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Indicators for ecosystem-based management on the Scotian Shelf: bridging the gap between theory and practice

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The need for a more integrated approach to ocean management is increasingly being recognized. Discussion on appropriate indicators and reference points supporting such an approach has focused on the technical merits of one set of metrics over another in servicing some management goal. Relatively little effort has been put into answering the question how one would use suites of indicators to meet the multiple conservation objectives defined in operational plans. Such an exercise is being undertaken on the eastern Scotian Shelf off Canada's east coast, as a national integrated management pilot. A number of ocean industries – fishing, oil and gas exploration, transport, and the military – utilize the area, a typical situation elsewhere in the world. A suite of conceptual ecosystem-level objectives has been identified to address biodiversity, productivity, and habitat issues. Operational objectives, which identify an indicator and reference points associated with each conceptual objective, are then stated. Utilizing this framework, individual ocean industry plans and activities can be reviewed in a consistent manner, to determine how they might be constrained by the conservation objectives for the area. Issues of spatial scale and cumulative impacts are addressed, and comment is made on future developments.

Keywords: biodiversity, conceptual objectives, conservation, cumulative impacts, implementation, integrated management, operational objectives, planning hierarchy, Scotian Shelf.

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Introduction

In Canada, the Fisheries Act, first enacted in 1857, has been a prime legislative vehicle governing ocean usage, particularly fishing. It regulates the capture, holding, and possession of all marine life, and makes unlawful the harmful alteration, disruption, or destruction of fish habitat. While it is periodically revised (most recently in 1991), its focus has been the conservation and protection of commercially exploited species and their habitat. Responding to both international legislation and national concerns about the cumulative impacts of all human activities on marine ecosystems, Canada enacted the Oceans Act in 1997. That Act outlined a new approach to managing ocean resources, based on the need for collaboration among all ocean users, as well as new management tools and approaches. Since 1997, Canada's approach to ocean management has started to emerge through a number of initiatives. Key among these was the establishment of a nationally coordinated integrated management (IM) programme (DFO, 2002a), consisting of pilot projects on the east and west coasts.

Our main purpose here is to illustrate how conservation under IM can be implemented practically, using the Eastern Scotian Shelf Integrated Management project (ESSIM; Figure 1) as an example. It is based upon the experience of the authors, as well as international dialogue (Garcia and Staples, 2000a; Sainsbury and Sumaila, 2003), and adopts the terminology of Jamieson *et al.* (2001). The framework has similarities to the Ecological Quality–Ecological Quality Objectives (EcoQ–EcoQO) approach of the Oslo–Paris Commission (ICES, 2001, 2002), but there are differences that may be instructive.

