similar to that of Gislason et al. (2000), but because IM for all ocean industries, and not just fisheries, was being considered, a more comprehensive objectives tree (discussed below) was ultimately produced. While future changes to this objectives tree may be required, testing so far has found it general enough to be able to address a large contingency of potential issues. Further, we have found that it is important to resist changing the overarching objectives tree to address local issues once it is established. Rather, locally relevant objectives should be elaborated from the generic tree through the unpacking process.

The conceptual objectives' tree (Table 3 and Fig. 1) outlined by Jamieson et al. (2001) has guided efforts in the Maritimes and Pacfic Region's IM projects since 2001.

The first level of the conceptual objectives tree states that biological ecosystem components (i.e. biodiversity), their roles in the ecosystem (i.e. achieving productivity) and the physical and chemical properties of the ecosystem that support the above should be conserved. The conservation of ecosystem biodiversity addresses obligations to the 1993 Convention on Biological Diversity and implies that no communities, species, or populations should be lost through human activities. The first branch (Table 3) under biodiversity is intended to conserve community-level structures. For example, if distinct bottom communities or seascapes (e.g. coral or sea grass communities) can be identified in a given ocean area, the intent would be to conserve as many of these as possible or at least ensure that human activities are not responsible for reduction of the overall number or diversity of these communities. The second branch is intended to conserve species-level diversity. Canada proclaimed the Species at Risk Act in June 2003 to safeguard species that are at risk of extinction. This sub-objective provides a formal means of addressing this Act in IM. The third branch is intended to conserve population structures within species, the underlying motivation being the maintenance of genetic diversity of a species. For instance, for fish species known to have a number of populations in a given area (i.e. a metapopulation such as Pacific salmon species inhabiting different adjacent rivers), this sub-objective addresses maintenance of all these populations.

Under the productivity objective, the first branch relates to conservation of species at the base of the food web, they being an explicit link between productivity at higher exploited trophic levels and the physical and chemical characteristics of the environment. The second branch addresses the overall balance of productivity within an ecosystem, ensuring that key features of trophic levels are not disrupted or otherwise modified through human activity. It deals with processes extending both up and down the food chain. The third branch relates to maintenance of the productivity of individual populations within an ecosystem and thus deals with species population dynamics. Most traditional fisheries management activities have been focused on this branch.

The third high-level conceptual objective addresses the conservation of the ecosystem's physical and chemical properties. The first branch addresses issues related to the maintenance of physical features both terrestrially (factors influencing run-off into the marine environment) and marine (bottomscape). Bottomscape includes corals, sponges, marine plants and other sedentary organisms that, through their biological activity, create structural bottom features. Thus, bottom-impacting fishing would be considered here, as are issues related to movement of water (i.e. tides, currents, etc.), such as the potential alteration of water flows by a dam or causeway. The second branch addresses contamination of the water, e.g., from hydrocarbon inputs from oil and gas exploration, and accumulation of contaminants within organisms, e.g., mercury within apex predators.

Interactions amongst biodiversity, productivity and habitat obviously occur. Therefore, a failure to achieve an objective in one part of the tree might impact the ability to achieve another objective in another branch, e.g., productivity might be constrained by reduced diversity, or vice versa. Because current science understanding underlying processes in many ecosystems (e.g. productivity–biodiversity interactions) remains poor, a challenge is to establish an IM process that allows us to manage human impacts as best we can now while additional knowledge is being accumulated. We suggest that dealing with ecosystem components separately, while keeping in mind their potential interconnections, is the best approach at this time. Where cause-effect models exist (e.g., underlying the Management Strategy Evaluation (MSE) approach of Sainsbury et al., 2000), these may provide indicators and reference points for the operational objectives of their associated conceptual objectives, perhaps across a number of branches of the tree. Where knowledge is lacking, operational objectives would likely have to depend upon expert judgement (e.g. Delphi approach; Crosby et al., 1997). This approach can accommodate a mixture of quantitative and qualitative ecosystem information in a similar fashion as advocated by Halliday et al. (2001).

The Sidney workshop did not discuss the prioritization of objectives within the generic tree. There have been subsequent national developments that direct that these should be based upon the presence of ecologically and biologically significant areas and species as well as degraded areas and depleted species. Criteria for these either have been developed (EBSA, DFO, 2004a) or are under development.

