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Proceedings

of a Workshop

on the

Ecosystem Considerations

for

The Eastern Scotian Shelf Integrated Management (ESSIM) Area

Bedford Institute of Oceanography
19 – 23 June 2000

R. O'Boyle, Chair and Editor

Bedford Institute of Oceanography
P.O. Box 1006
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FOREWORD

These Proceedings are a record of the submissions to and discussions at the Workshop on the Ecosystem Considerations for the Eastern Scotian Shelf Integrated Management (ESSIM) Area, which was held June 19-23, 2000. The purpose is to archive the activities and discussions of the workshop. As such, interpretations and opinions presented in this report may be factually incorrect or misleading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement has been reached.

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ABSTRACT

The Canada Oceans Act (1997) extends Canada's jurisdiction over the ocean to the full extent permitted under international law. With this claim of sovereign rights comes responsibilities, including the establishment of a governance structure, based upon the principles of integrated management, sustainable development, the precautionary approach, the collaborative approach and the ecosystem approach. In December 1998, the Minister of Fisheries and Oceans announced the ESSIM initiative to pilot this new comprehensive approach to Oceans management. In support of ESSIM, a workshop of scientific experts was held to 1) provide the initiative with a precautionary framework for ecosystem based management, 2) consider the current management approaches and consider where changes are required to meet ecosystem objectives, 3) describe the Eastern Scotian Shelf ecosystem, 4) consider potential indicators to guide management, 5) outline the monitoring requirements, and 6) consider to what degree the proposed Sable / Gully Marine Protected Area (MPA) meets the potential ecosystem-based objectives of ESSIM. This report presents the results of this workshop.

RÉSUMÉ

La Loi sur les océans du Canada (1997) accorde au Canada la pleine mesure de la compétence sur les océans permise par le droit international. Ces pouvoirs souverains s'accompagnent de responsabilités, concernant notamment la mise en place d'une structure de gestion publique, fondée sur les principes de la gestion intégrée, du développement durable, de l'approche de précaution, de la collaboration et de l'approche écosystémique. En décembre 1998, le ministre des Pêches et des Océans a annoncé le lancement du programme ESSIM (gestion intégrée de l'est du plateau néo-écossais), destiné à mettre en application cette nouvelle approche englobante de la gestion des océans. On a tenu un atelier d'experts scientifiques dans le cadre du programme ESSIM pour 1) définir un cadre de précaution applicable à la gestion axée sur l'écosystème; 2) étudier les méthodes de gestion actuelles et déterminer quels changements doivent y être apportés pour les rendre conformes aux objectifs en matière d'écosystème; 3) décrire l'écosystème de l'est du plateau néo-écossais; 4) envisager des indicateurs aptes à guider la gestion; 5) définir les besoins de surveillance et 6) déterminer dans quelle mesure la Zone de protection marine (ZPM) proposée dans la région de l'île de Sable et du Gully est conforme aux objectifs possibles du programme ESSIM concernant l'écosystème. Le présent rapport rend compte des résultats de cet atelier.

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EXECUTIVE SUMMARY

The Canada Oceans Act (1997) extends Canada's jurisdiction over the ocean to the full extent permitted under international law. With this claim of sovereign rights comes responsibilities, including the establishment of a governance structure based on the principles of integrated management, sustainable development, the precautionary approach, the collaborative approach and the ecosystem approach. In December 1998, the Minister of Fisheries and Oceans announced the ESSIM initiative to pilot this new comprehensive approach to Oceans management. This initiative is intended to test management approaches before broader application.

In support of the ESSIM initiative, a scientific workshop was held in June 2000 to:

1. Provide a framework for a precautionary approach to the incorporation of ecosystem objectives into integrated ocean management
2. Describe conservation objectives and regulatory measures for existing management plans, policies, and programs of government and ocean industries in the ESSIM area (including fisheries, oil/gas, etc.) and consider the changes needed to incorporate ecosystem objectives
3. Describe trends in fisheries, fisheries resources, oceanographic and ecosystem properties, and contaminants in the ESSIM area
4. Define indicators for potential ecosystem objectives of ocean management
5. Identify monitoring needs for selected indicators of ecosystem objectives
6. Consider to what degree the proposed Sable/Gully MPA meets potential ecosystem objectives of ESSIM, what ocean use activities are consistent with meeting the objectives and if additional MPAs are needed within the ESSIM area to meet ecosystem objectives

The workshop investigated the technical needs of ecosystem-based management and made suggestions and proposals for further work. Participants, both national and international, were invited based on their expertise.

Framework for a Precautionary Approach

A precautionary approach framework, with the following elements, was proposed as a guide to ecosystem-based management for the ESSIM initiative:

- Conservation objectives to maintain, within acceptable bounds, the diversity of ecosystem types, species diversity, genetic variability within species, the productivity of directly-impacted and ecologically-dependent species, ecosystem structure and function, and marine environmental quality

- Strategies based on reference points - limit and target, where appropriate

- Account of uncertainty, including reversal of the burden of proof, stakeholder involvement in the determination of acceptable level of risk, and monitoring of indicators and associated pre-agreed management actions that are essential for management

- Implementation of a decision-making process, including pre-agreement on actions (decision rules) to be taken depending on the state of indicators, and

- Evaluation of management system performance, including the relevance of the objectives, and the applicability of the indicators and reference points

The conservation objectives need to be clearly understood by all involved in the management system. There is a need to develop a series of descriptors for each objective in order to clarify what they encompass. The link between these objectives and the principles and approaches in the Oceans Act and other relevant international agreements would also be useful.

Management Considerations

Consideration should be given to adopting the following common set of ecosystem-based objectives in the management plans of all ocean sectors:

- human activities should be managed so as to maintain with acceptable bounds:
  - The diversity of ecosystem types
  - species diversity
  - genetic variability within species
  - the productivity of directly-impacted and ecologically-dependent species
  - ecosystem structure and function, and
  - marine environmental quality

With a common set of objectives, each ocean sector can judge where and how they may be having impacts or require specific actions.

A number of changes to current management institutions and tools are needed for ecosystem-based management, the most important being the requirement for new institutions (e.g. management boards) to coordinate activities of all existing agencies.

Trends and Indicators

Overviews of the trends in the various components of the ecosystem, from physical oceanography, through the plankton and benthic community, to the invertebrate, finfish, bird and marine mammal resources illustrate some of the dramatic changes experienced by the ecosystem in the ESSIM area over the last two decades. Groundfish resources have declined dramatically while invertebrates have increased. There has been an overall shift towards a lower trophic level of harvesting. Of particular note were the differences in oceanography between the northeastern and central sector of the ESSIM area, which could influence each sector's biological productivity.

While much is still to be done, there was progress towards the development of indicators for the ecosystem-based objectives.

Maintenance of the diversity of ecosystem types

The diversity of ecosystem types refers to assortment of ecosystem communities that one observes rather than the diversity of species within each ecosystem. For example, the benthos is composed of a number of different biological communities, dependent upon water depth, substrate, temperature and other factors.

For the planktonic communities, the geographic scale of the 'ecosystem types' is large (i.e. the so-called Longhurst areas defined at ocean basin scales in relation to physical oceanographic properties). Thus the whole eastern Scotian Shelf might be considered to be a single ecosystem type with respect to plankton.

In relation to the diversity of the benthos, the spatial distribution of ecosystem types on the eastern Scotian Shelf could be defined, as well as the amount of total area of each type which is being used or impacted by human activities. Potential indicators could be the total area of each benthic ecosystem type that is impacted, as well as the species composition and relative abundance at representative disturbed and undisturbed monitoring sites. Reference points could establish the maximum area percentage usage allowed by ecosystem type.

For the fish communities, the ecosystem types also occur at larger geographic scales than the eastern Scotian Shelf. Indicators were not considered further under this objective.

Maintenance of species diversity

Species diversity refers to the number of species within the management area. To achieve the ecosystem-based objective related to species diversity, it is necessary to prevent the extinction of species, and introductions of new species, as a result of human activities. A number of potential indicators (e.g. range contractions, population fragmentation, number of spawning units, critical habitat, exotic species) could be used as a set of scanning criteria to develop a list of potential 'species of special concern' – species that qualify for special monitoring. A group of experts should be established to both develop the criteria further and prepare a report on the application of these criteria to the species in the ESSIM area.

Maintenance of genetic variability within species

Genetic variability within species relates to the population structure - the number of stocks or stock components of a species in an area and the genetic makeup of each. A number of potential indicators were proposed to measure genetic variability within a species, including survey numbers/biomass, sex ratio, fecundity, and selection differentials, along with those mentioned above in relation to species diversity. A group of experts needs to develop the indicators further and apply these on a case study basis to the biological resources in the ESSIM area.

Maintenance of the productivity of directly-impacted species

Directly impacted species are those that some ocean use activity directly effects in some manner. For instance, in the case of fisheries, these would be the species targeted for harvest, whereas in the case of oil and gas exploration, these would be the species that would be directly impacted by the products of seismic, drilling or production activity.

The on-going work in DFO Science on indicators and reference points for finfish was acknowledged and encouraged. Some of this work has already been tabled in the Regional Advisory Process (RAP) as part of the fisheries management planning process. When this and other related work is sufficiently advanced, it would be useful to prepare a list of all species (commercial and non-commercial) in the ESSIM area, along with associated indicators and, where possible, reference points.

Maintenance of the productivity of ecologically-dependent species

Ecologically dependent species are those that are directly linked through the food chain (immediate predator and/or prey) to those species directly impacted by human activities. A number of potential indicators were discussed, all of which need further development. For instance, the biomass of forage species at a specific trophic level could be calculated and a limit reference point (biomass below which one should not fall) defined as 75 percent of the virgin biomass. For marine mammals, potential indicators include optimal sustainable population size, potential biological removal, foraging trip duration of lactating female, weaning mass of young, juvenile growth rate, pregnancy rate and age at maturity. For birds, indicators, such as the number of deaths that will prevent a population from recovering, could be developed using a Potential Biological Removal approach. Other indicators could be based on breeding success. DFO and EC will need to work together to develop these indicators further.

Maintenance of ecosystem structure and function

Indicators and reference points in relation to the overall structure and function of the ecosystem were considered. For instance, are there some characteristics of the ecosystem that can be measured that indicate its state and how it is changing? An indicator of ecosystem structure and function that shows promise is the slope of the size spectrum, perhaps calculated by guild or trophic level. Pauly’s FIB index is another possibility, as is fishery removals by trophic level. Unfortunately, our level of understanding of ecosystem structure and function is limited and thus it will be necessary to monitor a number of indicators which are not linked to management actions but will lead to increased understanding of the ecosystems.

Maintenance of marine environmental quality

Contaminant guidelines exist but apply primarily to the inshore area. Those for the offshore need to be rethought. Some information exists that could be compiled to provide guidance to the ESSIM initiative. A working group of the appropriate experts could be established to compile the existing information on indicators and reference points for the offshore area. Also, the Green Plan Toxic Chemicals Program report should be finalized and published.

Monitoring Requirements

A list of new monitoring initiatives was compiled at the workshop. This list needs to be revisited once the indicators have been finalized. Some of the new requirements include:

- Contaminant monitoring in inshore and offshore (e.g. basin sediments) areas
- Benthic monitoring for representative disturbed and undisturbed ecosystem types
- Enhancement of monitoring to meet species at risk needs
- Discard and compliance monitoring
- Small pelagic & juvenile / forage species surveys
- General invertebrate survey
- Calibration surveys for catchability
- Stomach content monitoring
- Cetacean monitoring on 5- 10 year basis

There is a number of funding issues with new monitoring activities that implicate industry involvement. The ESSIM initiative should consider forming a working group with ocean sector involvement to discuss monitoring requirements, funding and data ownership.

Use of Marine Protected Areas

Marine Protected Areas (MPAs) are a valuable tool under the Oceans Act to use in meeting the objectives relating to ecosystem and species diversity. The proposed Gully MPA, for example, will be designed to protect vulnerable species and a range of seabed habitats, but the degree of protection may be limited if it does not include a no-take/ no impacting activity zone. Some ocean activities (*e.g.* those that physically disrupt the seabed and those that degrade the quality of the water column) are less likely than others to be consistent with the ecosystem – based objectives. Thus there is a need to evaluate the activities that would negatively impact ecosystem diversity so that these could be excluded from MPAs. The latter would be no-take/no-activity zones, which would also serve the scientific need for reference or control areas.

There are a number of benthic ecosystem types within the ESSIM area that are not observed in the Gully. It was not possible to evaluate how the Gully MPA fits within the broader protection of ecosystem types within the ESSIM area without knowing the location of these. There are, for instance, basin and shallow marine ecosystem types not included in the area of interest. Thus, additional areas need to be set aside for restricted ocean use activity to maintain benthic ecosystem type diversity. Based on present knowledge, the spatial distribution of benthic ecosystem types needs to be mapped within the ESSIM area. Then, present ocean use activities could be superimposed on this map to determine the proportion of each type that is disturbed. This analysis would lead to the definition of additional areas that require special protection. 10 percent was suggested as a minimum area of each type that needs to be undisturbed, although this percent could vary by ecosystem type (e.g. deep corals may require a higher percent of protection than sand – based communities).

INTRODUCTION

The Canada Oceans Act (1997) extends Canada's jurisdiction over the ocean to the full extent permitted under international law. With this claim of sovereign rights comes responsibilities, including the establishment of a governance structure based on the principles of integrated management, sustainable development, precautionary approach, collaborative approach and an ecosystem approach. In December 1998, the Minister of Fisheries and Oceans announced the ESSIM initiative to pilot this new comprehensive approach to Oceans management. This initiative is intended to test management approaches before broader application.

The Oceans Act gives the government additional powers, to safeguard and protect the ecosystems off Canada's coasts. These new powers cannot effectively be used without considerable thought on the structure and function of the ecosystem-based management system implied by the Act. The intent of this initiative is to consider the objectives, strategies, controls and monitoring necessary to undertake ecosystem-based management along with the governance structures. The proposed science - management approach has many analogs to the single species management but it is fundamentally a new way of doing business.

DFO Regional management requested that a science workshop be held in June 2000 to consider the technical requirements of the ESSIM initiative. The meeting remit (Appendix 1) outlines the six tasks for the workshop, which paraphrased, were to:

1. provide the initiative with a precautionary management framework
2. consider current management measures and where changes are required to meet ecosystem objectives
3. describe the oceanographic, ecosystem and fishery trends of the Eastern Scotian Shelf
4. consider potential indicators to guide management
5. outline the initiative's monitoring requirements, and
6. determine to what degree the Sable/Gully proposed Marine Protected Area (MPA) meets the potential ecosystem-based objectives of ESSIM, what ocean use activities are consistent with meeting these objectives, and what additional MPAs are needed

To achieve these tasks, scientists in DFO and Environment Canada (EC) undertook analysis during the winter – spring of 2000 in preparation for the workshop. The workshop was to consider these analyses, debate and discuss the issues identified, and outline the requirements of further work. Participants (Appendix 2) were invited based on their expertise. Drs. K. Sainsbury and P. Mace were invited from Australia and the USA to both report on ecosystem-based initiatives in their countries as well as provide their insights on the ESSIM initiative.

The workshop was chaired by R. O'Boyle during 19 – 23 July 2000 at the Bedford Institute of Oceanography (BIO). The first day was devoted to presentations and discussion on the precautionary approach framework and management considerations. Trends and indicators for the oceanography, the benthos and biodiversity were covered on day two, while day three was devoted to presentations and discussion on the trends and indicators of the fisheries and the ecosystem. Monitoring requirements were discussed on day four, as was the use of Marine Protected Areas (MPAs). The last day was devoted to a summary discussion of the issues raised and suggestions for further study. Contrary to the initial schedule (Appendix 3), discussion was held after each presentation and not restricted to separate discussion sessions. To facilitate the discussion, presenters were encouraged to distribute copies of their presentations at the workshop. In addition, some presenters provided working papers (Appendix 4).

The chair assigned rapporteurs to summarize the discussions pertaining to each presentation, as well as provide overviews of comments and observations made on their task in the last day's summary discussion session. For the monitoring requirements, a separate presentation was not made, but rather each presenter stated their needs as part of their presentation. Therefore, the rapporteurs compiled these requirements throughout the workshop. The summary session on the last day provided the main observations and conclusions of the workshop to be considered by DFO Science and Ocean management.

PRECAUTIONARY APPROACH FRAMEWORK AND MANAGEMENT CONSIDERATIONS

Rapporteur: P. Mace

Remit: To provide a framework for a Precautionary Approach to the incorporation of ecosystem objectives into integrated oceans management.

To describe conservation objectives and regulatory measures for existing management and the changes needed to incorporate ecosystem objectives.

Maritimes Region Oceans and Coastal Management (OCM) Planning Process

R. Rutherford, Oceans Act Coordination Office, Maritimes Region Oceans Branch, DFO

In December 1998, the Minister of Fisheries and Oceans announced the Eastern Scotian Shelf Integrated Management (ESSIM) initiative in conjunction with the Sable / Gully MPA Area of Interest (AOI). The ESSIM initiative is the implementation of one of the recommendations from the 1998 Sable / Gully Conservation Strategy that integrated management approaches be applied to the larger ocean area surrounding the Gully AOI. The eastern Scotian Shelf is the first defined ocean management area (OMA) with an offshore focus under Canada's 1997 Oceans Act. The ESSIM initiative is being led by the Oceans Act Coordination Office (OACO) in the Oceans Branch, DFO Maritimes Region, concurrently with the development of an Oceans and Coastal Management Framework for the Region.

The purpose of this contribution was to provide the ocean management context for the application of the ecosystem approach under the Oceans Act. An overview of the Act and its implementation through integrated management plans, marine protected areas, and marine environmental quality provisions is provided, with a particular focus on the eastern Scotian Shelf OMA. The governance component of ocean management was described as a backdrop for the operationalization of ecosystem objectives in the eastern Scotian Shelf OMA. A nested approach is advocated, ranging from international visions and requirements for ocean management, through national and regional/zonal management contexts, down to the scale of OMAs and MPAs. A conceptual framework was presented for the identification of ecosystem objectives, indicators, reference points, and pre-defined management actions. The need to monitor trends was emphasized, as a means of employing the precautionary approach to trigger appropriate management actions before more drastic action is needed at limit reference points (i.e., the acceptable/unacceptable line). This framework also illustrates the requirement for more precautionary reference points and management actions in the context of an MPA, while showing that different reference points should be used for larger general use areas and industrial zones (e.g., city harbours).