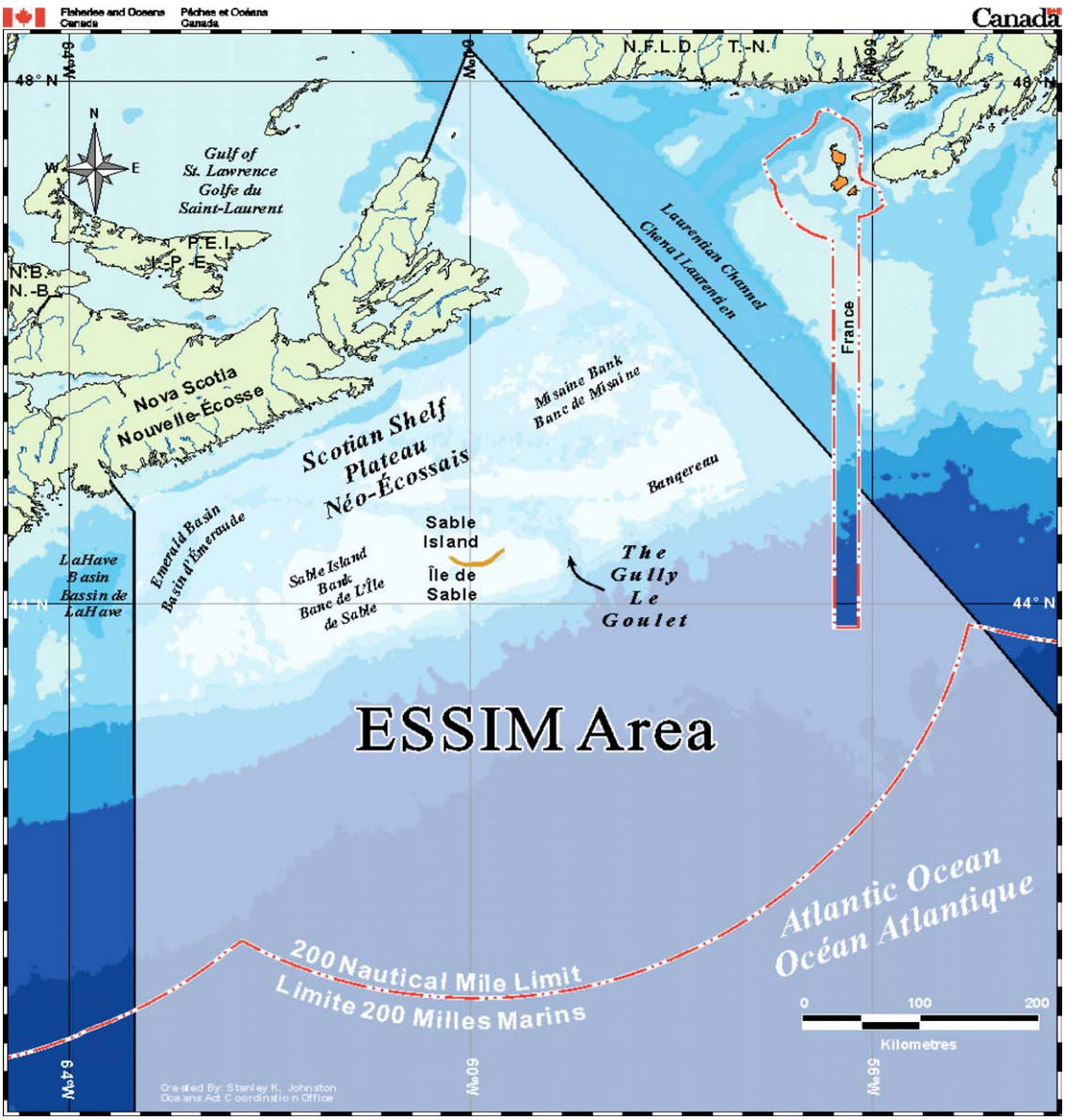

Figure 1. The Eastern Scotian Shelf Integrated Management (ESSIM) pilot area on Canada's east coast, showing the main physical features.

Many of the details of the ESSIM framework presented below are still under discussion. We only discuss the conservation objectives, but parallel work is currently underway on the socio-economic objectives. Also, the conservation objectives for IM have not been extensively discussed with stakeholders, and thus have not yet been fully incorporated into management plans. This notwithstanding, the framework developed so far should be of interest to those engaged in IM implementation.

Here we provide observations on the issues and difficulties encountered so far in applying the translation of conceptual into operational objectives in the ESSIM area. To illustrate the approach, only those aspects related to the national conceptual objective for biodiversity are elaborated upon. O'Boyle *et al.* (2004) provide information for all three national conceptual objectives.