3.2. Developing operational objectives

We described above the process of unpacking conceptual objectives to obtain operational objectives. However, there is a wide selection of potential indicators to choose from (see Rochet and Trenkel (2003) for a recent review) during unpacking and it is often not obvious how specific indicators can be associated most cost-effectively with specific conceptual objectives to achieve practical management outcomes. During unpacking, it is important to consider indicators according to their role in decision-making. Are the indicators being considered associated with the condition of the resource or are they relevant to management actions? Garcia and Staples (2000b) provide a comprehensive overview of different indicator systems in this regard. One system (the pressure-state-response (PSR) approach) classifies indicators according to the *state* of the ecosystem characteristic, human *pressures* on that characteristic and the *response* of management institutions to those *pressures*. The operational objective defined in Section 3.1 restricts itself to *state* indicators. Taking a PSR approach would require adding pressure and response indicators to the operational objective, e.g., maintain *state* above level x by limiting *pressure* to below level x by setting *response* at level y. For example, spawning biomass would be maintained above a reference point (e.g. minimum spawning biomass) through limiting fishing mortality below a reference point (e.g., $F_{0.1}$) by setting the total allowable catch at a certain level. We encourage adding such specificity to operational objectives as it forces definition of the decision rules under IM (Sainsbury et al., 2000; Payne, 1999).

Jamieson et al. (2001) highlighted difficulties in developing a suite of operational objectives from the conceptual objectives tree and, although they provided illustrative unpackings of some objectives, concluded that unpacking of the conceptual objectives tree needed to occur as part of a regional IM implementation process. They pointed out that this may best be done by a group of experts and stakeholders knowledgeable of the local ecosystem and available data. Regional unpacking workshops have therefore been conducted in pilot areas in both DFO Maritimes and Pacific regions to test the approach. Unpacking in Maritimes Region was done on an ocean industry basis, i.e.Scotian Shelf groundfish fishery, aquaculture, and oil and gas. Initial Pacific Region unpacking on the other hand, considered the development of operational objectives for all British Columbian ocean industries in a specific geographic area, the Central Coast, and in particular the Quatsino Sound Coastal Management Area (Jamieson et al., 2003). A later workshop (DFO, 2004b) considered a bottom-up approach in an effort to allow better focusing on those human activities impacting the environment. Impacts by existing industries in two geographical areas, Quatsino Sound and the deep-water trawled areas of Queen Charlotte Sound, were considered, keeping in mind the high level, nationally-defined conceptual ecosystem objectives they might be grouped under.

A number of lessons were learned (DFO, 2004b; O'Boyle and Keizer, 2003; Jamieson et al., 2003) from these exercises. Having an objectives tree that outlines the desired conceptual objectives and that formally links these to operational objectives used in everyday management forced consideration of why a particular indicator should be, or is being, measured. There was a tendency to use data availability to define the objective, rather than the converse. There will be occasions when firm scientific arguments for use of a particular indicator and reference point are not apparent. In these cases, expert judgement is appropriate.

Some participants in these exercises expressed concerns that 'their' indicators or the species they were working on were not adopted for use as an operational objective. Sometimes, this was because a number of potential ecosystem characteristics fall outside direct management influence, and so were considered largely irrelevant to local managers. For example, no obvious management response was evident if phytoplankton biomass fell below a certain level for natural reasons, or if water temperatures decreased. S. Gavaris (pers. comm. and reported in O'Boyle, 2003) suggested that such broad environmental health, or status, indicators be primarily used as reference point modifiers. In their study of Scotian Shelf haddock, Mohn and Simon (2002) studied decadal changes in that population's maximum sustainable yield (MSY), hypothesizing that this responded to decadal changes in phytoplankton production. The MSY reference point changed over time, something that management institutions should be considering. Environmental health, or status, indicators thus may have direct relevance for IM and need to be incorporated into specifications of selected operational objectives.

Groups undertaking an unpacking exercise may focus too much on one branch of the objectives tree, at the expense of other branches. This could occur when experts involved come from too narrow a technical background (e.g., mostly from population assessment). It is essential to unpack all branches to the degree possible and engage a wide array of expertise. Debate on which conceptual objective should be associated with a particular operational objective may help clarify the meaning and rationale of an objective, but detailed discussion can also sometimes be unproductive and waste time and energy. Unpacking is an iterative exercise in which what is proposed initially can be fine-tuned at a later stage. Also, an operational objective that may have been already considered under another conceptual objective may also be relevant to other conceptual objectives. It is thus important to maintain an overall objectives tree perspective in each unpacking exercise so as to recognize potential duplication, and to review the objectives tree at the end of the unpacking to ensure that all relevant conceptual objectives are adequately addressed.