A number of key questions and considerations were raised in the context of the eastern Scotian Shelf. Should the OMA be divided into sub-areas to enable nested and more ecologically appropriate management actions, and if so, how? Where should the protected areas be, both for the protection of key ecosystems/habitats, and for reference areas to assist in de-aggregating human impacts from natural variability? What new data are needed to assess and monitor ecosystem objectives for the area? These and other questions must be addressed for the operationalization of the ecosystem approach for ocean management.

Discussion

There were only questions of clarification on this presentation.

The Objectives of Ecosystem-Based Management
Mike Sinclair, Science Branch, Bedford Institute of Oceanography

The 1992 Convention for Biological Diversity (CBD) the Straddling Stocks Convention (UNFA), and the Code of Conduct for Responsible Fishing have generated broader conservation objectives for the management of ocean use activities. The 1997 Oceans Act obliges Canada to incorporate ecosystem objectives within an integrated ocean management framework. The pending legislation addressing species at risk of extinction will generate recovery plans for endangered marine species. Thus we are in a transition period with respect to the need for scientific advice on management of ocean uses (oil and gas, aquaculture, marine transportation, eco-tourism, recreational use and fisheries). Management will continue to occur at the sectoral level, yet the aggregate activities need to meet some yet to be defined ecosystem objectives. Fisheries management needs to take into account ecosystem considerations, and other ocean uses have impacts on the ecosystems that need to be evaluated in relation both to the fisheries impacts and the broader conservation objectives inferred under new international conventions and national legislation.

The ICES/SCOR Symposium on the Ecosystem Effects of Fishing, which was held in Montpellier in March 1999, provided some guidance on a framework for the incorporation of ecosystem considerations within fisheries management. The Symposium overview paper (Gislason et. al., 2000) lists six potential ecosystem objectives for ocean management - three addressing biodiversity and three addressing habitat productivity. The traditional conservation objective for the target species of fisheries management is subsumed within the latter three. For each objective, there will be a need to define indicators (time trends of an attribute) of relevance as well as reference points that trigger management action.

Maintenance of Ecosystem Diversity

The benthos is considered separately from the pelagic component of the marine biota. Due to recent advances in multi-beam and side-scan sonar, it is now possible to routinely map the bottom sediment type and define the number and geographic pattern of bottom communities in 'benthic ecosystems' that need to be maintained. The indicators to be monitored are 1) the spatial extent of disturbance (by fish gears, oil/gas operations, aquaculture sites, etc.) for each category of benthic habitat in the classification scheme, and 2) benthic community properties in 'no disturbance' areas (e.g. MPAs) and disturbed areas for each benthic ecosystem type. For this objective, it is assumed for planning purposes that some percentage of each habitat type would need to be undisturbed.

For the pelagic component of the biota, the geographic scale of ecosystems/communities is large (e.g. Longhurst areas for plankton) and the indicators would be measures of geographic patterns in plankton and fish community structure. The present monitoring activities on the Scotian Shelf (CPR line, seasonal zooplankton net hauls on transects, ecosystem trawl survey from Cape Hatteras to Cape Chidley) should be sufficient to generate the necessary data products.

Maintenance of Species Diversity

The minimum required for this objective is to provide indicators for the recovery plans of the species at risk of extinction. For the Scotian Shelf, the species for which recovery plans are already in place, or are expected to be developed, are right whale, harbour porpoise, leatherback turtle, Bay of Fundy Atlantic salmon, and Nova Scotia 'Uplands' Atlantic salmon. Other species of particular concern are sharks and skates (due to their low productivity) and possibly cusk. The indicators need to be considered at the geographic scale of Evolutionary Significant Units (ESU), and are species specific. They include:

- Rate of population decline
- Contraction in distributional area
- Number of spawning components
- Number of individuals and effective population size (Ne)
- 'Integrity' of essential habitat
- By-catch, or mortalities

Maintenance of Genetic Variability within Species

The indicators for this objective have some overlap with that above, but need to be considered for a much wider range of species, in particular for species that are commercially exploited.

There are at least two high profile concerns - the loss of spawning components and the reduction in genetic variability within populations (both due predominantly to fishing practices). The indicators include:

- Number of populations for exploited species
- Sex ratio
- Selection differential for life history parameters such as size-at-age and age-at-maturity
- Nearest neighbor estimates for sessile invertebrates

Maintenance of Directly Impacted Species

This objective subsumes the need to prevent growth and recruitment overfishing of the commercial species targeted by the diverse fisheries on the Scotian Shelf. The indicators are:

- Spawning stock biomass (B)
- Exploitation rate (F)
- Recruitment Trends

Recently there has been a move to broaden the scope of the indicators to include such measures as:

- Size/age composition of landings and of the population
- Weight/length at age
- Condition factor
- Areal distribution of landings and of the population
- Fishing effort
- Compliance of fishers
- Enforcement capability

With the use of a broader range of indicators, a qualitative stop-light approach (green/yellow/red ratings by indicator) is envisioned, which would complement the present use of quantitative assessment models.

Maintenance of Ecologically Dependent Species

This objective addresses the importance of food-chain interactions amongst the target species of commercial fisheries and the key predators and such species. It is of particular interest for fisheries on forage species such as krill and small pelagics. CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) has been a leader on how to deal with this ecosystem consideration. There are two approaches. The first was the traditional indicator for the target species (F and B), but takes into consideration that a larger biomass should be sustained than is the case under traditional fisheries management approaches. In essence, the reference point for biomass of the target species changes, but the indicators stay the same. The second approach includes the monitoring of key predators of the targeted forage species under commercial exploitation. Indicators could include:

- Abundance of key predators of exploited species
- Condition of key predator
- Percentage of prey species in diet of predator

Maintenance of Ecosystem Structure and Function

This class of objectives addresses emergent properties of ecosystems, although the entire concept of emergent properties is somewhat controversial. There is, nevertheless, agreement on the need to monitor properties of marine biological communities that are indicators of their structure and function. However, experts differ greatly in their opinions on the information content and ecological "reality" of many proposed indicators, and on concepts such as optimal balances among trophic level balance. Suggested indicators include:

- Slope of the size spectrum
- k-dominance curves
- Pauly's FIB index
- Aggregate removals by fishing at each trophic level

The data required for the above indicators are already being collected on the Scotian Shelf. The indicators, however, are not being routinely tracked over time.

Discussion

There was debate as to whether what were presented were objectives or a means to classify issues related to ecosystem-based management. The term 'ecosystem objective' can be misleading (Halliday, 2000) as it implies that there is some optimum state of the ecosystem and associated resources that can be attained through the control of human activities. It was suggested that it would be preferable to consider a single objective as 'the prevention of reduction in resource productivity or modification of ecosystem function, in ways that are difficult or impossible to reverse, as a result of human activity'. Under this approach, the attributes mentioned in the Sinclair objectives (diversity, productivity, etc) are associated with indicators and reference points and are thus part of the strategy to attain the single 'ecosystem objective', rather than being objectives themselves. Resolution of this issue was left to the discussion on the last day. This discussion highlighted the issue of terminology, which was a recurring theme during the workshop.

It was asked where introduced species fit into the structure. It was stated that they fit under the species diversity objective.

There was some discussion on the need to define an objective that addresses marine environmental quality.

A Precautionary Framework for the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative

R. O'Boyle, T. Potter and P. Koeller, Bedford Institute of Oceanography, DFO

Internationally, the precautionary approach (PA) is being explored as the preferred framework for management of living marine resources. Canada has yet to articulate a policy on PA, although there have been a number of studies from which is starting to emerge the elements of a Canadian – made PA. To date, fisheries have dominated these discussions, but the principles are applicable to ecosystem-based management. The PA should include the establishment of long-term objectives, strategies to attain these (including the definition of reference points and unacceptable outcomes), means to take uncertainty into account and the implementation of a decision-making process, the latter involving the establishment of pre-agreement on management actions (decision rules).

For ecosystem-based management, the long-term objectives should consider both productivity and diversity aspects, with the former considering directly impacted and ecologically dependent species as well as ecosystem structure and function, while the latter should consider diversity of ecosystems, species, and populations. Strategies to attain these objectives require the definition of indicators – with specific values or reference points (RP) – both limit and target. Given the number of ocean-based industries, it will be necessary to develop a suite of indicators and RPs associated with different ocean industry-based activities. In fisheries, fishing mortality and stock biomass have been two quantifiable attributes of the resources for which one can develop indicators and RPs. Given the complexities of the ecosystem, it will likely be necessary to adopt less quantitative indicators until the state of our knowledge allows establishment of more sophisticated indicators.

It is suggested that the techniques used in Environmental Impact Assessment (EIA) could be employed in ecosystem-based management. These techniques depend on a suite of indicators, which give general indications of the impacts of human activity. In fisheries, the analog to this methodology is the so-called 'Traffic-Light' approach, in which impacts are measured according to degrees of red, yellow or green, based on the stated RPs. An overall score of impacts could be attained by an average (weighted or not) of the individual indicators. It was recognized that a problem, which needs further work, is the unpredictability of impacts although even here, one can often provide a qualitative, short-term trajectory of impacts. It is evident however that the monitoring requirements of an ecosystem-based PA will be considerably in excess of current single species approaches, which has implications for information management. Also, in ecosystem-based management, to avoid institutional uncertainty, it will be essential to develop decision rules that specify what actions are taken when the ecosystem enters a RED or YELLOW zone, for instance. This will ensure that management is pro-active and not reactive, a problem common to many current management systems. In addition, the use of qualitative indicators will likely facilitate stakeholder acceptance of the approach.

Regarding management institutions for the ESSIM initiative, a technical review process exists (RAP) and some sectors (e.g. fisheries) have satisfactory planning vehicles (e.g. IFMPs). However, new decision-making institutions are required. It is important that the sector-based plans, which provide specific management actions, are integrated into an overall Ocean and Coastal Management Plan (OCMP) which meets the ESS and sector ecosystem-based objectives.

Elements of the PA are not new. However, the requirement for integration is, as is consideration of uncertainty and reversal of the burden of proof. Given the high degree of uncertainty in our understanding of ecosystems, the PA is an imperative of ecosystem-based management.

Discussion

The issue of terminology was raised, specifically in regard to indicator and performance measure (PM). In Australia, the PM is a measure of the deviation of the indicator from the reference point (Figure 1).

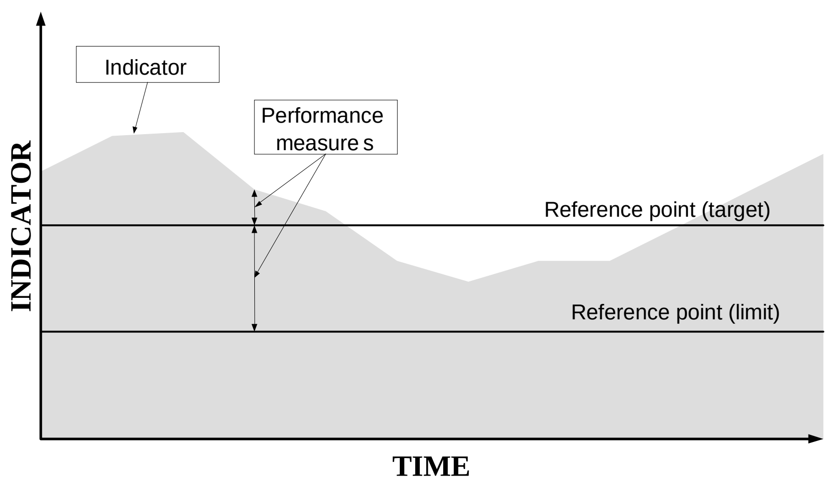

Figure 1. Performance Indicators, Performance Measures and Reference Points as used in Australia (Sainsbury et al., 1998)

In regional discussions about application of the Traffic Light method to fisheries, a distinction has been made also between the terms performance measure and indicator. However, in this case, it has been suggested that there are two categories of indicators, those that directly reflect the effects of managerial actions, e.g. F, and those reflecting attributes that cannot be controlled, e.g. water temperature. Only the former should be referred to as performance measures. The discussion underlined the need for clear descriptions of the definitions used in management.

An important issue raised was how to operationalize the PA for ecosystem-based management. What are the ecosystem features to be conserved, the strategies for conserving these (even if provisional) and how do these relate to specific ocean use activities? This focused discussion on the need for the presented objectives. It was suggested that if we focus too much on these, we will loss sight of the overall performance of management, a problem that has happened in the harvest fisheries. Some felt that it would be difficult to have successful management without objectives. This may be an issue of terminology. It was generally agreed that one needs to carefully consider the indicators and associated reference points in relation to some stated objectives.

It was noted that scientists in the Maritime region are experimenting with the Traffic Light method in stock assessment as a means to address problems encountered in sole reliance on complex model-based methods. Using an approach consisting of many indicators, rather than just a few, is expected to be more precautionary, not only by giving a more accurate indication of current stock status but also in providing faster recognition of changes in stock productivity. Whether an approach based on many indicators, some of which may be poorly measured or understood, is better than one based on a few indicators derived from complex models that often have biases and depend upon simplifying assumptions, remains to be demonstrated. It was noted that the Traffic Light method itself is not model or assumption free, and more parameters could create arguments about weighting schemes, values to assign to indicators, which indicators to use, etc. to replace the present arguments about the best formulation of models. It was mentioned that in Australia, the weighting of indicators to calculate aggregate indicators of system performance is avoided. It was acknowledged that the Traffic Light approach is a good mechanism to facilitate communication and consensus building as it can involve and empower stakeholders in decision-making. It does not preclude the use of model-based indicators / reference points within a Traffic Light framework. The merits of using the Traffic Light method in decision-making need to be evaluated within the context of the problem being addressed. It is a methodology for integration of information. Thinking about ocean issues, in contrast to fisheries, has not yet progressed to the point where the issue of integrating information can be addressed. The immediate issue is the development of appropriate indicators.

The Recent Evolution of U.S. Fisheries Science and Management with emphasis on ecosystem concerns and considerations
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Unlike Canada, the United States does not have a comprehensive Oceans Act, although it does have a National Environmental Policy Act (NEPA) that provides a certain amount of integration by requiring environmental assessments and environmental impact statements for a wide range of activities that impact the environment.

In the last five years, there has been increasing impetus in the United States to develop and implement an ecosystem-based approach to fisheries stock assessments and management. The Sustainable Fisheries Act (SFA) of 1996 amended the Magnuson Fisheries Conservation and Management Act to broaden the scope of fisheries management, so that it now includes more explicit consideration of overfishing effects, non-target species, fish habitat, and fishing communities. From an overfishing perspective, one of the most significant changes wrought by the SFA was a change in the definition of Optimum Yield from “maximum sustainable yield as modified by [relevant factors]” to “maximum sustainable yield as reduced by [relevant factors]”. This and related changes in the Act have been interpreted as being in conformance with key aspects of the Precautionary Approach, even though the Act does not explicitly use the term. Control rules that specify target and limit fishing mortalities as functions of stock biomass are now routinely being developed for managed U.S. fisheries, but these are generally based on single-species approaches.

Two major panels have recently been set up to advise the National Marine Fisheries Service (NMFS) on ecosystem-based management (EBM). In late 1998, the National Research Council released a report entitled "Sustaining Marine Fisheries" which contained many useful conclusions and recommendations, including that "... a significant overall reduction in fishing mortality is the most comprehensive and immediate ecosystem-based approach to rebuilding and sustaining fisheries and marine ecosystems". In early 1999, the Ecosystem Principles Advisory Panel report, mandated by the SFA, was completed. Among other things, this report recommended the development of Fishery Ecosystem Plans, development of indices of ecosystem health as targets for management, determination of the ecosystem effects of fishing, development of a program (ECOWATCH) to monitor trends and dynamics in marine ecosystems, and exploration of ecosystem-based approaches to governance.

The most recent NMFS National Stock Assessment Workshop (March 2000) was devoted to the theme of "Incorporating ecosystem considerations into stock assessments and management advice". It produced recommendations in the theme areas of ecosystem properties, biological and technological interactions, climate and other environmental effects, and secondary effects of fishing (workshop proceedings are still in preparation). Another relevant NMFS initiative is the Stock Assessment Improvement Plan, which is currently under development and includes three tiers of improvement, all leading ultimately to provision of the science and monitoring required for EBM.

The Magnuson Act is once again up for reauthorization, and it is likely that the next version will include even more explicit requirements for ecosystem-based approaches to science and management.

Discussion

The conclusion that precautionary and conservative single-species management would be a good first step towards meeting ecosystem objectives in marine fisheries was debated. It was argued that this is insufficient because it ignores the need for better surveys, enhanced monitoring, expanded observer programs, improved bycatch management, and other relevant factors. The response was that while the U.S. approach has tended to focus on single-species analytical models embedded in an ecosystem context, this has certainly not precluded consideration of the above-mentioned factors. On the contrary, the prerequisites for good ecosystem-based management seem to be similar to those that have been advocated for many years for good single species management (e.g. eliminate overfishing, eliminate overcapacity, and enhance monitoring of biological, physical, and chemical aspects of marine systems).

Management of marine ecosystems: the Australian experience
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There are two different but complimentary approaches being taken in Australia to improve management of the marine ecosystems – 1) development of mechanisms to integrate management of all uses of a regional marine ecosystem - with the aim of achieving ecologically sustainable wealth generation and 2) inclusion of ecosystem related objectives within the separate management arrangements for the various human uses of marine ecosystems.

The first approach is holistic and focuses on integrated 'Multiple Use Management' while the second maintains the 'sector at a time' management structure that is common worldwide while broadening the focus within each sector to include aspects of the surrounding ecosystem. The separate management of the sectors under a broadened range of ecosystem objectives is expected to make it easier to achieve integrated multiple use management for the ecosystems as a whole. Sector management alone cannot be expected to deliver integrated outcomes. The two approaches are required.

Examples of each approach are summarized with an emphasis on new initiatives and present activities toward managing the ecosystem effects of human use of the marine environment.