Integrated management planning

Planning hierarchy

IM of an ocean area involves a set of nested planning activities, from an overarching plan at the top, through ocean-industry-level planning, to intra-industry plans below (Figure 2). The overarching plan for the ESSIM area

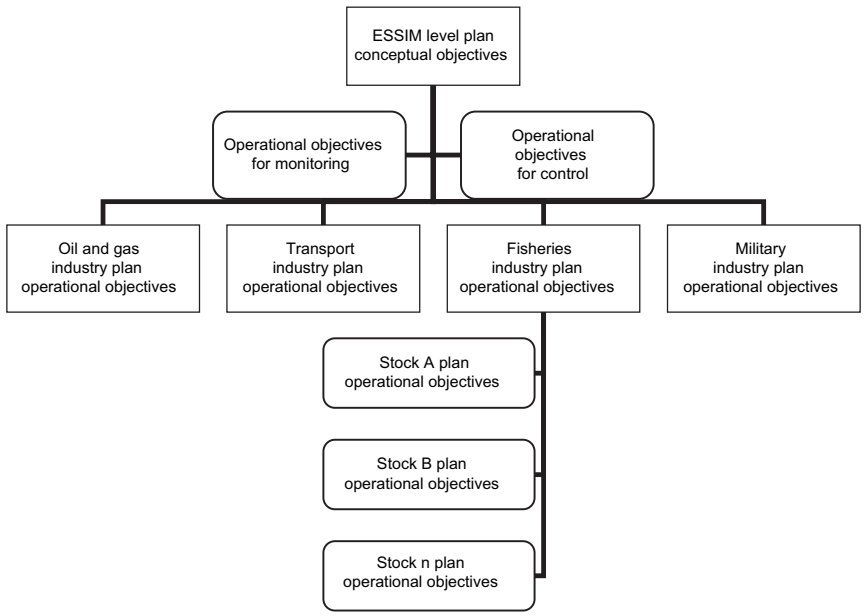

Figure 2. The set of nested plans for each of Canada's integrated management areas.

outlines the conceptual objectives to be addressed by all ocean industries operating there. The conceptual objectives are derived from those stated in national policy (Jamieson *et al.*, 2001), to provide national consistency in IM efforts.

The conceptual objectives are made operational by an "unpacking" process, which produces associated operational objectives consisting of an action verb, indicator, and reference point (Jamieson *et al.*, 2001). There are two uses for the operational objectives (Figure 2). When a number of ocean industry activities impact the same feature of an ecosystem, the cumulative impacts of the activities need to be addressed. An operational objective to control the cumulative impacts should have an associated management action that is triggered by a reference point. The second use is for determination of the overall "health of the ecosystem" in an IM area. In this case, the term "operational" refers to the need to monitor identified ecosystem features in relation to some desired reference point, but a management action is not triggered; only the state of the ecosystem feature of interest is tracked over time.

One step lower in the hierarchy, planning is undertaken by each ocean industry that reiterates the higher level conceptual objectives and outlines the specific operational ones, with associated controls, required to implement them in that industry. Operational objectives at that level address either specific activities within or cumulative activities across that industry. In the ESSIM area, ocean industry planning is being considered for at least fisheries, oil and gas, transport, and the military.

Within any one industry, there may be a need for more targeted planning. For instance, within the eastern Scotian Shelf fishing industry, there are numerous stock-specific plans. As with the higher level plans, the operational objectives in stock-specific plans are linked back to the conceptual objectives stated at the IM level. Similarly, within the oil and gas industry, environmental assessment of any proposed new activity is required under the Canadian Environmental Assessment Act. The national conceptual objectives were recently tested as a guide to the review of cumulative impacts of seismic activities. A similar exercise is currently underway for aquaculture site approvals. Both initiatives show promise in linking the control of specific activities within the industries back to the national conceptual conservation objectives.

This hierarchical approach to the planning for IM is consistent with the need to address the impacts of human activities at different levels. Some activities have wide-ranging impacts, whereas the effects of others are limited spatially. Management addresses people, not ecosystems, and therefore it is important to provide an institutional structure that organizes human activities appropriately, a point raised in consultations with the Scotian Shelf fishing industry (Murphy and O'Boyle, 1999).