Finally, many participants commented on the benefits of the unpacking to identify and prioritize future research efforts. The final objectives tree identifies those branches needing additional research attention to determine operational objectives for practical, cost-effective resource management.

3.3. Regulatory activities under integrated management

As IM is an extension of present ocean management activities, the current suite of regulatory tools used by managers will continue to be utilised, but ideally in a more coordinated fashion within and across agencies mandated to effect management. For example, primary regulatory measures for the fishing sector will continue to involve gear, season and catch limitations as well as time and area closures for specific issues such as juvenile and spawning fish protection. Increasingly, area restrictions are being proposed to address ecosystem, as opposed to specific species issues; this trend will likely continue and intensify. An important tool is the Marine Protected Area (Anon., 1999b; Jamieson and Levings, 2001; Shackell and Willison, 1995). Under the Canadian Ocean Act, MPAs can be internally zoned to include a range of restrictions, from controls on specific activities to establishment of no-take reserves (Murray et al., 1999; Jamieson and Lessard, 2000). However, there are few examples that we have found where the need for an MPA has been explicitly linked to an IM objective. While establishment of no-take MPAs has sometimes become an objective in itself as an insurance policy in case management by other means was not as successful as desired, we suggest it is preferable to rationalize not only MPAs but all existing regulations back to the IM objectives tree.

As an example, in the pilot ESSIM initiative, there has been discussion on the need to conserve biodiversity of benthic communities. This conceptual objective would apply to all ocean industries and would be achieved through restriction of uses (=human impacts) in specified zones. To achieve protection, one must (1) identify, or classify, relevant benthic communities, (2) determine the sensitivities of benthic communities to specific ocean uses, and (3) establish appropriate uses zones. Classification systems have been evaluated (Arbour, 2002), and an ESSIM ocean climate zonation, based on concepts of Southwood (1977, 1988) where the relative adversity of environment is related to a species' and community's tolerance and response to additional disturbances, is under development (DFO, 2005b).

3.4. Reporting frameworks for integrated management

We advocate assessing and reporting overall IM progress against each conceptual objective separately, and to achieve this, a process or framework that allow relatively easy assessment by managers of a variety of different attributes needs to be utilised. Such frameworks already exist: some use rankings of attributes, which are then summed to produce a single value that measures achievement against a maximum possible value (e.g., Index of Biotic Integrity (IBI) (Karr, 1981)), while others utilize a visual assessment process, such as the Traffic Light Method (TLM) (Caddy, 1999), in which the level of each indicator is assigned a colour (good (green), satisfactory (yellow) or bad (red)) and a manager makes an overall assessment by evaluating the proportion of green showing. An overall acceptable IM monitoring framework thus considers a suite of indicators and reference points to allow a simultaneous monitoring of progress against all IM objectives. Some objectives will reflect indicators and reference points based on models (e.g. the MSE of Sainsbury et al., 2000), while others may be based on expert knowledge, stakeholder input (Traditional Ecological Knowledge), and so on as defined in the unpacking process described earlier. Dependence on a suite of indicators, rather than just a few, is necessary to detect degradation of the ecosystem, but there is not yet enough experience in this subject area to allow recommendation of an optimal number of indicators to monitor. There may also be key indicators that should be monitored, which are particularly good measures of the impacts that different human activities have, perhaps by being relatively measurable and efficient in integrating responses of other parameters. On a negative side, given our present limited knowledge of ecosystem reactions to management actions (Walters et al., 1997), regulation of activities may at least initially be based more on qualitative, subjective, albeit expert, judgments. Unfortunately, having many ill-defined indicators may not be as desirable as a few well-understood ones (O'Boyle, 2003); the lack of an explicit model defining cause and effect can be controversial and will make choice amongst competing management actions difficult.

Communication of approaches and results amongst managers, stakeholders, and researchers is an important function of IM. One advantage of the above-mentioned multi-indicator reporting frameworks is that they allow tabular outputs of progress towards all objectives through presentation of both current performance and performance in relation to historical patterns (see DFO, 2003 for an example as applied to the Eastern Scotian Shelf). Other communication tools which might be used to report indicator performances for various dimensions of sustainable development are reviewed by Garcia and Staples (2000b).

4. Structures of integrated management

4.1. Integrated management area

Single species fisheries management has typically used a fished stock's area as the basis for areal zoning of regulatory activities. While efforts have been made to define management units as closely as possible with biological stock boundaries, this is often not possible. Early life history stages may be found in distinct areas separate from where commercially harvested adult stages may occur, and adults from different sub-stock components often intermix. Also, fishers and fleets from different areas may express operational and cultural differences, as is typically the case with transboundary resources. Thus, single stock management unit boundaries tend to be based on a combination of both biological and institutional realities.