<u>Integrated regional marine planning and multiple use management</u>

There are three different Australian initiatives aimed at delivering integrated multiple use management of regional marine ecosystems. Each has a quite different level of legislative and formal policy support, and each has a different approach to incorporating scientific input.

1. National Oceans Policy (NOP)

In late 1998, the Australian federal government announced the National Oceans Policy (Anon 1998a). While not backed by legislation, the policy is binding on federal government agencies and can be implemented within the jurisdiction of the State governments by agreement. It is expected that the need for new legislation will be examined in the next few years based on experience with implementing the policy. The NOP provides the goals, principles and planning arrangements for integrated ocean management. The main principles are maintenance of ecosystem integrity, integrated planning and management for multiple ocean use, promotion of ecologically sustainable marine-based industries, and a decision process that is transparent, participatory and precautionary.

Implementation of the NOP is through regional management plans. The regions are based on 'large marine domains' - areas that show affinities in their oceanographic, geological and biological attributes, and reflect Australia's major marine ecological systems. The first regional marine plan will be developed for the SouthEast (SE) Australian domain, roughly the SE corner of Australia, south of about 37^{o}S and including Tasmania and Macquarie Island. It will be completed by 2003. The planning process includes:

- preliminary assessments of regional values, uses, threats and opportunities,
- development of regional and sectoral objectives and performance measures,
- identification of initial options for regional integration,
- negotiation of options, and
- development of the final plan

The needed information and science support will be developed through these steps in the planning process. After approval of the plan, there will be an annual process of implementation and monitoring, with the regional plan formally reviewed after five years.

2. Great Barrier Reef Marine Park Authority (GBRMPA).

This was established under an Act of Parliament in 1975 to manage the Great Barrier Reef Marine Park. The GBRMPA has a very high level of legislative authority, with its Act having priority over all other acts, except those relating to air and sea navigation. The aims of the GBRMPA include protecting the reef while allowing reasonable use. The park is managed through the spatial zoning of uses, including a variety of multiple use zones and some highly protected conservation zones. Significant uses that are managed under this framework include tourism, line fishing and trawl fishing.

The GBRMPA has a long history of management, supported by scientific assessment and community consultation (Kenchington, 1990). GBRMPA has managed a wide variety of wealth generating uses of the coral reef ecosystem, has established a system of highly protected areas, and is widely recognized as having successfully fulfilled its mandate but improvements are possible. Currently, the marine protected area system is being extended to improve its representation of ecological community and habitat types, and management of the effects of inter-reef trawling on both target species and the broader ecosystem is being reviewed.

GBRMPA has established a number of supporting research programs to provide scientific input in areas of need. In the early years, these programs were rather ad hoc and responsive rather than pro-active. But they have now evolved into a formally structured Cooperative Research Centre that includes GBRMPA, other regulating agencies in the region and the main research providers. This Centre provides an effective mechanism for regulators and researchers to identify well targeted and feasible research in support of management.

3. Northwest Shelf Integrated Environmental Management

The state government of Western Australia has initiated a four year program to deliver integrated multiple use management for the Northwest Shelf region of Australia. This is in recognition of the increasing human use of this region, and the increasing interaction of both these uses and their management processes. The goal it to achieve Ecologically Sustainable Development of the region within existing legislative and policy arrangements. No new legislation or policy is planned.

The Northwest Shelf initiative has two components that will operate in parallel, while remaining closely linked:

1) development among the state and federal regulating agencies of an institutional response that delivers effective and efficient integrated regional management; the uses requiring an integrated management response include oil and gas, fisheries (commercial and recreational), tourism, regional development, aquaculture, indigenous use, and conservation
2) establishment of a scientific program to provide the scientific information and methods for multiple use planning; this includes information and methods to assess the consequences of proposed management options in a risk context; an important aim is to demonstrate practical and science-based methods that support integrated regional planning to achieve Ecologically Sustainable Development

The scientific work is structured to use the Management Strategy Evaluation methodology (Sainsbury et al, 2000, and Figure 2). Consequently the modeling project will include development of models that reflect key uncertainties about ecosystem dynamics and the consequences of human use. Management tools will include development and evaluation of adaptive feedback strategies that explicitly link the results of monitoring to subsequent management responses in pursuit of management objectives.

Figure 2. Framework for Management Strategy Evaluation.

Ecosystem objectives in sectoral management

There has been a recent trend to broaden the objectives of management for all industry sectors to include ecosystem considerations. A major driver has been the National Strategy for Ecologically Sustainable Development, agreed in 1992, and the associated Inter-Governmental Agreement on the Environment that provides a formal commitment by all governments in Australia to implement the principles of Ecologically Sustainable Development. These principles stipulate that development should be maintained and enhanced in an environmentally sound manner, that environmental considerations be integrated into all decision making, that conservation of biological diversity and ecosystem integrity are fundamental considerations, and that a precautionary approach be used in decision making. There was specific agreement to establish a representative system of Marine Protected Areas as an element of maintaining ecosystem integrity. While all sectoral management has increasingly included ecosystem considerations, here just two examples are described.

1. Marine Protected Areas

The Inter-Governmental Agreement on the Environment specifically called for establishment of a representative system of Marine Protected Areas as a means of maintaining ecosystem integrity (i.e. ecological processes and systems) and to protect biodiversity at all levels. It is also recognized that Marine Protected Areas are both a conservation tool and a use of the marine environment that competes with other uses in the context of regional multiple use management.

Guidelines and criteria for the National Representative System of Marine Protected areas have been developed (Anon., 1998b). Three of the criteria relate to the comprehensiveness, adequacy and representativeness of the system. Interpretations of these terms, and performance indicators based on them, have been developed (Anon., 1999). There are ongoing efforts to improve the operational interpretation of the criteria, the practical measurement of outcomes and performance, and integration of the role and management of Marine Protected Areas within a Regional Marine Planning context.

All Governments in Australia are identifying and, as appropriate declaring, Marine Protected Areas in the waters under their jurisdiction. Marine Protected Areas recently declared by the federal government include a 25 mile wide and about 200 mile long strip to the edge of the EEZ in the Great Australian Bight, 15 of 70 seamounts off southern Tasmania, and about 25 percent of the area around Macquarie Island and within the Australian EEZ.

2. Fisheries management

There are two major activities under-way in response to the recently increased focus on ecosystem issues within fishery management and assessment.

1) The development of nationally consistent reporting against Ecologically Sustainable Development (ESD) objectives for all Australian fisheries. The aim of this is to produce a 'first approximation' report covering all fisheries in about 18 months. It is a first

approximation because it will be based mainly on what can be done with existing information and analyses. Gaps and future needs will be identified in the process for later improvement. The ESD objectives span ecological, economic and social issues, and a major focus is development of practical operational interpretations of the objectives. The process, which has just recently began, is:

- developing draft criteria, performance indicators and guidelines through a high level committee comprising stakeholders and the fishery regulators from all Australian governments (e.g. Figure 3);
- consolidating the extensive and diverse range of performance indicators already in use (e.g. Sainsbury et al, 1998) through a series of case studies on selected fisheries that have contrasting economic value, by-catch levels, information availability and level of multi-species targeting;
- refining the sustainability indicators and guidelines; and
- applying the refined indicators and guidelines across all fisheries to give a 'first approximation' report for Australia.

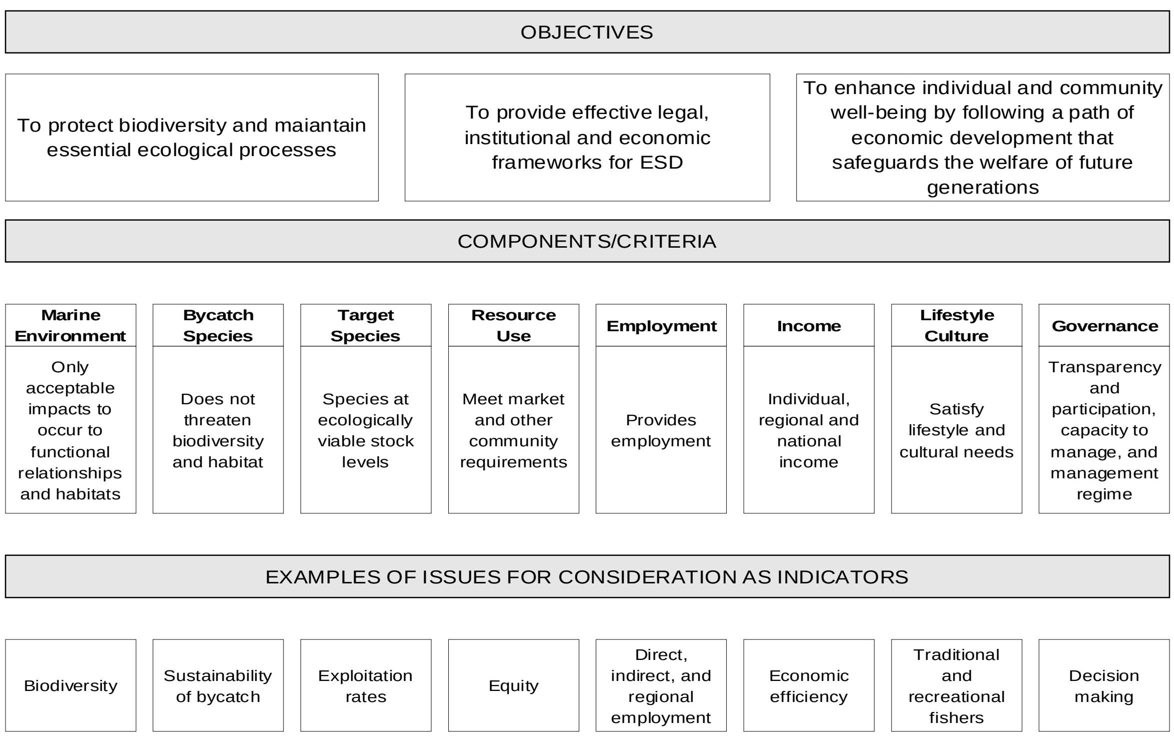

Figure 3. Examples of draft interpretations of the objectives of Ecologically Sustainable Development as applied to fisheries.

2) Development of robust indicators and performance measures for the ecosystem effects of fishing.

It is recognized that existing experience and methods for assessing the ecosystem effects of fishing are limited (e.g. Sainsbury et al 1998), and that the national 'first approximation' described above is likely to be weak in that regard. Consequently, a parallel initiative has been established to develop and test indicators and performance measures for sustainability of non-target species, habitats and food-chain dependencies. This development and testing will make use of Management Strategy Evaluation methods and techniques.

Summary

Developing methods to support integrated marine ecosystem management is a very challenging task. The methods must be scientifically transparent and reviewable, and they must be understandable and defendable to the public, stakeholders and regulators. And they must be able to do this despite very high levels of uncertainty about the way ecosystems operate and with very sparse observations on the present state of the ecosystem. To achieve stated objectives, it is clear that management will need to be precautionary in the face of lack of complete knowledge, and the scientific input will need to help identify the level of precaution that is appropriate.

Although the challenges are great, many activities are now underway to begin to address them – both for integrated multiple use management of ecosystems and for better inclusion of ecosystem issues within sectoral management. These include policy, planing and scientific activities. Most of the present activities in Australia have one – four year time horizons, and it is clear that these activities are part of a longer journey of incremental improvement toward integrated and sustainable use of marine ecosystems.

Many nations, including Canada, Australia and the US, are addressing similar issues to incorporate ecosystem considerations into management of human uses of the marine environment. There would be value in establishing mechanisms to ensure that the scientific effort is coordinated and collaborative. These mechanisms would avoid duplication, provide ongoing peer input and review, and help ensure consistent (but not necessarily identical) outcomes. Consistent outcomes among the three countries would go a long way toward developing international standards and practice.

Discussion

It was evident that Australia has a well-developed National Oceans Policy to promote ecologically sustainable development (ESD), including supporting institutions and pilot programs. It appears ahead of Canada in this regard and consequently, we can learn much from Australia's experience. It was mentioned that the ESD plans are overseen by a board made up of Ministers from five portfolios and that Australia is rapidly moving from a proscriptive to risk-based approach that accommodates both the PA and adaptive management. Also, plans include robust indicators as well as operational objectives and targets, consistent with the PA.

Interestingly, the robustness of the plans is specifically tested by a Management Strategy Evaluation (MSE), which involves simulation-testing methods. It was noted that while there is a preference for the use of quantitative PIs, qualitative ones are used as well.

Australia is trying to 'keep it simple' by continuing to use current sector plans to the extent possible and only to modify these to the extent that these are incompatible with ESD. It was emphasized that in most countries, there is a mismatch between the current resource management institutions and the needs of ecosystem-based management and that the latter will not only require, but also force, different agencies to cooperate.

Ocean Activities and Ecosystem Objectives on the Eastern Scotian Shelf: Are Changes in Governance Required?

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The existing conservation and environmental protection objectives and regulatory measures for key ocean use sectors in the eastern Scotian Shelf area were examined for fisheries, oil and gas, marine transportation, maritime defence operations, and potential ocean mining. These ocean sectors were analysed to determine the extent to which ecosystem objectives are considered and incorporated both in current sector management planning as well as that set by regulatory authorities and legislation. The capabilities and effectiveness of current governance/institutional structures were assessed, and changes required for addressing defined ecosystem objectives identified and proposed for each ocean use sector. In addition to sector-specific considerations, the paper (Herbert et al, 2000) addresses the issues of aggregate and cumulative ecosystem effects and makes recommendations for meeting ecosystem objectives in the Eastern Scotian Shelf area.

Discussion

The presentation and subsequent discussion focused attention on the following ocean sectors and their needs:

- *Commercial Fishing*: The need for an overview mechanism for science advice and fisheries management planning to ensure achievement of ecosystem conservation objectives above the level of individual fisheries.

- *Oil & Gas*: The need to review oil and gas leasing processes for fisheries and ecological sensitivity. Currently, there is no independent monitoring of offshore petroleum industry; lack of enforcement, and penalties/sanctions are at the discretion of the Canada – Nova Scotia Offshore Petroleum Board. As well, there is a need for systematic mapping and identification of sensitive areas.

- *Marine Transportation*: The need to consider effluents from all vessels, not just oil tankers. As well, interdepartmental coordination needs to be enhanced

- *Maritime Defense*: The need to investigate the potential impacts of explosives and sonar on marine life.

- *Potential Ocean Mining*: Strong opposition is expected from the fisheries sector and environmental NGOs and thus there is a need to identify ecologically sensitive areas and assess potential impacts.

The workshop considered the recommendations presented in Herbert et al (2000), as a useful start for further development. However, it was emphasized that, currently, interdepartmental coordination is mostly done by MOUs and similar mechanisms. Therefore, participants identified the need for new institutions (e.g. management boards) to coordinate activities of all existing agencies. The approach would be to initially develop a forum, anticipating that this may lead to the formation of a management board.

When asked if the list of sectors was complete, the response was that recreational uses, aquaculture and eco-tourism are primarily inshore activities that were not considered in detail. As well, the presentation focused on what was considered as impacting sectors. For instance, the laying of marine cables was considered to have minimal environmental impact and thus was not included. In the ocean management context, cables have greater socio-economic impacts than environmental impacts.

It was noted that while DFO is currently using the Fisheries Act to facilitate ecosystem-based management, specific accords are being developed with the management bodies of some sectors to ensure the broader application of ecosystem considerations. Marine environmental quality guidelines, standards, and regulations under the Oceans Act would help define the indicators that we would like to see used in an ecosystem approach.

There appear to be different standards for different ocean uses. (e.g. allowable amounts or dilution of wastes dumped). The government has a very important role in ensuring both conservation and a level playing field for ocean users. This relates to the need for greater co-ordination as stated above.

The lack of independent monitoring of activities and impacts within most sectors was apparent. While many sectors have undertaken monitoring requirements, as required by Environmental Impact Statements (EIAs), there has been little external auditing of this.

There was debate on the importance of land-based sources of pollution. There are estimates that about 70 percent of offshore contaminants originate from land-based activities. This highlighted the issue of the area covered by ESSIM. Currently, the initiative is focused on offshore activities and issues seaward of 12 nautical miles. The ESSIM nearshore boundary is issue-driven and currently the initiative does not include land-based issues. It is intended that the inshore will eventually be included in the initiative, but given the number of jurisdictions involved, governance of the inshore will have to occur over the next one to two years. For the moment then, land-based activities would not be currently included in the initiative. It was agreed, however, that the science involved in ESSIM should consider all the relevant geographic areas influencing the ESS.

TRENDS AND INDICATORS – OCEANOGRAPHY, BENTHOS AND BIODIVERSITY

Rapporteur: K. Frank

Remit: To describe trends in the ecosystem (physical and biological oceanography, benthos and biodiversity).

To define indicators for the potential ecosystem objectives of ocean management.

Seasonal and Interannual Variability in the Hydrographic Properties on the Eastern Scotian Shelf

K. Drinkwater, Ocean Sciences Division, Bedford Institute of Oceanography

The proposed ESSIM area includes two main hydrographic regions. The first, on the northeastern Scotian Shelf, is bounded by the Laurentian Channel, the shelf break off Banquereau and eastern Sable Island Bank, and the submerged ridge that extends from Sable Island inshore to the coast, including Middle Bank. The other hydrographic region is the central Shelf, extending from Middle Bank to the western edge of the NAFO Division 4W line (63º20'W) and includes deep troughs such as Emerald Basin. The surface layer (0-30 m) waters in both regions undergo large seasonal variability (16º C), indeed the largest anywhere in the North Atlantic. On the northeastern Shelf, surface salinities have a larger range and a much lower minimum than on the central shelf, due to the more direct influence of the outflow from the Gulf of St. Lawrence. Also, the northeastern region is covered by ice in winter whereas little to no ice is present in the central region. The subsurface (including near bottom) waters on the northeastern Scotian Shelf are typically 2º-4º C and derive primarily from the subsurface outflow from the Gulf of St. Lawrence. In contrast to the principally two-layer system in the northeast Shelf, in the central region, there is a two-layer system in winter but three layers in summer. In the central region, subsurface (>100 m) waters are relatively warm (usually 6º-10º C) originating from the offshore slope waters that penetrate through the Scotian Gulf between Emerald and LaHave Banks into the basins. There is little to no seasonal cycle in the waters much deeper than approximately 100 m in either region. In winter, a single layer of cooler water overlies the deep layer in the central region. As the very near surface waters warm in the spring and through into summer, the remnants of the cold winter waters are trapped between the warm surface and warm deep waters, hence is called the cold intermediate layer.