Development of the hierarchy

Three national conceptual objectives, with a hierarchy of associated sub-objectives, have been established to guide the conservation of the biodiversity, productivity, and habitat in the IM areas (Jamieson *et al.*, 2001). Based on experiences with several "unpacking" pilots (Jamieson *et al.*, 2003; O'Boyle and Keizer, 2003), we suggest that the following sequential steps would be required to make the linkage between national conceptual objectives and lower-level

operational ones: (i) identifying the relevant local conservation issues; (ii) identifying ecosystem components, characteristics, and relevant conceptual objectives; (iii) identifying the appropriate ocean industries to be involved in implementation; (iv) defining operational objectives for both the IM area and for each ocean industry.

The relevant conceptual objectives are defined in the first two steps, the operational ones in the last two. Once a preliminary set of operational objectives is developed, modifications may be needed, based on discussion with stakeholders (e.g. NGOs, government managers and officials, scientists, the public), to ensure that all issues have been interpreted consistently.

The ESSIM plan

Step 1: identifying relevant conservation issues

Perceptions among stakeholders on the key issues, be they human pressures, ecosystem states, or management responses, may differ considerably. It is necessary to initiate extensive dialogue and probing of what the issues are, before appropriate conservation objectives can be stated. This is currently underway in an ESSIM stakeholder working group. The product will be a list of conservation issues (in clear layman's terms) that are important to the stakeholder community (Coffen-Smout *et al.*, 2001; O'Boyle *et al.*, 2004). Those related to the conservation of biodiversity are given in Table 1.

Table 1. Issues in the ESSIM area associated with the national conservation objectives related to biodiversity, as identified by regulatory agencies (RA), ocean industries (OI), and other stakeholders (others).

National conservation objective: to conserve sufficient components to maintain the natural resilience of the ecosystem
Sub-objective: Maintain community biodiversity
RA: Distribution of impacts of human activities on benthic communities
OI: Effects of activities on benthic communities (fishery, trawling; oil and gas, oil well pad; military, explosives)
Others: Protection of fragile benthic communities, e.g. coral communities in all areas, bottom communities in the Gully
Sub-objective: Maintain species biodiversity
RA: Recovery of all species at risk
OI: Interaction with species at risk (fishery, bycatch; oil and gas, drilling waste and seismic surveys; transport. shipping noise, ballast water, collisions; military, explosives)
Others: Protection of charismatic species at risk, e.g. bottlenose whale, leatherback turtle
Sub-objective: Maintain population biodiversity
RA: Genetic diversity of population
OI: Safeguard population spawning components
Others: —

During the process, it is important to identify clearly which national conceptual objectives address the various issues. If benthic disturbance of coral communities is an issue for a number of ocean industries, the same conceptual objective (*in casu*, the maintenance of biodiversity) should apply to all. Addressing habitat impacts of bottom fishing under one objective and habitat impacts of oil and gas exploration under another would confound efforts to address the cumulative impacts of the two activities.

Step 2: identifying conceptual objectives

Once the conservation issues have been identified, it is necessary to identify the broad features of the ecosystem (communities, species, populations; Jamieson *et al.*, 2001) that are implicated in each issue, keeping in mind that as the "ecological distance" from a human activity increases, the likelihood of meaningfully managing that impact decreases.

Defining the conceptual objectives for the IM area in terms as specific as possible greatly facilitates later identification of the associated operational objectives. One means to add specificity to the conceptual objective is to consider the characteristic of the ecosystem component that requires protection. The characteristic is a biological property of the ecosystem, separate from our ability to measure it (Jamieson *et al.*, 2001). It is equivalent to the criterion of Garcia and Staples (2000b). For example, recruitment is a characteristic of a population, in contrast to numbers of age-one animals from a population model, which is a measurable quantity or indicator of recruitment. The dialogue must identify what characteristics of the various ecosystem components need protection, so that the conceptual objectives can be stated.