With IM, as with single stock management, a geographical area with a common set of objectives and indicators being monitored is needed, within which progress towards achieving objectives can be assessed. As with single species management areas, we advocate that these be based on a combination of biological and institutional considerations. We desire to control the impacts of human activities on ecosystems and it is the latter that we manage, not the ecosystems themselves.

In Canada, there have been two initiatives to date to address desirable IM boundaries. Prior to 2004, Fisheries and Oceans Canada (DFO) had no approved national, science-based, marine ecological unit classification system, although other federal agencies had proposed different ones (see Powles et al., 2004 for a summary). DFO's Oceans Branch had introduced the concept of the Large Ocean Management Area (LOMA), within which IM would be effected, but while boundaries for some of these had been suggested, they have not yet been finalized. In 2003, DFO determined that it required an initial science-based ecoregion classification to facilitate IM, with ecosystem management objectives then to be determined and adapted to each distinct ocean ecoregion area. Powles et al. (2004) summarise the 17 marine ecoregions accepted for Canada's three oceans—four in the Pacific, six in the Arctic and seven in the Atlantic Ocean. Some LOMAs may ultimately encompass an entire ecoregion, while others may be nestled within one ecoregion.

4.2. Manager and stakeholder engagement

The need and advantages for stakeholder engagement in IM has been highlighted by a number of authors (e.g. FAO, 2003; Jamieson et al., 2001). Traditionally, renewable resource managers have interacted with individual ocean industries separately, but since a common vision and goals are being determined with IM, IM has created a need for both intra-industry cohesiveness and inter-industry consultative and decision-making organizations. An example of recent intra-industry changes stimulated by the ESSIM initiative is the creation of the Maritimes Fishing Industry Roundtable, established specifically to facilitate dialogue within the fishing industry on issues related to IM. Regarding inter-fleet interaction within the fishing industry on the Scotian Shelf, there already exist a number of management bodies to facilitate consultation and decision-making. The fishing industry has encouraged developing these incrementally (Murphy and O'Boyle, 1999) to meet the needs of IM, thereby ensuring that the concepts and terminology of IM relate to existing management approaches and can be readily understood. Without this, a 'cultural communications gap' might occur that would impede progress towards IM. There is a need to establish inter-industry bodies, of which the ESSIM Forum (Coffen-Smout et al., 2002), created to facilitate inter-industry IM dialogue, is an example.

There is also a need for management agencies to have intra and inter-agency discussions on IM. The required operational changes both within and amongst agencies are as important as those required by stakeholder groups; particularly in large agencies, different groups may operate quite independently, with the possibility of their working at cross purposes. At the Sidney workshop (Jamieson et al., 2001), ocean managers provided insight on the challenges and pitfalls they face in implementing IM. Integrated management imposes a great deal more complexity on management than in the past, with the need to overlay ecosystem considerations on traditional roles and responsibilities. The main goal of management planning – harmony among users – now has to be attained amongst all industries, not just among traditional fishery groups. Consultative and planning processes have to change, with greater inter- and intra-industry dialogue; managers have to change their predominantly single industry focus to embrace a broader clientele. This may lead to resistance unless clear reasons are presented for why IM will lead to better ocean management. Clearly stated and justified objectives that provide the rationale for IM are required. Managers face a hierarchy of "visions" or issues, from international treaties and national concerns to local issues. The challenge is to link local issues with larger national and international visions in order to maintain the support of both stakeholders and the public. Managers also highlighted the need for a concise list of well-justified indicators and reference points to guide management actions. Having numerous indicators and reference points without their obvious management applicability will impede rather than aid implementation of IM.

5. Concluding remarks

Integrated management on Canada's East and West coasts is still in its initial stages. While progress has been made, development of IM will be a long-term, ongoing, adaptive process that will involve the testing of many alternative approaches to determine which approach works best and is most cost-effective. Incorporation of conceptual objectives for the dimensions of sustainability (social, economic, and cultural), technical review of ecosystem monitoring approaches, and the continuing need for research on appropriate indicators and reference points are just some of the major IM challenges ahead. Progress to date has been substantial though, and the broad outline of what is required to implement IM is starting to emerge. Through continued efforts such as those presented in this paper, we are confident that the goal of achieving realistic and effective ecosystem-based management will be realised.

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