As the mean hydrographic properties differ between the two regions, so too do the interannual temperature and salinity trends. In the northeast, subsurface temperatures during the past 15 years have been the coldest observed in the over 50-year record. From relatively warm conditions during the late 1970s and early 1980s, temperatures dropped dramatically in the mid-1980s and remained below the long-term mean (defined as the years 1961-90) until 1999-2000. The minimum temperatures were recorded in the early 1990s. The temporal trend in the subsurface waters on the northeast Scotian Shelf parallel those in the Gulf of St. Lawrence and off southern Newfoundland. In the deep waters of Emerald Basin, the 1980s and 1990s were generally warmer-than-normal and indeed the early 1990s were the longest extended period of warm temperatures in the past 50 years. However, in the fall of 1997 cold Labrador Slope Water (temperatures 4º-8º C) replaced the Warm Slope Water (8º-12º C) of southern origin along the shelf break on the Scotian Shelf. By December, this colder slope water was penetrating through the Scotian Gulf and by February 1998 had flushed Emerald Basin. Temperatures declined from almost 10º C to approximately 6º C and salinities dropped by almost 1 ppt within the Basin in a span of tow to four months. The cold, less saline conditions remained throughout 1998 but by early 1999, the hydrographic properties in the Basin and along the shelf edge had returned to conditions more akin to the Warm Slope Water. The penetration of the Labrador Slope Water onto the central shelf was also observed during the 1960s when cold conditions persisted for approximately a decade. The cause of the southward extension of the Labrador Slope Water along the shelf break is thought to be related to an increase in the density-driven (baroclinic) transport of the deep Labrador Current around the Tail of Grand Bank. This, in turn, is forced by changes in the large-scale atmospheric circulation. The variability in the surface temperatures in the ESSIM area is largely due to atmospheric forcing and as such is highly variable in time. Of particular note are the warm ocean temperatures during the past two years, which are attributed to the warm atmospheric conditions. During the 1990s, low salinities in the upper layers led to the strongest vertical stratification of the water column in the past 50 years. The low salinities are due transport from off the Newfoundland shelves and the Gulf of St. Lawrence.

It should be kept in mind that hydrographic changes at the shelf break and over the slope, e.g. in the Gully, may not necessarily be reflected in either the properties observed over the shelf in the northeast or the central region. This is because of topographic barriers in the northeast and time delays required for cross-shelf exchange of water properties in the central region.

Discussion

The question was asked as to how oceanographic information might be used to assist the ESSIM project. Descriptors of ocean climate are relatively easy to develop but are ocean climate RPs useful? It was felt that knowledge of the oceanographic characteristics does assist in understanding both the causes of changes in the ecosystem and the reasons for regional differences in biological productivity. For instance, the presentation highlighted the differences in oceanographic characteristics between the northeast and central parts of the Eastern Scotian Shelf (ESS). The northeast is influenced by water flowing out of the Gulf of St. Lawrence while the central part is influenced more by off shelf and Labrador water. This is believed to contribute to differences in the underlying productivity in the two areas.

Monitoring Needs

It was generally felt that hydrographic monitoring through the Atlantic Zonal Monitoring Program (AZMP) and fisheries surveys is reasonably adequate to describe the interannual and longer-term variability on the Scotian Shelf, except for the upper slope and deep areas such as the Gully. There, generally a reduced number of stations coupled with strong advection, large Slope Water gradients, and short term variability due to Gulf Stream eddies contribute to more poorly defined hydrographic trends than on the shelf. For the deep waters on the shelf, such as in the basins, hydrographic properties change relatively slowly and the present coverage is considered adequate. On the banks, higher temporal resolution would better define “true” monthly and annual mean conditions and reduce the uncertainties but the presently available sources still appear to be reasonably adequate. Throughout the area, the present sampling is not adequate to resolve short-period changes or events (days to a month). The surface layer in particular experiences large short-period temperature changes but these can be monitored via satellite. However, more surface salinity measurements are required.

In addition, the monitoring identified below would fill some of the identified gaps and help to resolve trends in the hydrographic properties in the ESSIM area:

- Additional (2-3) CTD stations at shelf edge (200-1000 m) on Halifax and Louisbourg AZMP sections (to help resolve the major shelf/slope frontal system and shelf break circulation)
- Additional deep-water (300-1000 m) CTD stations (5-10) on March and July groundfish surveys, both in Laurentian Channel and at shelf edge (also to resolve the major shelf/slope frontal system and circulation)
- Additional west-east CTD sections across the Gully, east of Sable Island (major cross-shelf exchange conduit)
- Extension of the St. Pierre Bank AZMP CTD section to Banquereau Bank (major pathway for GSL outflow)

Seasonal-mean circulation on the Eastern Scotian

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A three-dimensional, prognostic, fully nonlinear, finite-element model with an advanced turbulence scheme is being used to provide a quantitative description of climatological seasonal-mean circulation and tidal currents on the eastern Scotian Shelf. The model solutions consist of density-, wind- and boundary-driven currents. The M2 and K1 tides are simultaneously computed to represent tidally induced turbulent mixing and bottom friction and tidal rectification. Note that in a prognostic model, temperature, salinity, and thus density are modified from initial conditions to be dynamically consistent with the flow and hence are output variables of the model, while in a diagnostic model they are input variables and do not change over time.

The seasonal-mean circulation fields over the eastern Scotian Shelf from the present prognostic model have indicated a strong and persistent shelf break current and a more variable surface–intensified nearshore Nova Scotian Current (NSC) south-westward. The model solutions reveal pronounced topographic-scale features over banks and basins, and substantial cross-shelf exchange. The model solutions are in approximate agreement with observed transports and currents for the primary flow features, but there are notable discrepancies in seasons/areas.

The prognostic model flow fields provide a dynamically consistent representation of the seasonal circulation implied by various observational datasets. The circulation consists of flows from the Gulf of St. Lawrence (imposed at the Cabot Strait boundary) and from the Newfoundland Shelf (imposed at the southern Newfoundland Shelf boundary) with an overall south-westward flow tendency over the Scotian Shelf. The Cabot Strait outflow onto the eastern Scotian Shelf occurs year-round as a seasonally varying bifurcation or trifurcation with branches onto the inner, outer and mid-shelf.

The NSC in the model solutions is mainly density-driven and its magnitude and direction are in good agreement with available moored measurements. The NSC has strong seasonal and alongshore variations in its transport and horizontal and vertical extents. The seasonal cycle of the volume transport of the model shelf break current is qualitatively consistent with satellite altimeter observations (Han et al, 1993) and earlier diagnostic model solutions (Han et al; 1997). However, the prognostic solutions produce stronger currents (associated with an enhanced shelf/slope front at depth) than the diagnostic solutions, comparable to those in Han et al.'s (1999) solutions that are forced with additional barotropic boundary flows required to make good comparisons with observations at Cabot Strait. The southwestward shelf-edge (from the centre of Emerald Basin to the 1000-m isobath) transport across the Halifax section varies from 0.2 Sv in summer to 1.8 Sv in winter and spring. The shelf break flow has alongshore variation and includes baroclinic and barotropic components.

The anti-cyclonic gyres and/or partial gyres over the banks and the partial cyclonic gyres in the Gully and Emerald Basin are persistent features of the prognostic model flow fields and have significant seasonal variations. The cross-shelf currents are also vigorous and seasonally varying, contributing to the along-shelf changes of both the NSC and the shelf break current.

The inclusion of major tidal currents in the prognostic models provides representations of three-dimensional M2 and K1 tidal currents, and of the frictional and mixing effects of tides. Model tidal currents show approximate agreement with observational estimates and reveal the uniqueness of the mixed semidiurnal/diurnal tidal system over the eastern Scotian Shelf. However, higher model resolution including bottom topography is needed to better simulate the system.

The study results have demonstrated improved dynamical consistency of the prognostic model over the diagnostic model. The prognostic adjustment allows the model dynamics to filter out unphysical features in initial temperature, salinity, density and therefore circulation fields and to restore robust features that may have been over-smoothed in the diagnostic solutions. In particular, the regional prognostic model does demonstrate the ability of mitigating the sensitivity of the solution to the open boundary conditions, something that a diagnostic mode does not have. Nevertheless, moored measurements in key locations at the open boundary and on the inner shelf and shelf/slope front, nested modeling and/or data assimilation are needed for improving the model solutions further.

Discussion

It was asked if circulation modeling was at the point where it can make accurate predictions on the trajectory of oil spills or other events. These are short-term events that tend to be driven by highly variable wind forcing. The BIO finite-element models and other models (e.g. Dalhousie, IML and BIO sea-ice models) have some predictive capabilities for short-term (hourly to daily) events, but this predictability is limited the reliability of wind predictions and other factors.

It was asked what impact did the historical cooling have on the seasonal retentive properties of the offshore banks such as Banquereau. This hasn't been evaluated but could be examined in a similar manner to which circulation changes associated with the 1960s cooling on the shelf west of the Halifax line has been examined (Loder et al. 2000). It is expected that the changes in density (T&S) were not as great as implied by the temperature changes, since temperature and salinity changes tend to have offsetting influences on density. It was requested that an analysis of the circulation pattern in the ESSIM area during the 1980-90s be undertaken. A proposal for this was submitted to the Ocean Climate Program this past year, but was not funded. Re-submission will be considered in the next funding cycle.

It was asked if modeling of individual years could be conducted. The BIO models have been used to predict interannual variability in circulation driven by winds and upstream inflows (e.g. Hannah et al. 2000), and exploratory studies for density-driven circulation on the western Scotian Shelf are underway. Individual year modeling of the density-driven circulation on the ESS requires a quasi-synoptic shelf-scale temperature/salinity survey, including full-depth sampling to the 1000-m isobath, as well as information on the upstream inflow. Exploratory model studies involving altimetry and *in situ* data, and model enhancements in areas such as data assimilation are underway or being discussed in the Ocean Sciences Division and elsewhere (e.g. Dalhousie).

Monitoring Needs

The lack of year-round current meter observations at key sites is seen as a major limitation to description and prediction of circulation and hydrographic variability in the ESSIM area. There is a need for more current meter observations at key locations to calibrate and validate the circulation and hydrodynamics models. The priorities would need to be determined through consideration of the circulation dynamics, and the focal areas of ESSIM. The following, limited duration, current and hydrographic measurements would be of immense value to present circulation modeling initiatives in the area:

- 2-3 current meter moorings for 2-3 years on each of inner (coast to Misaine Bank) and shelf-edge (200-1000 m) portions of Banquereau section (major frontal systems and circulation arteries)
- 1 current meter mooring for 2-3 years at 300 m on outer edge of Halifax section to complement PERD/industry mooring at 1000 m (major frontal system and circulation artery)
- 3 current meter moorings for 1 year in Gully: at 200-300 m on E and W sides, and in deep channel (800-1000 m)
- Seasonal subsurface drifter releases on line across western side of Cabot Strait (east of Scatarie)

Contaminant Trends on the Eastern Scotian Shelf

P. Yeats, Marine Environmental Sciences Division, Bedford Institute of Oceanography

Information sources include four different reviews between 1984 and 1998. The most comprehensive of these was prepared as part of the Green Plan Toxic Chemicals Program (GPTCP), but was never finalized or published. It would be worthwhile to update and publish this review. Other information sources are regulatory data, published reports and papers including those documenting surveys conducted during the GPTCP, chemical databases in DFO, Environment Canada (EC) and National Research Council (NRCan), and three current projects in the Marine Environmental Sciences Division (MESD).

Contaminant sources include (in approximate order of importance) (1) Gulf of St. Lawrence outflow, (2) offshore exchange, (3) precipitation, (4) N.S. rivers, (5) leakage from industrialized areas including industrialized harbours and the Sable Offshore Energy Project (SOEP), and (6) shipping. Relative importance of sources will vary from one contaminant to another, but the Gulf will be most important for most contaminants. Importance of industrial activities on the open shelf is poorly quantified but could be significant. Much of the contaminant discharge will be deposited near the source (i.e. within the harbour for discharges from land, within a few kilometres of the rig for SOEP), but some will escape to the open shelf. Minor sources could be most important for specific segments of the ecology (e.g. oil from shipping effect on birds).

Reviews agree that data coverage for the open shelf is rather sparse, but that the available data indicates generally low (often near background) levels of contaminants. Inshore areas are a different story, with extensive contamination of industrialized harbours and some indication of contamination problems in other harbours and/or estuaries.

There are documented declines in levels of some important contaminants whose sources have been controlled (e.g. DDTs and PCBs in seals, dissolved oil in surface waters). Sediment core records for Emerald Basin show that deposition of many contaminants over the most recent 25 or so years have significantly exceeded deposition over the preceding century.

Discussion

The workshop considered that the update and publishing of the Green Plan Toxic Chemicals Program review would be worthwhile.

A number of questions were asked about indicators and reference points for marine contaminants. Regarding the former, while the list of contaminants is relatively complete, there are a number of details that require addressing, such as normalization of contaminant levels by sediment texture and organic content, etc. Regarding reference points, guidelines exist when dealing with water for human consumption and both marine water and sediment quality standards exist. However, the guidelines for the biota (i.e. what is the limit for copper in a mussel) are contentious.

There was discussion on the location and timing of monitoring of dissolved hydrocarbons. The percentage of oiled birds has increased 3.2 percent annually since early 1970s (mainly associated with floating oil south of Newfoundland). This prompted comment on the bird impacts, which were also discussed on the third day.

It was pointed out that potential contamination from aquaculture development on eastern Scotian Shelf is not being monitored, although far-field impacts of aquaculture are being studied. In contrast, eutrophication surveys exist in Bay of Fundy/Gulf of Maine, where the industry is required to monitor their own effluents.

Monitoring Needs

Contaminant concentrations in water, sediment and shellfish can all be used to assess environmental quality. Measured levels can be compared to quality guidelines or known background concentrations. Present marine quality guidelines are not ideal for offshore areas. All relate to estuaries/harbours, so relevance to offshore is questionable. There is a need for more appropriate guidelines for areas like the eastern Scotian Shelf. Required monitoring activities are:

Inshore:

- Contaminant levels in shellfish (mussels, lobsters, etc.) – need to consider biological changes/cycles and effect these have on the contaminants
- Monitoring of shellfish closure changes – this is already being done by EC (no action by DFO needed); it was acknowledged that the amount of area under shellfish closures was increasing, but that there was no data on trends
- Changes in extent of, and potential for, eutrophication (nutrient overload) in harbours and relationships to anthropogenic activity; again, no data on trends

Offshore:

- Contaminant discharges through Cabot Strait in inflowing water; no data on discharge from the Gulf since 1975
- Spatial survey (not trend monitoring but on decadel basis) of contaminants in sediments in depositional areas of ESS
- Dissolved/dispersed oil in shelf waters. Possibly use contamination in selected biota (indicator species) recovered from groundfish surveys, etc. for monitoring, something similar to “Mussel-Watch”

Trends in Nutrients and Phytoplankton on the Eastern Scotian Shelf
G. Harrison and B. Petrie, Ocean Sciences Division, Bedford Institute of Oceanography

Data used in the evaluation of trends in nutrients and phytoplankton on the Eastern Scotian Shelf (ESS) were derived from a variety of sources and include results of surveys spanning the past 30 plus years. The MESD-maintained nutrient database is comprised of some 30,000 nitrate, phosphate and silicate observations on the Scotian Shelf/Gulf of Maine system; 6,000 of these are from the ESS (4VW NAFO regions). Approximately 20,000 phytoplankton (chlorophyll a concentrations) observations are maintained in the Ocean Sciences Division (OSD) database of which approximately 4,000 are from the ESS. More recent collections of nutrient and chlorophyll data in the ESS region (1998-present) have been made as part of the Atlantic Zonal Monitoring Program (AZMP). Synoptic surface chlorophyll maps (about 1.5 km resolution) of the ESS have also been routinely collected on a by-weekly basis (since fall 1997) from the satellite-based ocean colour sensor, SeaWiFS. From these archived data, seasonal climatology of nutrients and chlorophyll (and primary production) has been generated for the ESS. For this analysis, the ESS was further subdivided into a northeastern sector (Sable Is., east) and central sector (Sable Is. to Halifax).

Generally speaking, seasonal trends in nutrient concentrations are “typical” for north temperate waters, i.e. near-surface concentrations are maximum in winter, decrease rapidly in spring due to biological (phytoplankton) consumption, remain low in summer and increase again in fall as biological activity wanes and vertical mixing processes increase. Differences are observed between the northeastern and central sectors of the ESS region, however, with regard to the timing and extent of summer depletion of nutrients. Low-frequency variations (decadal variability) in nutrients appears to follow hydrographic variations, i.e. during the “cold” 60s (and 1998), nitrate concentrations were lower than average and oxygen concentrations were higher, associated with the incursion of Labrador Slope Water (LSW).

Seasonal chlorophyll variations on the ESS are also similar to what is observed on other north temperate continental shelves; a pronounced spring (and less obvious fall) peak in abundance are observed. The timing and magnitude of these abundance peaks are different between the northeastern and central sectors of the ESS. Satellite ocean colour data give an unprecedented spatial and temporal view of phytoplankton variability. Data collected over the past two plus years, for example, show that the timing, magnitude and areal extent of the spring bloom on the ESS differed dramatically between 1998 and 1999. Data are insufficient at present to assess low-frequency (decadal) variations in phytoplankton abundance from these data, however, evidence from the Continuous Plankton Recorder (CPR) suggest that phytoplankton concentrations increased significantly between the mid-1970s when the CPR data collection stopped and the early 1990s when the surveys were resumed.

The spatial and seasonal patterns in nutrient concentrations and phytoplankton abundance are sufficiently different in the northeastern and central sectors of the ESS that consideration should be given to sub-dividing the region for the purposes of ESSIM.

Discussion

It was reiterated that the ESSIM area should be considered as composed of northeast and central sectors. One can link the nutrient trends to Labrador Current influences, which are different in the two areas. As well, the phytoplankton dynamics in the two sectors are different, with the northeast having a larger spring bloom than the central sector, which exhibits no fall bloom.