Table 2 presents the ecosystem components, characteristics, and potential conceptual objectives related to biodiversity for the ESSIM area. An important feature of the biodiversity objectives is that human impacts on each benthic community type would only be acceptable if the cumulative impacts across ocean industries remain within specified limits. One means of doing this is by applying limits to the total allowable area of disturbance for each type, dependent upon the vulnerability to that type of disturbance. Initial attempts are being made to categorize the vulnerability of benthic community types on the Scotian Shelf to human activity, using the adversity/stability model of Southwood (1977, 1988). While these show promise on providing the necessary limits for management purposes, much research is still required to move to the operational stage.

Step 3: identifying ocean industries to be involved in implementation

Next, it is necessary to determine which ocean industries must formulate operational objectives to address the various conservation issues. This step requires significant ocean industry input. Although the conservation issues

Table 2. Ecosystem components, their characteristics and formulated conceptual objectives (numbered), related to the national biodiversity sub-objectives for ESSIM. Interim objectives identified during the unpacking process (• or ••) are also provided.

National conservation sub-objective
  Ecosystem component and their characteristics
    (Interim) conservation objectives formulated
Maintain community biodiversity
  Benthic community types in ESSIM area − distribution of each type
    • Protect types susceptible to disturbance
    •• Prevent significant adverse alteration of each type
    1. Maintain area of disturbance of each benthic community type within identified limits
  Coral community in Stone Fence area − distribution
    • Protect fragile coral communities in ESSIM area
    •• Prevent significant adverse alteration
    2. Maintain area of disturbance area of coral community in Stone Fence area within identified limits
  High-diversity benthic community in the Gully − distribution
    • Protect high-diversity benthic communities
    3. Prevent significant adverse alteration of high-diversity benthic communities in the Gully
Maintain species biodiversity
  Invasive species in ESSIM area − number
    • Protect natural communities from invasive introductions
    4. Prevent significant adverse introduction of exotic species
  Non-target species in ESSIM area − bycatch
    • Maintain continued existence of non-target species
    •• Minimize impact of fishing activity on non-target species
    5. Minimize incidental mortality of fishing activity on non-target species (i.e. bycatch)
  Species at risk in ESSIM area (e.g. bottlenose whale, leatherback turtle, cod) − abundance
    • Restore abundance
    6. Manage recovery of all species at risk
Maintain population biodiversity
  Populations under human pressure (e.g. cod, flatfish, snow crab) − genetic diversity within populations
    • Maintain meta-population structures
    •• Maintain components of populations impacted by human activity
    7. Prevent elimination of spawning/breeding component by human activity

were identified during Step 1, this does not imply that the potential for impacts of each industry on each ecosystem component has been considered in detail. Therefore, the expected impacts by industry need to be sorted explicitly by ESSIM conceptual objectives (Table 3), so that like impacts can be managed by similar operational objectives in different industries.

Step 4: defining operational objectives

Identifying the indicators and reference points required to formulate ESSIM operational objectives primarily involves technical discussion within the scientific community. There is a large literature on indicators and reference points for integrated management (see Rochet and Trenkel, 2003, for a review) and how these might be classified and used in management systems (e.g. the pressure-State-response classification; OECD, 1993; Garcia and Staples 2000b), so they will not be discussed further here. Suffice it to say that all operational objectives should state both limit and precautionary reference points, and identify associated management actions consistent with the formulation of control rules (Sainsbury and Sumaila, 2003).

Table 3. Ocean industries in the ESSIM area implicated (*) in achieving the biodiversity-related conceptual objectives (CO, numbered 1−7; see Table 2).

Plan/industry	1	2	3	4	5	6	7
IM area plan	*	*	*	*	*	*	*
Fishing industry	*	*	*	—	—	—	—
Stock plan (e.g. groundfish)	*	*	*	—	*	*	*
Oil and gas industry	*	*	*	—	—	—	*
Transport industry	—	—	—	*	—	*	—
Military	—	*	*	—	—	*	—

As mentioned above, at the IM area level in the planning hierarchy, operational objectives have two purposes: (i) monitoring progress towards all conceptual objectives; (ii) control of cumulative impacts across ocean industries. Note that it is the suite of all operational objectives at this level that would be used to determine progress against all ESSIM conceptual objectives, so providing an overview of ecosystem health. Table 4 outlines potential operational objectives related to the conservation of biodiversity. For each objective, the action verb, indicator, limit, and precautionary reference points are stated, as is the associated management action required for implementation. The three operational objectives with associated management actions are concerned with the maintenance of community biodiversity and address cumulative impacts across all ocean industries. To maintain the area of disturbance of each benthic community type within identified limits, reference points for the spatial fraction disturbed are currently under investigation. Once these are available, there would be an allocation of the area of this disturbance among the industries involved, so the allocation can be used to guide their activities. The other two objectives requiring management action define the area of coral area and Gully benthic community that can be disturbed (zero in each cases; note that limit and precautionary reference points are the same). This is to be managed through a closed area (coral) and a marine protected area (the Gully), the coordinates of which would be recognized in the respective industry plans. For the remaining four operational objectives, indicators and reference points are provided that are designed to monitor progress towards achievement of the conceptual objectives.

Table 4. Biodiversity-related operational objectives with composing elements (action verbs: L, limit; M, monitor; D, distribute. Indicator: AD, area disturbed in km^2; LRP and PRP, limit and precautionary reference points, respectively; LtA, long-term average; lq, lower quartile; X and Y, to be determined; PBR, potential biological removals; SAR, species at risk; FI, fishing industry; C, catch) and associated management actions for the ESSIM level plan, and as an example for the groundfish (GRDF) stock plan.

CO	Operational objective (Action verb/indicator/LRP/PRP)	Management action
ESSIM plan		
1	L/AD by type/X/Y	Allocate AD to individual industries
2	L/AD of coral/0/0	Establish closed area
3	L/AD in the Gully/0/0	Establish MPA
4	M/# non-native species/LtA/lq LRP	None
5	M/average % bycatch in directed FI/LtA average/lq LRP	None
6	M/# SAR/Lta/lq LRP	None
7	M/No non-viable meta-population/LtA/lq LRP	None
Groundfish plan		
1	L/AD by type/$\%_{GRDF}$ ($\%_{FI}$ of X)/$\%_{GRDF}$ ($\%_{FI}$ of Y)	Enforce closed areas as defined in groundfish plan
2	L/AD/0/0	Enforce closed area
3	L/AD/0/0	Enforce MPA
4	Not applicable	Not applicable
5	L/%bycatch on each trip/15%/10%	Restrict FI if bycatch $\geq$ PRP; close areas/seasons if bycatch $\geq$ LRP
6	L/C_{SAR}/X_{GRDF}% of PBR/80% of LRP	Limit FI if $C_{SAR} \geq$ PRP; Close FI if $C_{SAR} \geq$ LRP
7	D/F by component/X%/Y%	Limit C by component to X% of TAC

Note that performance of some of these operational objectives is only indirectly linked to industrial impacts. Aggregate, yet simple, indicators (e.g. the number of meta-populations considered non-viable) such as these have been used elsewhere to provide overviews of ecosystems (DFO, 2003; Garcia and Moreno, 2003). The reference points are currently under investigation, and values given are for illustrative purpose only.

The main vehicle for ESSIM implementation is industry-based planning, i.e. fishing (incorporating stock plans), oil and gas, transport, and the military (Table 3). Contrary to the overarching ESSIM plan, all operational objectives in these plans have an associated management action, and none is for monitoring only.

Illustrative operational objectives for all industries are provided in O'Boyle *et al.* (2004). Here, we focus on the groundfish plan (DFO, 2002b) to show how stock plans would fit into integrated management (Table 4). The overall fishing industry plan includes operational objectives to conserve community biodiversity (CO 1). The ESSIM plan would have allocated some percentage area of allowable disturbance to the fishing industry, although actual percentages have not yet been decided. A proportion of this area would then be allocated to each stock plan (e.g. groundfish), and to achieve this, the fishing industry may decide to use a system of closed areas.