It was asked how the productivity of the ESSIM area compares to that elsewhere in the world. It is a highly variable system to which comparisons are difficult.

Regarding potential indicators and reference points (e.g. timing of blooms, magnitude of blooms, locations of blooms, overall system productivity), it was queried as to whether or not these were needed. It was felt that we need to increase our understanding of the links between the phytoplankton and the other biota before establishing reference points, which are far in the future.

The relationship between spawning events and the spring bloom was suggested as an area for further study.

The discussion then focused on biodiversity, for which the information available from the CPR could be investigated. As well, it was debated whether or not it is possible to define good and bad phytoplankton species. With the exception of the obviously bad or harmful (to humans) species such as toxic dinoflagellates, it is unclear what might constitute a good or bad situation with respect to phytoplankton. The same comment would apply to indicator species (rare or vulnerable). Overall, it was felt that it would be premature to develop indicators and associated RPs for management purposes for this component of the ecosystem. In contrast, monitoring and research efforts should continue to increase our understanding of the ecosystem's dynamics.

Monitoring Needs

Our current archive of historical data and recent implementation of the AZMP suggest that monitoring of nutrients and phytoplankton on the ESS is reasonably adequate. Deficiencies do exist, however, in data on wintertime nutrient concentrations and on community structure and species diversity of phytoplankton populations and their changes over time.

Changes in abundance of mesozooplankton and krill on the Scotian shelf and western Atlantic, years 1961 –1999

D. Sameoto, Ocean Science Division, Bedford Institute of Oceanography

Scotian shelf zooplankton data from a variety of sources were analyzed for abundance trends during 1961-1999. These data suggested multi-year cyclic abundance changes in phytoplankton, *C. finmarchicus* and euphausiids. During the 1990s, the Eastern Scotian Shelf (east of longitude 62° W) had lower levels of *C. finmarchicus* and euphausiids than were found on the Western Scotian Shelf (west of longitude 62° W). This contrasted with the Scotian Shelf Ichthyoplankton Program (SSIP) years (1979-82), when there were no significant differences in the zooplankton abundance and biomass between the eastern and western shelf. Since 1991, the phytoplankton and *C. finmarchicus* indices on the eastern shelf and in the western Atlantic, as indicated by the CPR data, showed similar changes, suggesting that they may be influenced by similar biological and/or physical processes. Changes in abundance of these indices were compared to changes in the yearly North Atlantic Oscillation (NAO) index. No significant relationship was found with the NAO index during 1959-98. However, there was a step increase in the biological and NAO indices starting in 1991 that continued to 1998.

Discussion

It was asked how the zooplankton community in the ESSIM area compares to that in other areas in the world. Comparisons are difficult but it may be similar to communities in the Norwegian fjords.

It was asked if the patterns of krill abundance observed in Emerald Basin could be extrapolated to other geographic areas. Yes, similarities in abundance trends exist over wide geographic areas in the 1990s. However, it is not yet possible to explain the trends in krill abundance by changes in abundance of predators or prey.

Regarding potential indicators and associated reference points for management purposes, as with the phytoplankton, the level of understanding is such that these cannot be developed at this time.

Monitoring Needs

Current sampling for zooplankton greater than 5-mm length (i.e. macrozooplankton) is felt to be inadequate, but that for animals less than 5 mm is felt to be adequate. The timing of the AZMP surveys (April and October) are poor months for sampling zooplankton. The only stated need was for more frequent net sampling throughout the year, as abundance estimates are based on acoustic measurement.

Mesozooplankton Community Structure and Diversity on the Eastern Scotian Shelf
D. Sameoto and E. Head, Ocean Sciences Division, Bedford Institute of Oceanography

The Eastern Scotian Shelf contains areas that are hydrographically distinct. The northeast (e.g. Louisbourg Line) is influenced primarily by the outflow from the Gulf of St. Lawrence (GSL). Farther west (e.g. Halifax Line) inshore areas are influenced by the GSL outflow, via the Nova Scotia Current, but central and offshore areas (including Emerald Basin, Emerald and Western Banks) are subject to intrusions of water from beyond the shelf-break. In spring and fall, small species (e.g. *Oithona* sp., *Pseudocalanus* spp.) are dominant numerically in all areas and slope-water species are occasionally found on the Halifax Line. Small and rare species contribute little to the mesozooplankton biomass in spring, which during the 1990s was dominated by the copepod *Calanus finmarchicus* in the west and its congener *Calanus hyperboreus* in the northeast. This regional difference may have been exaggerated by cold conditions in the GSL in the 1990s, since there is evidence that *C. finmarchicus* was more important in the GSL outflow in the 1980s. The difference is ecologically significant, because *C. finmarchicus* eggs and nauplii are important food for larval fish, whereas *C.hyperboreus* offspring are not. It is possible that a warming trend in the GSL, which began in the late 1990s, may lead to higher levels of *C. finmarchicus* in the GSL: high levels were found in the northeast in 1999. In the fall during the 1990s, mesozooplankton biomass was 5 to10 times lower than in the spring, although *C. finmarchicus* levels were still significant in the GSL outflow.

Discussion

While the Eastern Scotian Shelf has a similar plankton community to the one upstream in the Southern Gulf of St. Lawrence, it has to be kept in mind that the basins are major sources of *in situ* reproduction; adults are advected into these areas where they reproduce. It was particularly interesting to learn that *C. hyperboreus* is now dominant in both the Gulf and northeastern part of ESS. As well, events in the northeast generally start a month later than in the western areas.

Regarding potential indicators and reference points, it was felt by some that to get a valid estimate of plankton diversity would require high levels of sampling and thus it would be impractical to develop these. It was countered that an index can be calculated on a specified level of sampling, as it is only an index. The bigger question is what to do with this information once you have it. As with the phytoplankton, it was considered premature to develop indicators and associated Reference Points for management purposes at this time.

Monitoring Needs

No additional monitoring needs were identified.

Ichthyoplankton Communities on the Eastern Scotian Shelf
N. Shackle, Marine Fish Division, Bedford Institute of Oceanography

Larval fish diversity on the Scotian Shelf was examined using data, representing 91 genera, collected during the Scotian Shelf Ichthyoplankton Program from 1978-1982. Two diversity indices (Genus Richness (GR) and Shannon's Entropy H) were relatively lower from December to February/March and relatively higher and stable from April to September/October. Taxon composition changed seasonally. Total median log abundance (log(number of individuals + 1)/1000 m^3) was low from December to February, increased in March, was stable from April to June and declined from July to October. The results suggest that the abundance trends of most taxa were not coincident with either a spring or fall bloom of calanoid copepods. Log GR was significantly positively related to H ($r=0.62$, $p<0.001$, $n=1853$). A negative exponential best described the relation between log GR and log abundance. H was not related to log abundance in winter and in summer/fall, and negatively correlated in spring/summer. Thus, diversity increases with abundance but at higher levels of abundance, the composition is dominated by relatively fewer genera. Western/Sable Island bank had higher levels of GR and abundance in all seasons. Additional banks were diverse and productive during warmer months.

Discussion

The presentation underlined a number of trends in diversity that occur (high diversity during April – October, taxon composition changes, trends in increasing numbers of ‘cold’ species and decreasing numbers of ‘warm’ species, areal differences, etc) but with little explanation of the causative processes. It was particularly interesting that the Sable Island/Western Bank area, an area of high diversity, also exhibits a high level of benthic biomass. It is possible that habitat features are associated with species diversity or richness.

Regarding indicators and reference points, indices based on the ichthyoplankton might be useful measures of long-term spatial and temporal changes in diversity, and be more representative of the fish communities than those calculated using the bottom trawl survey information. It would be useful to compare indices derived from the two data sets.

Monitoring Needs

No specific monitoring needs were stated.

Patterns in Benthic Diversity and Biomass Distribution on the Scotian Shelf

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Examples of studies to assess Scotian Shelf benthic megafauna invertebrate population distributions (through trawl survey by-catch), and community biomass and taxonomic composition changes (due to bottom trawling and ecological processes involved with food supply to the benthos through benthic-pelagic coupling) were reviewed. Sediment type profoundly affects benthic invertebrate taxa present. Diversity (species abundance and composition) reflects benthic habitat structure (physical complexity), stability and predation, while biomass is proportional to food supply. Benthic species community diversity is determined by the proportions of infauna, epifauna and mobile megafauna which, due to the necessity to use different sampling tools, are seldom assessed in a single study. These faunal groups may be classified by functional feeding groups. In general, substrate type and organic matter supply determine large-scale patterns of distribution and community species composition. For example, the proportion of suspension feeders decreases and the proportion of deposit feeders increases as the abundance of fine particles increases. Substrate type, food availability, hydrodynamics and oxygen supply determine habitat suitability for all taxa. These variables may create onshore-offshore gradients in distribution and account for well-recognized non-homogeneous (aggregated) distribution patterns in many benthic invertebrates.

A literature review of benthic studies on the Scotian Shelf and adjacent areas (primary and secondary literature sources) was undertaken as part of the creation of a DFO benthic biomass mapping database. Results to date were presented using maps to illustrate the history of benthic faunal sampling in different areas over the past four decades. The Gulf of Maine has been studied most intensively (341 stations), followed by the Bay of Fundy (310 stations), and the Scotian Shelf (122 stations), however the data may be insufficient to assess trends in temporal/spatial changes in biomass or community taxonomic composition over the past four decades. With the exception of recent benthic surveys associated with trawling impact studies, no time series sampling (repeated sampling at a single location) has been undertaken. Effort currently underway to analyze benthic infauna biomass distribution, stratified by bio-physical zones and sediment type on the Scotian Shelf, were described.

Discussion

The presentation provided a system to characterize the benthic community, based upon substrate, temperature and depth. Epifaunal communities appeared to be dominated by key species while others appear to be benthic 'dead-ends' (e.g. sand dollars). Overall, abundance decreases with increasing depth and distance from continentinal margin, with the mud zone at 500-700 m a zone of high benthic production.

The main problem is the lack of data. Historic collections are not very useful. There are no seasonal studies and no long-term database except that of the trawl impact experiment. Even here, the objective has been to determine impacts and not to conduct systematic surveys. The groundfish trawl survey has only recently started to fully enumerate the invertebrate species collected. While it would appear that a rich source of information about the benthos might reside in groundfish diet studies, these do not provide meaningful information, as fish are highly selective feeders. However, presence/absence data might be of some use. Another potential data source is that of the hydraulic dredge data from Banquereau in the late 1990s. This needs to be investigated.

The intention in the short-term is to develop a map of the benthos on the Scotian Shelf based on the relationship of species type to sediment size. It was noted that this would not provide any information on the quantity of a species, which will require a systematic survey design. It was mentioned that the deposition zone at 500-800 m could be a good monitoring site for the benthos.

Overall, the program is at its beginning but with time will allow development of an understanding of how the benthos uses primary and related production. There is hope that general patterns will emerge.

Regarding potential indicators and reference points, the first step is development of a standard classification of the substrate, based on geology, currents, depth and distance.

Monitoring Needs

The following needs for monitoring community structure, abundance and biomass (production) of benthic infauna, epifauna and megafauna within various geological provinces on the Scotian Shelf were developed at the workshop. A benthic ecosystem characterization program on the Scotian Shelf should have four components:

1. Large-scale spatial survey of macrofauna and bottom substrate distribution
   - overall biomass relationships from stratified random sampling based on surficial geology (to cross broad depths zones and sediment types)

- single or paired samples to cover as broad a region as possible (includes all representative sediment types)
- use of multi-beam data (if available) to stratify sampling based on sediment type
- alternatively, transects of stations running from tops of banks to basin depths (on and off shelf) can be sampled to document community structure and biomass in relation to depth and substrate
- a third approach is to used a fixed sampling grid over a broad area containing variations in depth and substrate type within the grid

2. Time series sampling for temporal variations in benthic infauna/epifauna
   - transect of stations sampled repeatedly (Halifax or Louisburg Sections) where related data for hydrography, nutrients, chlorophyll are available
   - few samples at each site (video grab=0.5 m^2, 5 x 0.1 m^2 Van Veen grabs); diversity measures sensitive to area sampled, should be standardized
   - concurrent sediment samples to relate infauna/epifauna to substrate type
   - periodic multiple sampling (n=10) at one site (variability in biomass and taxa)
   - observations two times per year (spring before the bloom, late summer/fall)

3. Analysis of trawl survey data to assess invertebrate megafauna populations
   - utilize annual trawl surveys to establish "average" distribution patterns and inter-annual variability for selected invertebrates
   - standardize observation procedures for epifauna and megafauna collected as trawl by-catch
   - develop 'catchability' coefficients that allow quantitative estimates of population size from species collected as by-catch

4. Micro-scale spatial survey macrofauna-substrate distribution patterns
   - collaborative studies with geologists to examine changes in benthic communities associated with small scale physical surface features (bedforms) such as sand ridges/troughs, shell beds
   - if multibeam data is available (or can be obtained), variations of sediment type on a small (local) scale can be compared to differences in benthic taxa and biomass

Species at Risk Requirements for Monitoring Species Diversity in the ESSIM Area
R. Bradford, Diadromous Fisheries Division, Bedford Institute of Oceanography

Animal species reported from within the ESSIM area include invertebrates, fishes, reptiles and marine mammals with occurrences including occasional strays, seasonal migrants, and resident species (benthic, demersal and pelagic). Many species are organized as distinct, identifiable assemblages that persist in their composition through time (e.g., demersal fishes, Mahon et al. 1998). However, the species assemblages are not always associated with accepted biogeographic boundaries and they can shift in location through time (Mahon et al., 1998). Furthermore, only a few of the species occurring within the ESSIM area are known to be endemic to the area, with the result that the marine organisms occurring there are organized into units well below the biological species (e.g., stocks, stock complexes). The population structure for many other animals occurring with the ESSIM area has not been the subject of investigation. These factors indicate that the development of monitoring programs to provide an early warning of species that may be at risk of extinction will need to consider:

1) the level of organization (population, stock complex) of the animal below the species level that would represent an irreplaceable loss to the ecosystem. These are usually referred to as distinct population segments (DPS) or Evolutionary Significant Units (ESU). Their identification will need to be based on the best information available (genotype or phenotype either singularly or in combination depending on the data available). Lack of full scientific certainty cannot be used as a reason to delay measures to avoid or minimize threats to 'species' at risk.
2) which performance measures will need to be applied to individual species. Consideration will need to be given to life-history variability among species (e.g., size/age at maturity, fecundity, mortality, habitat requirements) and whether or not the available data provides reliable measure of inter-annual trends in abundance. Also, extinction risk criteria developed to monitor the status of terrestrial organism that are based on animal abundance and/or distribution (i.e., the IUCN decline criteria) are not good performance measures for marine fish species. Alternative criteria will need to be developed
3) whether the biology of the animal is such (e.g., occasional strays, seasonal migrants) that monitoring activities will need to extend beyond the geographic boundaries of the ESSIM area

Discussion

As stated in the presentation, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) uses the IUCN criteria, along with other information, as guidelines to determine the status of species. The analyses emphasized problems with the IUCN criteria for marine species and the need for better criteria. Australia has developed a set of extinction criteria that might be of use to Canada. It was also mentioned that FAO is convening a workshop on criteria for assessing species at risk, which may provide guidelines.

It was asked what is the relationship between these criteria and a limit reference point. The risk of extinction should be more severe than stipulated by a limit reference point.

Monitoring Needs

There is existing capacity within the ESSIM area to monitor species abundance, distribution and habitat and/or oceanographic conditions as a consequence of core DFO activities. Additional capacity may be required to calibrate numerical abundance to abundance indices (e.g., research survey data), interpret survey data in light of distribution/demographic considerations, and there may be a need to adapt survey designs to address species specific issues. The numerous time series of stock assessment data may provide some measure of the relevance of conventional extinction risk criteria (e.g., decline criteria) to exploited marine fish stocks.

Maintenance of Within Species Diversity

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The 1992 Convention on Biological Diversity (CBD) provides a definition and framework for the conservation of marine resources, including communities of species and distinctive ecosystems, as well as the diversity of the gene pool within individual species. The concept of biodiversity is complex and has often been used ambiguously in fisheries science to refer to species composition and relative dominance. While species diversity is an important element of biodiversity, other elements must also be considered. These include ecosystem diversity, functional diversity, landscape or spatial diversity (including temporal diversity), and genetic diversity.

Ecosystem diversity can be defined as the collection of assemblages, communities and habitats within a region. Functional diversity can be considered to be a component of ecosystem diversity and may have a reduced number of representatives, for example mussel reefs and oyster reefs may play the same functional role in the ecosystem while representing different benthic assemblages. Landscape diversity captures the information in ecosystem diversity and places it into geo-referenced space, while temporal diversity describes the changes in landscape diversity over time. Genetic diversity describes the amount of genetic information within and among individuals of a population, a species, an assemblage, or a community and will be influenced by landscape diversity. These categories of biodiversity have led to a compartmentalization of the elements, commonly at the gene, species and community levels, however there is a continuum of diversity within and between each of these.

From a genetic perspective, the long-term goal is not to “conserve” or “preserve” but to allow for adaptation to environmental change and for continued speciation in order to maintain evolutionary flexibility for the future. This requires knowledge of the structure of genetic variation within the species and how it is partitioned within and among populations. Both types of variation must be maximized in order to maintain the full potential for evolutionary change.

Genetic variation can be reduced through three principle mechanisms: extinction (loss of genes or gene complexes), hybridization (e.g., breakdown of co-adapted genes) and loss of genetic variation within populations. The later may be due to natural selection, selective fishing, and in the case of small populations, to genetic drift and inbreeding. In this instance, migration can be seen as a balancing force, introducing new genes into the population. The vulnerability of the resource to these risks depends upon various intrinsic aspects such as the nature of the resource (e.g., wild and exploited, wild unexploited), the components of its diversity (e.g., breeding organization, phenotypic variation, life history traits), the nature of human intervention (e.g., habitat degradation, overfishing, introductions), and the genetic properties affected (e.g., selection, genetic drift, mutation). Environmental modification, such as toxic pollution and the forcing of physiological tolerance limits, pose high to extreme risks to a number of genetic processes. Of the activities associated with wild harvest and aquaculture, overfishing and selective fishing pose the most severe threats to loss of genetic variation.

When we come to determine objectives and indicators for the maintenance of within species diversity, we have to consider the life history and biological attributes of the organisms. To date, about 275,000 species of marine organisms drawn from 43 phyla have been described, but the estimated number of marine inhabitants are likely to be on the order of millions. Within such a diverse group, there are many biological differences that are likely to have great importance for the conservation of individual species. Consequently, the indicators used to evaluate performance will not apply equally well to all marine fin- and shellfish species.

However, it is possible to infer genetic structure for some species based on their biological characteristics. For example, anadromous fish with strong homing instincts can be expected to have a high degree of among-population variation, whereas species with large population sizes, high fecundity and pelagic larvae will have a high degree of within-population variation. Other examples of categories include predatory species, species with localized distributions and sessile benthic invertebrates.

The single most important factor for sustaining high levels of genetic variation within a population is the effective population size (Ne). Ne is the number of male and female breeders in a population. Ne is the most important variable in assessing population viability. Maintaining large Ne increases the likelihood that favourable mutations will become widespread and deleterious ones will be eliminated. Importantly, Ne is influenced by the breeding structure of the population in three ways: sex ratio (deviations from 1:1 reduce genetic diversity), variation in the number of offspring per family (deviations from equal numbers reduces genetic diversity) and fluctuating population numbers (genetic diversity is reduced with fluctuations to low levels). The later element shows that Ne has a temporal component and must be monitored over time.

Effective population size can be inferred from two very different data sources: biological data and genetic data. In controlled situations (aquaculture broodstock) or instances of low population numbers (e.g. whales), Ne can be estimated with some degree of confidence. However in most cases we do not have the information we need on Ne and therefore rely on proxy measures to mitigate against loss of genetic variation. Due to the lack of information on Ne for even our most valuable commercial species, we often have to resort to proxy measures. These include estimates of population abundance determined from surveys or censuses (Nc) which are themselves estimates of the true population size, and spawning stock biomass (SSB) which is also an objective that is calculated for stock assessments of some species. You can see that just knowing the SSB or Nc is insufficient to estimate Ne (e.g., biomass does not tell you numbers). However, if we must rely on these proxies, management practices, which maintain large numbers and consider sex ratio, population fluctuation, nearest neighbour (for sessile invertebrates) and selection differentials will increase our confidence of a viable Ne.

Variation among populations is often reflected in the phenotype and is often easier for managers and others to appreciate. Also, provided that the Ne is large within each of the populations, monitoring spatial diversity is more amenable to our present databases (survey, fish log, etc.).

How can landscape or spatial diversity affect genetic diversity? The loss of populations through removal (capture or death), redistribution or loss of critical habitat can produce range contraction and/or population fragmentation. Both can affect genetic diversity through the loss of genes and gene complexes and by altering gene flow. The loss of a population can produce secondary effects such as hyperaggregation, recolonization and redistribution, which also alter gene flow. However, many species only show physical subdivision at spawning time and so the temporal component of landscape diversity becomes pertinent. Provided that there is a high fidelity to spawning grounds, this characteristic can be indicative of high levels of among-population variation. In these cases, preserving the number of spawning components will also sustain genetic variation within the species. Therefore, by monitoring for range contraction, population fragmentation, number of spawning components, and maintenance of critical habitat, we can detect potential changes in among-population genetic diversity.

Discussion

The presentation provided an interesting and thought provoking perspective on potential indicators of genetic diversity, both at the species and population level. Regarding potential indicators, the following were discussed as possibilities:

<u>Within Population</u>

- Survey Numbers/Biomass
- Sex Ratio
- Fecundity
- Selection Differentials

<u>Among Population</u>

- Indices of Range Contraction
- Indices of population fragmentation
- # of spawning components
- area of critical habitat

Further work on these indicators is required to develop them further before use in the ESSIM area. It was suggested that application of developed indicators in a case study for the ESSIM area would be useful to pursue eventually.

There was discussion on the applicability of the discussed indicators in evaluating extinction risk, in preference to the IUCN criteria. There was agreement that these indicators could be profitably pursued in this regard but as with indicators of genetic diversity, would require further development.

Monitoring Needs

Data from current monitoring activities can allow calculation of the within population indicators. Monitoring for range contraction, population fragmentation, number of spawning components and maintenance of critical habitat, would be needed to detect potential changes to among population genetic diversity.

TRENDS AND INDICATORS – FISHERIES AND ECOSYSTEMS

Rapporteur: K. Zwanenburg

Remit: To describe trends in the ecosystem (fisheries and ecosystem).

To define indicators for the potential ecosystem objectives of ocean management.

Community Metrics and Ecosystem Structure and Function

K. Zwanenburg, Marine Fish Division

A synopsis of a number of ecosystem metrics was presented. The metrics were derived from the results of the summer trawl surveys conducted on the Eastern Scotian Shelf between 1970 and 1999. The indices were restricted to fish and related to fish community size structure (integrated community size structure), distribution of fish numbers across species (K-dominance, Shannon-Wiener Diversity index, Simpsons Diversity index, and species richness).

Significant results show that overall size structure (as expressed by the integrated community size frequency) of demersal fishes has decreased since 1970s. This has been the result of steady erosion of the larger specimens especially in the commercially exploited species.

Analysis of the K-dominance (a measure which looks at the distribution of biomass between species in the ecosystem or community) indicates that biomass is somewhat more concentrated in fewer species than was the case in the 1970 but that this has occurred previously (1975). The significance of this finding is debatable and no implications were discussed.

Other measures of diversity showed no long-term trends save for species richness that has shown a steady increase since the late 1970s. Such increases have been observed in other trawl survey series around the world and were found to indicate improved and more complete species identification rather than actual changes in species richness. The more rapid increase in the early 1990s may be the result of an increase in the number of cold-water species that began to occupy the shelf during the cooling period that began in the mid 1980s.

Based on the results of Pauly's 1995 work, and on the results of Ecopath models for the Eastern shelf, the annual mean trophic level of exploitation was estimated for the period 1960 to 1998. The temporal dynamics of these estimates were discussed in relation to both the total removals reported from the area and the species composition of these removals. Finally, based on Pauly's 1995 work, an estimate of the biomass primary production required to sustain such removals was presented. How this estimate relates to estimates of total primary production on the eastern shelf was discussed.

Discussion

The Pauly's FIB index, while constant until the early 1990s, has declined since. This is the same trend seen using the Ecopath model and is supported by the observation of increased recent landings of molluscs and crustaceans. One concern with the diversity trends was the quality of the survey data. With better on-board species identification protocols, it is possible that the changes may be artificial. However, it was felt that the increase in the invertebrate community is real. The trends provide only a partial view of ecosystem structure and there are no measures of ecosystem function.

The calculation of the primary production needed to support the total production of the ESSIM area was considered very interesting. It showed that the primary production was orders of magnitude higher than that necessary to support higher trophic level production. This was considered a useful comparison, which should be confirmed.

Regarding indicators and reference points, there are a number of diversity indices available in the ecological literature. However, many are not useful and are to be avoided (Rice, 2000). There is considerable work to do regarding choosing appropriate indices of diversity. It was felt that the size spectrum has promise in providing an indicator of ecosystem diversity. While it is not possible to provide an indicator and associated RP for ecosystem diversity for management purposes, it was suggested that harvest removals by trophic level should be monitored on a routine basis.

Monitoring Needs

Much of the information presented depended upon the bottom trawl surveys, which miss the pelagic component of the ecosystem. Additional survey activity, complementary to the bottom trawl surveys, would be required.

Trends in exploited and bycatch species: Invertebrate Fisheries
S. J. Smith, Invertebrate Fisheries Division, Bedford Institute of Oceanography

There are directed fisheries for seven species of invertebrates in the ESSIM area. The oldest of these is for lobster in the inshore areas of Eastern Nova Scotia and Cape Breton. Catch records exist from the 19th century but landings by the currently used lobster fishing areas are only available from 1946. The newest fishery is for rock crab, also in the inshore area and the landing series dates from 1994 to the present. Northern shrimp have been fished in the deep holes off of Canso and Cape Breton since 1979. While snow crab has been fished on the Eastern Scotian Shelf since 1978, the fishery has expanded in the last few years to cover a large part of the 4VsW area. Scallop fisheries have existed since the early 1980s on Banquereau (mainly Icelandic scallops, *Chlamyus islandica*), Middle Bank (sea scallop, *Placopecten magellanicus*) and Sable/Western Banks (sea scallop). The fishery on Middle Bank has been under voluntary closure since 1997. The Arctic surfclam fishery started in 1987 and is confined to Banquereau Bank in the ESSIM area but a large part of the landings of this species have come from the Grand Banks in the past. Landings for scallops, surfclam, shrimps and snow crab have increased over the last few years and are currently at or near their highest level in their respective time series.

Catch rate information from fishing logs are available from all these fisheries except for the lobster fisheries, where a limited index fishermen program has been implemented. Catch rates for scallops, surfclam, shrimps and snow crab are at or near their highest levels in their respective time series. Time series of species/area specific surveys are available for the scallop, shrimp and snow crab. The survey series for the snow crab dates from 1997. All of the current surveys for these species are conducted jointly with their respective fishing industries. Exploratory surveys for surfclam and related species were conducted by DFO in the early 1980s. There was a joint industry/DFO hydraulic dredge survey using Roxanne data for surfclam and related species on Banquereau Bank in 1996 and 1997. There are no wide-area omnibus surveys for invertebrates on the Eastern Scotian Shelf as there are for groundfish species. However, invertebrates caught on the groundfish surveys are now being identified and recorded.

By-catch information from the invertebrate directed fisheries is limited. Observer data is only available from the larger vessel fisheries and coverage is limited. The Nordmore grate was introduced into the shrimp trawl fisheries in 1991 to reduce bycatch and all reports are that this change was successful in doing so. Exploratory fisheries in the deep-water areas near the 4W/4X border are currently being conducted by the fishing industry to evaluate the potential for offshore lobster, Jonah crab and red crab fisheries.

Discussion

Most of the questions related to clarification of the fishery and resource trends. However, it was noted that a number of the invertebrate fisheries in the ESSIM area are relatively recent with the time series of abundance / biomass growing and that explicitly stated reference points by which to evaluate harvest impacts do not exist for some of the fisheries.

The efforts to record the invertebrate information collected on the summer bottom trawl surveys were noted and encouraged. There was discussion on how this information would be used. Survey catchability-corrected biomass has been calculated but are critically dependent on the estimates of the catchability. Work on these estimates is required.

Monitoring Needs

Current survey efforts, both by DFO and co-operatively with industry, should be able to meet most monitoring needs. There is a need for survey activities to groundtruth the catchability estimates.

Trends in exploited and bycatch species: Finfish Fisheries

P. Fanning and R. Mohn, Marine Fish Division, Bedford Institute of Oceanography

The first part of the presentation focused on trends in the ESSIM area of commercially exploited species, based upon landings trends from NAFO and the DFO ZIFF files, abundance trends inferred from DFO bottom trawl surveys, and population reconstructions. This required the use of catchability coefficients to convert survey catch rate to population abundance. Problems in the quality of the landings data were highlighted. Trends were grouped according to small pelagics, silver hake, large pelagics, haddock, other groundfish, flatfish, and cod. In relation to small pelagics, herring abundance has increased since the early 1990s, although that of other species remains low, at least from a survey perspective. Silver hake and haddock abundance has shown similar trends with both increasing in mid 1980s highs and declining since. In relation to flatfish, there have been overall declines in the community, although the abundance of yellowtail may have increased in recent years. Redfish abundance was reasonably high in the late 1980s but has declined to recent low levels. The abundance of other groundfish has declined to low levels gradually since the mid 1980s. There was a discussion on the relative merits of different assumptions of natural mortality in the 4VsW cod assessment.

The second part of the presentation focused on the use of indicators and reference points in fisheries management. The integration of analytical, biological and other related information is hampered by their disparate nature, in terms of precision, applicability and type. Simplification of a resource's status into a number of (discrete) states has been discussed for some time in other fora and thus an initiative to develop a practical application of these ideas was brought forward to RAP in 1999. A set of annotated figures was presented as an illustration of the codification of indices that are currently available. 4VsW cod was chosen as an example because of the dynamic nature of this stock over the last 30 years. The fishery was greatly reduced in 1976-77, then experienced a period of strong recruitment. After strong biomass in the early 1980s, there was a period of steady decline leading to a closure in 1993. The values used in the example were from the 'standard' model description for 4VsW cod, which included predation by seals. Three categories of indices were chosen - healthy, concern and danger. Defining three categories is consistent with the precautionary approach concept of targets and limits. A precautionary target level separated the healthy category from concern and a limit target level delineated concern and danger. Histograms showing green or uncolored during healthy years, and yellow and red for 'concern' and 'danger' respectively were presented. For further illustration, the categories were given numeric values so that an overall state could be assessed. A simple weighted average for this summation was chosen but non-linear rules may be found to be more useful. A table outlining the indicators and reference under discussion was presented. It was reiterated that the analyses are meant as illustrative rather than as definitive guidelines, to initiate rather than conclude discussion.

Discussion

The information for the first part of the presentation depended primarily upon NAFO landings statistics, the bottom trawl survey (pre and post 1970) and species-specific surveys conducted by DFO Science. It was noted that very little information on the ecosystem shoreward of three nautical miles is available, which impacts the ESSIM initiative capability of managing the inshore.

As most of the trends presented were of survey – catchability corrected biomass, the accuracy of the q value is critical. These are particularly difficult to determine for the invertebrates. It was queried if the trends observed were real. Some could be due to redirected fishing effort (spike in lobster landings due to closure of groundfish fishery). Others may be due to some environmental impacts.

Regarding indicators and reference points, Table 1 was based on recent work in Marine Fish Division. While this set represents work underway, it was noted that it provides a useful classification system of the indicators. It was felt that the environmental indicators are primarily valuable in aiding the interpretation of the biological indicators, rather than useful in guiding management decisions. Further development of this list of indicators and associated reference pints was encouraged.

The example of how a set of indicators/reference points could be used in decision-making received much interest. This was an illustration of the Traffic Light method described on the first day, which is being explored by the RAP Fisheries Management Studies Working group (FMSWG). The software received particular interest. It was noted that decision-makers would likely want to understand how a common set of indicators is behaving compared to another set of indicators, which would be addressed by the classification system mentioned above. It was suggested that a simulation could be undertaken using historical information to determine whether or not decision-making using this method would be superior to the status quo.

The issue of projections using the Traffic Light method was discussed. The workshop could provide no guidance on this but encouraged the FMSWG to further research this question.

Monitoring Needs

While current monitoring activity can provide much of the necessary information, there is a need to groundtruth the catchability estimates and provide new estimates for the invertebrate species. Additional monitoring is required for the discarding and compliance indicators, which should be undertaken with consultation with industry.

Table 1. Proposed indicators of stock status to monitor exploited populations of fish and invertebrates. Not all indicators are available or applicable to all species.

Indicator	Reference Point	Interpretation	Metric
Population Dynamics Indicators			
Biomass (total over specified ages)	B_{lim}, B_{buf}, B_{tr}		B_{a+}, biomass in given age range
Exploitation	F_{lim}, F_{buf}, F_{target}		F_{fr}, fully recruited F
Recruitment			N_a, numbers at early age e.g. 1
Survey-based Indicators			
Biomass index			age/length based CPUE in kgs
Recruitment index			age/length based CPUE in num.
Total Mortality (Z)			annual or smoothed Z's
Biological Indicators			
Condition factor	Compared to historical series	low condition can be due to either high density effects or poor environment	Predicted weight at a given age
Age structure	Compared to historical series	low diversity usually from truncated age dist^n	Age diversity or interquartile range
Size structure (maturity?)			
Geographical dist.	Compared to historical series	population reductions often reduce size of occupied territory	area occupied by given quantile of survey catch
Growth rates			
Environmental and Ecological			
Environmental regime	Compared to historical series	severe temperature regime can reduce growth, reprod. and survival	proportion of RV sets in 'preferred' temperature
Fishing Industry Indicators			
Fishers reports on recent biomass trend		Industry perception of trend in status	positive or negative indication
Fishers reports on small fish abundance		Industry perception of trend in recruitment	positive or negative indication
Geographic range	Compared to historical series	population reductions often reduce size of occupied territory, fishery may be driven by management considerations	area occupied by given quantile of commercial catch (possibly by statistical unit)
Over/under quota	TAC	failure to reach quota may indicate overestimated abundance, can be confounded by management measures	percent or absolute deviation

Indicator	Reference Point	Interpretation	Metric
Fishery Management Compliance			
By-catch impact	Proportion of directed F??	impact of other fisheries on mortality of given stock	Bycatch partial F?
Size regulation	Compared to historical series	may indicate recruitment	Frequency and distribution of small fish closures
Unaccounted mortality	Proportion of directed F??	impact of other unreported catch or M on mortality of given stock	Discard partial F?, Change in M?
Habitat impact	Compared to historical series	loss of identified spawning or other obligate habitat may reduce survival or reproduction	proportional area of impacted habitat
Quality of statistics reporting	Fully described and accurate statistics for fishery, bycatch and discards	errors in statistics will increase uncertainty and cause precautionary reduction in harvest levels	subjective confidence assessments and estimates of required adjustments

Maintenance of Ecologically Dependent Species

R. Mohn, Marine Fish Division, Bedford Institute of Oceanography

Estimation of the status of ecologically dependent species (EDS) is generally more difficult than it is for those that are exploited. The first problem is the absence of commercial information, which may include landings, effort, geographical information, size information and perhaps biological samples. Secondly, because they are of more economic value, there may be directed surveys for them or broad-spectrum surveys may be directed to preferentially sample the exploited members of the ecosystem. The landings are useful in scaling indices to absolute values in virtual population analysis and related assessment techniques. As both commercial information and surveys are the keys to most stock assessments, the EDS are racing with the handicap of having (at least) one leg missing. In most cases, their status will be based on surveys or indirectly inferred using another species as a status indicator.

Most of the development for this review is in terms of species pairs - an exploited species and an EDS. The roles of ecologically dependent species within an ecosystem can be categorized into four functional groups: 1) technical interaction alone, 2) EDS is prey of one or more exploited species, 3) EDS is predator of one or more exploited species, and 4) EDS is both predator and prey. These categories may change for a species at it ages. For example, herring eat larval cod, while adult cod eat herring. The EDS – herring - is either a predator or prey depending on the life stage of the cod. A second consideration within each pair is the principal species of interest - the exploited, the EDS or both. For example, in the grey seal - cod pair of the Eastern Scotian Shelf (ESS), it is the condition of the cod resource that is currently of concern. In the Antarctic whale-krill system, the EDS is of current concern.