The conceptual objectives on the coral (CO 2) and Gully (CO 3) benthic communities would be met in like manner. Operational objectives to meet the species biodiversity objectives (CO 5, CO 6) would be met through limits on bycatch and on catch of species at risk (SAR), the latter guided by specific allocations of potential biological removals (PBR). Note that the management action might be different, depending on whether the limit or precautionary reference point had been reached. The population biodiversity objective (CO 7) would be met through the distribution of fishing mortality bycatch allocations to each population component.

To illustrate how cumulative impacts across ocean industries are addressed through the planning framework, the operational objectives related to the diversity of benthic communities are extracted here from all plans (Table 5). At the ESSIM level, an overall allowable disturbance per benthic community type would be established on the basis of the vulnerability of each type to human activities. The allowable area of disturbance is then partitioned among the ocean industries, as indicated. Each industry would then have to decide, through a consultative process, how their allocation would be distributed among their stakeholders. In the case of fisheries, the groundfish and scallop plans might receive fractions of the industry's allocation. In the case of the oil and gas industry, the allocation might require limits on the number of wells situated within each benthic community type, to ensure that the summed footprints of each well would be within the industry's allowable disturbance allocation.

Table 5. Illustration of treatment of cumulative impacts under ESSIM for conceptual objective 1 (maintain area of disturbance of each benthic community type within identified limits), based on limit (LRP) and precautionary reference points (PRP), as identified in Table 4. SCA, scallop; OG, oil and gas; other terms as in Table 4.

Plan	LRP/PRP	Management action
ESSIM area	X/Y	Allocate % disturbed by industry; implement through industry plans
Fishing industry	$\%_{FI}$ of X/$\%_{FI}$ of Y	Allocate % disturbed to stock plans
Groundfish stock plan	$\%_{GRDF}$ ($\%_{FI}$ of X)/$\%_{GRDF}$ ($\%_{FI}$ of Y)	Restrict areas of groundfish fishing
Scallop stock plan	$\%_{SCA}$ ($\%_{FI}$ of X)/$\%_{SCA}$ ($\%_{FI}$ of Y)	Restrict areas of scallop fishing
Oil and gas industry	$\%_{OG}$ of X/$\%_{OG}$ of Y	Licence number of wells by community type

Concluding remarks

The framework for integrated management of the eastern Scotian Shelf ecosystem draws upon the experience of the authors and concepts currently being discussed in Canada and elsewhere (Sinclair and Valdimarsson, 2003). A key feature is that the framework partitions the implementation into a hierarchy of smaller planning elements. This is critical, because integrated management requires interaction with, and buy-in of, the entire community. Everyone must see their role in the overall plan, and contribute meaningfully to discussion about the issues that affect them directly. However, this will require developing innovative governance structures, and many lessons have still to be learned in this regard.

The ESSIM Forum (Rutherford *et al.*, 2005), a discussion group involving all ocean industries, has proved effective in communicating the overall planning approach. The needs of IM have been discussed extensively with the fishing industry, and changes have been made to the groundfish plan, with a similar process initiated with the scallop fishery. Now indicators and reference points have to be discussed among the scientific and ocean management community at all levels of the planning hierarchy. To address this, an ESSIM Science working group has been formed, and it is currently evaluating the information needs as well as the requirements to fill knowledge gaps.

Although still in the early days of testing, with many lessons on its utility still to be learned, the framework shows promise in providing a useful planning tool. Further development may draw on experiences with comparable exercises in both Europe (ICES, 2001, 2002) and Australia (Sainsbury and Sumaila, 2003). Such an exercise will, it is hoped, bring us closer to the realization of integrated management of our oceans.

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