In addition to the role of EDS in the ecosystem, the models used for assessing them and the data requirements of these models were reviewed. The models range in complexity from simple production models requiring the estimation of only two parameters to ecosystem models requiring scores of parameters. Most dynamic models used to assess EDS are simplified single species models, which require less information than the usual assessment, or simple ecological models of no more than three species. Of course, there are fallbacks such as the ubiquitous 0.5MBo, which are sometimes called into action when there are no data for analysis – and little idea of either M or Bo.

This work reviews the data and models needed to assess each of our categories of ecologically dependent species.

Discussion

The presentation focused on those species that, while not harvested, are ecologically linked to those that are. The definition used here included those species that are by-catch in directed fisheries. The approach has been to model the interactions based on available knowledge. This prompted discussion on the complexity of the models. Experience has shown that the addition of complexity can lead to chaotic model behaviour. Certainly, as model complexity increases, the information requirements increase even faster. More model complexity may not be good.

Without the appropriate structure, two or three species models can be misleading. However, it was replied that two species models can work in some instances (e.g. krill - whale), although this may not be the case for the Eastern Scotian Shelf. The problem is that the ecosystem may function the same way even though the structure may have changed, because multiple pathways can lead to the same result.

The discussion considered ecosystem vulnerability. Can we determine the vulnerability of the ecosystem given only the number of species in the system? How does this relate to the number of linkages (primary vs. secondary). Could the number of linkages that the fishery has an impact on, versus the number of natural linkages, be used as an index of vulnerability? In response, it was noted that there exists a large literature on foodwebs. It shows that model predictability is low as alternative pathways take over when some linkages are removed or altered. It is the weak links that appear important to the ecosystem.

Regarding indicators and reference points, it was suggested that there are some simple things that could be done. We could identify the number of forage species, with the indicator being the biomass of the forage species. Australia found that detailed information on prey species was not useful and thus uses 75 percent of the long-term combined prey species biomass as a reference point. One could examine the number of linkages to weigh concerns with excursions above or below the reference point. We could also document the aggregated removals at each trophic level, a point made earlier in the workshop.

Monitoring Needs

There is a need for forage species surveys.

Given the complexities of the linkages in the ecosystem, it was suggested that Marine Protected Areas (MPAs) could be used to provide reference areas i.e. areas where the ecosystem is untouched by any activity and to which impacted areas could be compared. They would represent the ‘control’ of the adaptive management approach. Specific monitoring of these areas would be required.

There is a need for stomach analysis and monitoring that is not coupled to the decision-making (no reference points required). Funding for this might come from industry.

Fishery Effort Trends on the Eastern Scotian Shelf

J. Black, Marine Fish Division, Bedford Institute of Oceanography

Historical effort trends from the NAFO database were presented, along with recent trends using the Zonal Interchange File (ZIF) database of Canadian landings. NAFO effort data (effort hours, fish days, ground days) include foreign fleets operating in 4VW from 1986 - 1997. The effort data were partitioned by country, vessel, gear, tonnage class, area, and main species caught.

Combined total effort since 1960 shows peaks in effort during the 1960s and 1970s. The effort trends show similar trends when the measures are reported (Figure 3).

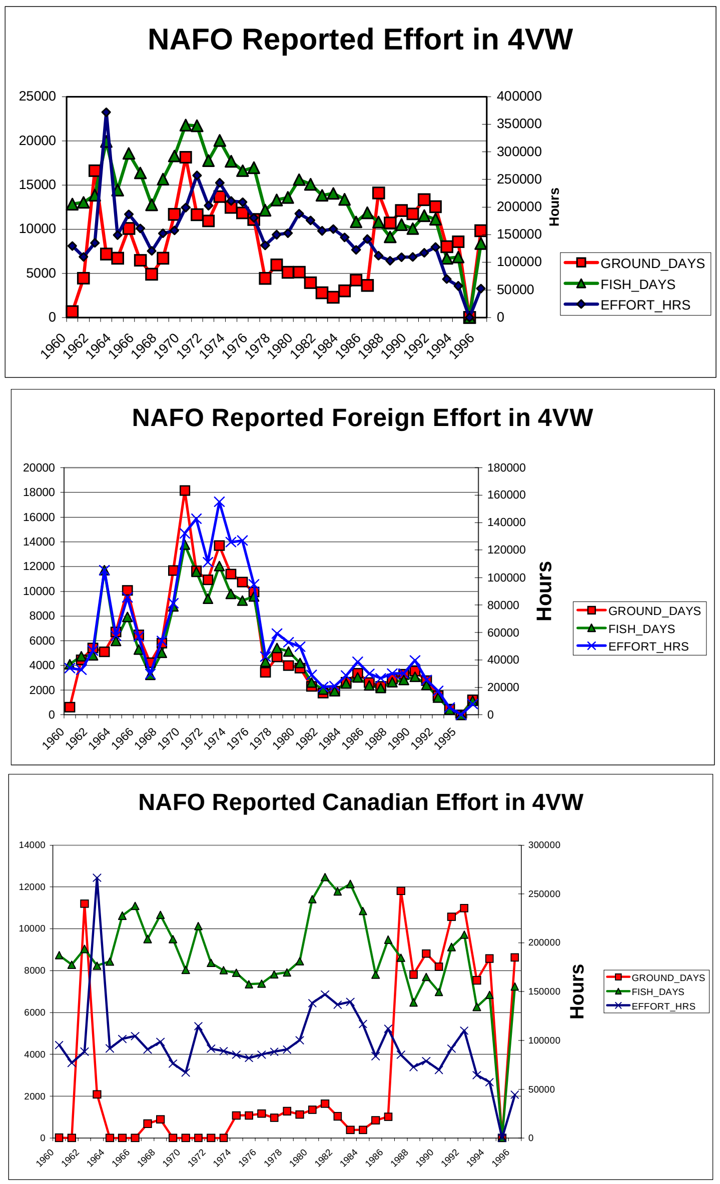

Figure 3. Trends in Total Fishing Effort

Trends in effort by gear class are unique to specific fisheries (Figure 4). The extension of jurisdiction in 1977 and the cod fishery collapse in 1994 are reflected in changes in effort trends between targeted species.

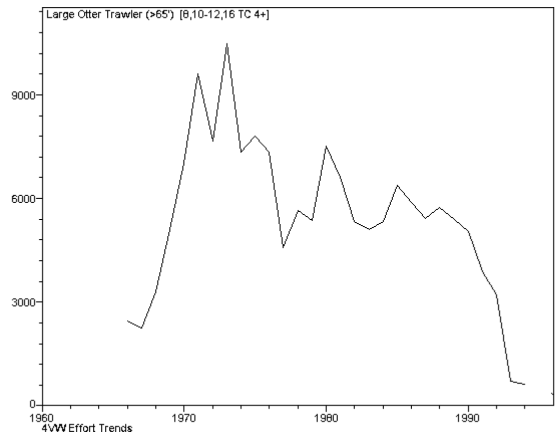

Figure 4. Trend in Large Otter Trawler Fishing Effort

The ZIF database of Canadian landings (1986 - 1999) includes sea days, ground days, fishing days, hours, and count as effort measures. The reported effort varies with gear and fishery. Fishing days reported for various main species caught indicate strong shifts in effort between species groups and gear classes. Since 1990, location information is available for a portion of catches. When catches by species group and gear type are plotted monthly, recurrent seasonal patterns are evident (figures 5 and 6).

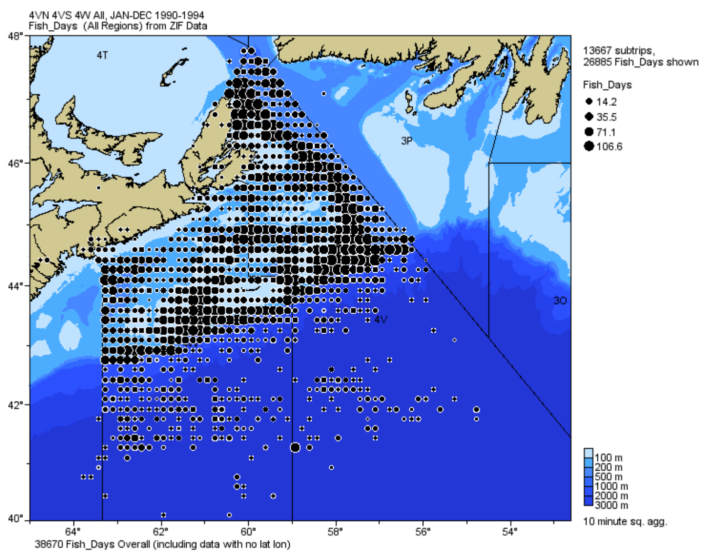

Figure 5. Distribution of Fishing Effort on the Scotian Shelf (1990 – 94)

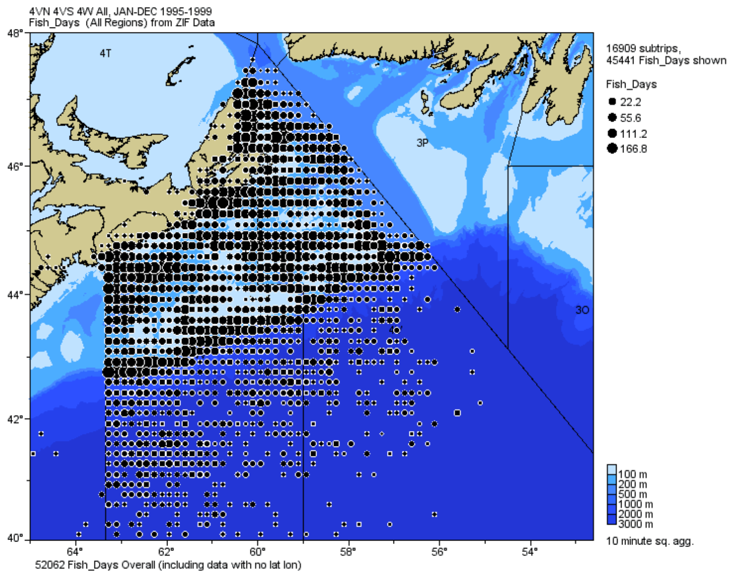

Figure 6. Distribution of Fishing Effort on the Scotian Shelf (1995 – 99)

Since 1998, offshore scallop vessels report their position to DFO scientists hourly using a Satellite link service. Using the observation time, and position an approximate 'speed' between reported positions is inferred. Low speed observations are considered to be representative of fishing location. Detailed effort location maps may be made from these collective records.

There are a number of caveats with the use of this data. Effort trends are subject to error through missing data, changes in reporting units, and misreporting. Catch and effort regulations directly influence effort trends. Technological change can profoundly influence the validity of effort measures, e.g. multibeam imaging of scallop banks have allowed scallop fishers to avoid trawling unsuitable grounds, and have reduced the effort to meet quotas significantly.

Effort data will be valuable to facilitate various analyses. The spatial distribution of effort trends can be useful for resource conflict management when sufficient data are available.

The 'black box' approach to monitor fishing activity may provide sufficient spatial/temporal resolution to increase the usefulness of effort measures as a performance indicator.

Discussion

The workshop found the trends useful in describing the activities of commercial fleets in the ESSIM area. Questions related to clarification of the figures and trends.

A short presentation was given by Scott Coffen-Smout of the Oceans Act Coordination Office of the spatial distribution of cumulative catch, using MapInfo. A thematic mapping approach using GIS is useful for analysis of spatial / temporal distribution of all ocean use activities for conflict avoidance / resolution to minimize ocean space competition in the broader ocean management and planning context. The disadvantage with GIS is that data analysis and modeling is limited, although 4th generation GIS systems that allow this are starting to appear.

Regarding indicators and reference points, the workshop considered a number of possibilities. Indicators could be developed on a fishery by fishery basis and indicators of gear impacts could be developed by gear type, month and year. With the information on spatial resolution, it is possible to entertain micro-scale management, particularly in documenting conflicting ocean uses in certain areas.

Monitoring Needs

The key monitoring need is assurance of reliable location information collection for all gear types and fishing activities.

Marine Mammals
D. Bowen, Marine Fish Division, Bedford Institute of Oceanography

Some 30 species (25 cetaceans, 5 pinnipeds) of marine mammals inhabit the ESSIM area. Among these, 25 cetaceans are the large baleen whales, such as the blue whale and fin whale, and toothed whales ranging in body size from the sperm whales to the harbour porpoise. Whereas most cetaceans are seasonal residences, the northern bottlenose whale is likely a year-round resident of the Gully. The residence time and abundance of most cetacean species are highly uncertain and there is little information on trends in abundance within ESSIM. The range of all cetacean species in the area extend well beyond the ESSIM boundaries. Seals are numerically more abundant than cetaceans in the ESSIM area, with grey seals numbering several hundred thousand individuals. Grey seals are highly mobile predators showing seasonal shifts in distribution, which likely reflect changes in prey availability and the requirements of reproduction and moult. Harbour seals are also year-round residents in ESSIM, but their numbers are not known. Harp seals and hooded seals, mainly juveniles, are also present seasonally, but again distribution and abundance in the ESSIM area are unknown. There is little information on the diets of cetaceans within the ESSIM area. By contrast, the diets of grey seals and harbour seals are reasonably well known. Ecologically (in terms of consumption), grey seals are likely the dominant marine mammal within ESSIM, but cetaceans could be as important as a group. With the exception of grey seal pup production on Sable Island, there is no long-term monitoring of marine mammals in the ESSIM area.

Discussion

Discussion revolved around how these populations fit into the trophic structure of the ESS. Particular note was made of the dramatic annual rate of increase (12%) exhibited by the Sable Island grey seal herd. At this rate of increase, the pupping grounds on Sable Island may be full by 2003. There are other pupping grounds outside of Sable, which are being monitored and these other sites are expected to become increasingly used after 2003.

It was mentioned that the residence time for grey seals in the ESSIM area by quarter was initially assumed, but that now refined estimates are available through satellite tags, which show some seals as very wide ranging and some that are very sedentary (i.e., use Sable Island Bank for much of the year).

A number of questions were posed on the seal diet. Around Sable, the diet consists of sandlance, cod, flatfish, capelin, and silver hake. Three or four species dominate as determined from scats. The new Fatty Acid (FA) signature work shows that other species such as skates or shrimp, which have no hard parts, are being consumed. These data will provide improved estimates of the composition of the seal diet. The time lag in detecting a food item in the fatty acid will depend upon feeding rate, food type and consistency, etc, and it will be in the order of weeks. Some species will be hard to detect as they have similar FA signatures (i.e. pollock and cod).

It was asked what other species, besides grey seals, should be monitored. Pilot whales are numerous and eat squid. There may be thousands of white-sided dolphins and a few large whale species (fin whales) that nevertheless consume considerable biomass. All would be good candidates for monitoring.

Regarding indicators and reference points, there are no formal ones used at the moment for any of these species. However, potential indicators, used elsewhere, are:

- optimal sustainable population size
- potential biological removal (PBR)
- foraging trip duration of lactating female
- weaning mass of young
- juvenile growth rate
- pregnancy rate
- age at maturity

Monitoring Needs

Marine mammals present unique problems for monitoring as they are long lived, generally inaccessible, segregated by age and sex, with a population structure that is poorly known. These create the potential for highly variable population estimates at considerable cost.

Grey pup production is currently monitored every three years in the ESSIM area and in the rest of the species Canadian range. DFO might wish to revise this schedule if pup production levels off to be in a position to investigate density dependent changes in demography. For cetaceans and other pinnipeds, it might be useful to adopt a longer-term approach in which, say every 5 years, the focus of a year’s monitoring would be a particular group of species that could be surveyed using the same type of platform. Annual surveys of these long-lived species are not useful because of the slow rate of population change.

Seabirds on the Scotian Shelf

A. R. Lock, Canadian Wildlife Service, Environment Canada

Two seabird communities were delineated and management difficulties identified:

- Coastal seabirds (characterised by large clutches, earlier maturity, higher adult and juvenile mortality, and many, generally small, colonies). Examples are gulls, terns, cormorants and eiders.
- Pelagic seabirds (characterised by single egg clutches, late sexual maturity, generally lower juvenile and adult mortality and few, large colonies). Examples are puffins, murres, fulmars and shearwaters.

Canadian Wildlife Service (CWS) knowledge of seabirds in Atlantic Region was examined and the CWS Gazetteer of Marine Birds in Atlantic Canada was identified as the most readily available summary of these data. Databases and their spatial and temporal data gaps were identified.

Current threats to pelagic seabird populations were identified as oil pollution, hunting, and the fisheries by-catch. Aquaculture licensed in an ad-hoc manner with no effective coastal zone planning was identified as a major problem challenging conservation of coastal seabirds, particularly in its erosion of traditional feeding areas for sea ducks.

Oil pollution is of major concern in the management of pelagic seabird populations. Analyses of oil recovered from beaches and from beach-cast birds over two decades has shown that it comes from the machinery spaces of ocean going ships. A CWS model which overlays shipping density onto pelagic bird distributions allows identification of areas of greatest risk. CWS has undertaken beached bird surveys off southern Newfoundland since 1983 and these have shown that the rate of oiling is variable but has increased over this period by an average of 3 percent per year. In contrast, oiling rates in the North Sea have been decreasing in the same time period. At present, about 90 percent of birds cast ashore in southern Newfoundland are oiled. This is among the highest rates of oiling observed anywhere.

Seabird contribution to energy flow on the Scotian Shelf was examined, and it was noted that in NAFO area 4VsW, seabird annual food consumption is estimated to be some 60,000 tonnes, about two thirds the consumption of grey seals in the same area. The lack of information on non-breeding season diets of pelagic seabirds was noted and identified as an area requiring research.

The concept of integrated management of the oceans was welcomed, and it was hoped that this meant that future exploitation of fish stocks would be undertaken in a manner that took account of the management needs of non-economic species. It was suggested that from a seabird manager's point of view, integrated management of the oceans would be a fact when:

1. DFO manages aquaculture in the context of planned coastal zone use
2. DFO works to reduce seabird by-catch by prohibiting gill nets set close to important seabird colonies in breeding season.

Discussion

The presentation indicated the importance of considering birds as part of the ESSIM initiative. There have been a number of large-scale changes in pelagic bird distribution in the ESSIM area due to an increase in prey availability, most notably sandlance and capelin. There is good evidence that the fishery has led to increases in the coastal bird populations, such as gulls and cormorants, perhaps due to fishery offal and discards. As well, there is a significant interaction between aquaculture and bird populations.

In contrast to coastal birds, such as gulls, most breeding colonies of pelagic seabirds are not in Nova Scotia due to the presence of high caloric food elsewhere (off Newfoundland, Greenland, Antarctica, etc).

The presentation underlined the need for more cooperative work between DFO and EC, as fish management decisions are having a direct effect on bird dynamics. Also, while it was estimated that seabirds remove about 60,000t of biomass annually from the ESS, there is little information on what they are eating. The ESSIM initiative provides an opportunity to define how best to consider the bird populations in ecosystem-based management.

There was considerable discussion on marine oil and its impact on marine birds. Evidence points towards regular day to day dumping and spilling of engine room fuel oil as the source of this marine contaminant. There has been an increase of 3 percent per year in the incidence of bird oiling. The source of this problem appears to be enforcement of existing regulations.

Regarding indicators and reference points, it was pointed out that while pelagic birds are caught in gillnets, there are no regulations to prevent this. The latter could be based on analyses such as Potential Biological Removal (PBR) approach. This could provide indicators and reference points, such as the number of deaths that will prevent a population from recovering. Indicators could also be formulated to assist coastal zone planning i.e. aquaculture zoning in appropriate area and exclude gill nets from sea-bird breeding areas.

Monitoring Needs

The gaps in the Gazetteer data set need to be filled.

Monitoring of the level of PAHs from four remote sites (away from oil point sources) is required to determine how the oil concentration in the environment is changing.

Monitoring of out-of-breeding season bird diets is required.

Trends in Fish Biomass – Implications of Converting Trawlable to True Biomass Estimates
K. Zwanenburg and J. West

Catchability (q) estimates for all fish species commonly caught during the bottom trawl surveys of the Eastern Scotian Shelf were used to convert estimates of trawlable biomass to estimates of "true" biomass. These were compared to those derived from Sequential Population Analyses for those commercially exploited species for which SPA based analyses are available as a check for consistency. The temporal dynamics of biomass for a number of groups of demersal species using both trawlable and q-corrected biomass were then compared. One of the most significant implications of using q-corrected biomass is that they can be combined for species while trawlable biomass cannot. Changes in species group composition that is implied by these estimates of q-corrected biomass were then examined. The relative exploitation rate were estimated for a number of species for which such estimates are not available but which have been landed in increasing numbers since the abundance of more traditional commercial species has declined. Finally, trajectories of q-corrected and trawlable biomass for all fish species on the Eastern Scotian Shelf were presented.

Applying catchability coefficients to estimates of trawlable biomass resulted in estimates of true biomass, which were higher in all cases. The most significant impacts were for flatfish, semi-pelagic species (like redfish) and especially small pelagic species. For small pelagics, recent biomass estimates increased from about 100,000 t to approximately 1,500,000 t. Comparisons on SPA estimated total biomass to q-corrected trawlable biomass indicated relatively similar temporal trajectories for cod and haddock although in both cases the q-corrected estimates showed greater interannual variability. For 4VsW cod, SPA estimated biomass was also significantly higher than q-corrected biomass especially for the period 1983 to 1990. For silver hake, the two methods of estimating biomass gave overall similar trajectories but with higher interannual variability and overall biomass estimates for the q-corrected relative to the SPA estimated biomass.

Species composition (expressed as relative biomass) on the eastern shelf was examined for 5-year blocks for the period 70-99 using q-corrected biomass estimates. The most significant findings were that sandlance and capelin have made up in excess of 80% of total fish biomass since 1990. Demersal gadoids, which made up approximately 18% of total biomass in the early 1980s presently make up less than 1% of biomass. In contrast 46% of landings continue to be taken from the demersal gadoids component of the ecosystem.

Exploitation rates implied by the proportion of landings relative to q-corrected biomass are low (less than 0.05) for white hake, wolfish, redfish, Atlantic halibut and flatfish. For cod haddock and pollock range from 20 to 35%. Estimated exploitation of cusk and silver hake exceed 75%.

Estimates of trawlable biomass for all fish combined shows a decline from until 1997 with as subsequent upturn to the present. Q-corrected biomass has shown a variable increase since the late 1970s to currently high estimates. This increase is being driven mainly by increases in small pelagic, sandlance and capelin biomass.

Discussion

The presentation, based on catchability (Q) corrected bottom trawl survey information, provided a number of trends (demersal fish down, pelagics up, size of exploited fish down, size of unexploited hasn't changed) and questions which pointed out the difficulty in separating environmental and effort effects. The carrying capacity of the ecosystem is higher now due to an overall shift to a lower trophic level. It was noted that the trends in the northeastern and central parts of the ESS appear different.

Regarding indicators and reference points, as stated under the earlier section on community metrics, it may be possible to develop indicators that will improve our understanding of structure and function but indicators for management purposes are in the future.

Monitoring Needs

An annual pelagic survey would be a useful addition to the monitoring program.

Comparative Dynamics of Exploited Ecosystems in the Northwest Atlantic (CDEENA)
Alida Bundy, Paul Fanning, Caihong Fu, Lei Harris and Julian West, Marine Fish Division, Bedford Institute of Oceanography

There is an on-going ecosystem project on the eastern Scotian Shelf, which is now in its second year. CDEENA is a zonal project that evolved from a high priority research fund and involves the Maritimes, Quebec and Newfoundland. The question driving this project is "What have been the relative effects of fishing, trophic interactions and environmental variation on the population dynamics of marine finfish and shellfish inhabiting shelf ecosystems of the Northwest Atlantic?" The aims of the projects are: (i) to model the structure and function of the shelf ecosystems of eastern Canada and to determine how the physical and biological components of these ecosystems change over time and space. (ii) to use these models to investigate hypotheses concerning the impact of fishing, environmental changes, mortality, and trophic interactions on the dynamics of Atlantic cod and other groundfish and (iii) to fill critical gaps in the knowledge required to develop model descriptions of these ecosystems. The underlying concept of the project is comparative. Thus ecosystems will be compared in time and in space. Two parallel modeling approaches will be used - mass balance models and dynamic models such as minimum realistic models and tropho-dynamic models. The eastern Scotian Shelf will be modeled for the early 1970s, 1980-1985 and 1995-2000. Dynamic models will be used to simulate between these periods and to test hypotheses concerning changes that have been observed in the eastern Scotian Shelf ecosystem. In addition to the modeling components, there are data collection, analysis and field programs designed to fill critical gaps in our knowledge, e.g. diet information and catchability data.

Results from a two species dynamic model (cod and grey seal) and a preliminary 1980-1985 mass balance model (Ecopath) were compared. The two species dynamic model demonstrates that there is considerable variability in natural mortality (M) with time. It predicts that there was large juvenile M in the early 1980s. The mass balance model also indicates a large unexplained natural mortality for juveniles during this time period. This unaccounted mortality may be due to discarding.

Biomass estimates from Ecopath estimates were compared with biomass estimates derived from an analysis of catchability (see Zwanenburg above). There were some differences between these estimates and it is unclear how these should be treated. In particular, Ecopath estimates a far greater biomass of sandlance, small demersals and small pelagics.

Some of the uncertainties in the Ecopath model were discussed, such as biomass estimates for sandlance, small demersals and small pelagics, consumption estimates and cetacean biomass estimates.

Discussion

The value of modeling an ecosystem different ways (in this case, Mass Balance, Trophic Dynamic and Minimum Realistic Models) was apparent from the presentation and ensuing discussion. Large differences between the mass balance and q corrected survey biomass estimates were observed. Explaining these differences is a challenge but will lead to better understanding of the ESS ecosystem.

Questions were raised as to the areas used in the models. In particular, it was queried as to whether or not the models should consider the ESS as composed of northeast and central components. The northeastern component appears to be linked to the movements of organisms out of the Gulf of St. Lawrence whereas the central component may be more influenced by shelf events. It was noted that Ecopath doesn't address spatial structure although newer versions that incorporate space are being developed (e.g. Ecospace).

Regarding indicators and reference points, there was discussion as to how any such indices would be used in decision-making. The degree of our uncertainty may be such that it might not be possible in the near term to provide useful guidance to managers. Rather, the real value of the modeling approach is to increase our overall understanding of the ecosystem.

The discussion returned to the ecosystem objectives stated on the first day. It was felt by some that the objectives were really a classification system of issues to consider. Others felt that that they do provide long-term guidance to ecosystem-based management. In the end, it was agreed to keep these objectives as stated.

Monitoring Needs

To improve our understanding of the ecosystems, surveys of small pelagic feeders, small demersals and large and small crustaceans are required.

USE OF MARINE PROTECTED AREAS

Rapporteur: B. Hatcher

Remit: To what degree does the Sable/Gully proposed MPA meet potential ecosystem objectives of ESSIM?

What ocean use activities are consistent with meeting the objectives?

Are additional MPAs needed within 4VW to meet ecosystem objectives?

Marine Protected Areas and System Planning

D. Fenton, P. Macnab and R. Rutherford
Oceans Act Coordination Office, Oceans Branch, Bedford Institute of Oceanography

With the passage of the Oceans Act in 1997, DFO assumed responsibility for the development and implementation of a national system of Marine Protected Areas (MPAs) in marine, coastal and estuarine waters of Canada. This presentation differentiates among three related management tools: i) MPAs as defined in the Oceans Act, ii) MPAs as conceptualized around the world, and iii) fisheries closures as implemented in eastern Canada. The information needs, planning requirements and various methodologies for identifying sensitive and important areas (i.e., potential MPAs) on the Eastern Scotian Shelf were introduced. In general terms, two categories of MPAs have evolved - harvest refugia with a fishery focus and habitat areas protected for biodiversity objectives. Under the Oceans Act, MPAs are defined as areas of the sea that have been designated for special protection. MPAs are intended to conserve and protect a range of species and their habitats, including commercial and non-commercial fishery resources, endangered or threatened marine species, unique habitats and areas of high biodiversity or biological productivity. MPAs are long term measures that encompass broad biodiversity and habitat protection goals in a multiple-use ocean environment, whereas fisheries closures are generally created for commercial stocks, often for single species management purposes (see Frank below on the Emerald – Western juvenile haddock closure). Unlike the MPA process, there is no involvement by other government departments or non-fishery stakeholders in the establishment of fisheries closures and no consideration of other ocean activities (e.g., oil and gas, ocean mining, tourism, ballast water discharge). Although most of DFO's current MPA pilot projects were selected as stand alone sites (e.g., the Sable / Gully), the Oceans Act does call for a systematic approach to area identification within broader regional planning exercises. System planning for MPAs usually involves the application of site selection guidelines and criteria to mapped layers of ecological and socio-economic data. Benthic and pelagic marine regionalization schemes have been developed in some areas (e.g. Australia, Scotian Shelf) to help guide this identification process. Emerging approaches to system planning include delphi methods, representative sampling, percentage targets, distinctive area identification and network creation for the protection of different life stages and seasonal habitats. Threats and human activities considered in system planning can be categorized into three general classes: habitat destruction or modification, species exploitation and species disturbance. The timely identification of sensitive, valuable or unique habitats is important not just for MPAs, but also for general planning purposes such as environmental impact assessment and multiple use zoning.

The Sable / Gully Marine Protected Area Pilot Project: Are We Meeting Ecosystem Objectives?

D. Fenton, P. Macnab and R. Rutherford,
Oceans Act Coordination Office, Oceans Branch, Bedford Institute of Oceanography

The Gully is a deep submarine canyon that separates Sable Island Bank from Banquereau Bank. In December 1998, the Gully was announced as an Area of Interest (i.e. pilot project) in DFO’s Marine Protected Areas (MPA) program. This presentation provides an ecological overview of the area, a history of resource use, a chronology of conservation efforts, some detail on proposed conservation objectives and an examination of several key activities as they relate to ecosystem concerns. The ecosystem objectives stated at the beginning of this workshop share many similarities with the conservation objectives articulated for the Gully: to maintain ecological integrity and biological diversity, to provide a refuge area for species at risk, to protect core habitat for northern bottlenose whales, to maintain environmental quality, to prevent alterations to physical processes, to minimize disturbance to benthic communities, to protect finfish diversity and age structure and to develop the Gully as a scientific reference area. Given these conservation objectives for the Gully, there are specific activities that might not be consistent with meeting the objectives. For example, if we intend to minimize disturbance to benthic communities and protect coral, aggregate mining may be considered inappropriate. At the present time, the main activities in the area are hydrocarbon development, fisheries and shipping. When the Gully MPA initiative was announced, DFO committed it to interim protection and a stipulation that no new activities be allowed in the Area of Interest (AOI). Oil and gas activity has not been permitted by the Canada-Nova Scotia Offshore Petroleum Board since 1998 and an eastern extension to the foreign silver hake fishery in 1999 excluded the Gully AOI. From the range of specific concerns and issues being examined by the Oceans Act Coordination Office, cetacean bycatch and noise impacts are presented here in detail. Whales, seabirds and turtles are subject to accidental capture in various types of fishing gear throughout the ESSIM area and at least one entangled northern bottlenose whale has been reported in the Gully AOI. Various precautionary measures and management options are discussed. The uncertain impacts from sound associated with seismic operations around the AOI are more difficult to quantify. Targets are elusive owing to minimal knowledge of sound propagation, unpredictable biological response and varying definitions of acceptable exposure levels. Furthermore, a measurable decibel and frequency range will be difficult to regulate, monitor and enforce. Beyond these examples, all existing and potential activities need to be assessed against conservation objectives. Potential management measures require careful consideration by DFO, industry participants and other regulators to ensure that conservation targets will be met and that ecosystem objectives are not compromised.

The Emerald – Western Juvenile Haddock Closure
K. Frank, Marine Fish Division, Bedford Institute of Oceanography

A juvenile haddock (*Melanogrammus aeglefinus*) closed area was established on the offshore banks (Emerald and Western) of the central Scotian Shelf (in NAFO Div. 4W) in 1987. The fishery management objective associated with the establishment of the closed area was to protect incoming recruits and thereby allow the stock to rebuild. Our evaluation of the effectiveness of the closed area revealed that the management objective was not fully met. The expected trend of declining juvenile mortality coincident with the establishment of the closed area (and high mortality preceding its imposition) was not readily apparent. The lack of response expected from the imposition of closed area may have been due to several factors: 1) the proportion of juveniles within the closed area steadily declined and a majority of year-classes during the post-closure period remained unprotected; 2) the closed area remained open to fishing by fixed gear whose catches inside the closed area and surrounding areas in Div. 4W steadily increased; and 3) the resident haddock stock deteriorated in terms of growth and condition due to a combination of historical over-exploitation and large-scale environmental changes. The closed area does appear to have had some benefit to other groundfish species in terms of increased abundance, notably American plaice (*Hippoglossoides americanus*) and winter flounder (*Pseudopleuronectes americanus*).

Discussion

It was asked what were the criteria used in drawing the Area of Interest boundary of the Gully MPA and did marine biodiversity considerations play in the identification of these and the regulations of the MPA. A core area centered on key cetacean habitat served as the initial boundary and was subsequently expanded to include other physical features that capture the overall canyon environment. The biodiversity criterion used was the habitat diversity as predicated upon seabed topography.

It was queried as to the purpose of the Gully MPA, to which it was replied that much of the original focus of conservation efforts by DFO and others was to conserve whales (primarily Northern Bottlenose) and corals in the area. Current efforts in developing a management plan are broadening out the purposes for the area as an MPA, such as benthic biodiversity conservation and its role as a scientific reference area. The current Gully Science Program is providing further information to support this effort.

How does the Gully MPA differ from a fishery closure? Should it be a no-take zone? A fishery closure only relates to fishing activities. Regarding it being a no-take zone, this could be one of the options but this hadn't been considered to date. Further research into the role the Gully as a complete no-take area and any subsequent benefits to currently fished populations, such as halibut, need to be investigated.

It was asked what role would the Gully play in developing ecosystem approaches to ESSIM (and *vice versa*). It is a component of the larger ESSIM system and will be considered in that context.

Questions were asked regarding DFO's obligation to monitor an MPA after its declaration. It was stated that monitoring needs and associated costs would be included in the management plan.

There was discussion on the criteria used to select an area for an MPA. Guidance for the Canadian situation could be gained from Australia, where 17 criteria are used, grouped according to representativeness, comprehensiveness, uniqueness, naturalness, ecological importance, national/international importance, biogeographical importance, productivity, and vulnerability. The weighting of these selection criteria depends upon the objectives of the particular MPA. It was suggested that the ESSIM initiative obtain and consider the specifics of these criteria and any others.

The presentation on the haddock box underlined the importance of considering fishery closures as a part of the overall regulatory package. As seen elsewhere in the world, without appropriate safeguards, a closure will simply redistribute effort and lead to increased exploitation elsewhere. For haddock, the closure could not be considered a success, as the timing was bad with respect to environmental, effort and stock dynamics. However, there is evidence that it enhanced larval export downstream. Thus, there may be collateral impacts on the ecosystem (due to displaced effort), as well as collateral benefits to the ecosystem in the recruitment of both target and non-target species.

There was a general discussion on the use of MPAs to meet ecosystem-based objectives. It was considered that they are a valuable tool to meet the objectives relating primarily to ecosystem and species diversity, but would have implications for the other objectives as well. In particular, it would be useful to define representative areas that would not be impacted by human activities. This would serve two purposes. First, it would allow maintenance of ecosystem diversity and second, it would provide control areas to which other areas impacted by human activity could be compared.

It was proposed that MPAs be used in the ESSIM area to maintain benthic ecosystem diversity. It was suggested that the benthic habitat types in the ESSIM area be described and located and that a representative percentage (figures of 5 to 10 percent were suggested) of the total area of each type be allocated to MPAs. Others asked about the need to consider pelagic diversity and inshore, intertidal areas. This lead to discussion on whether or not these areas should be take or no-take/no-activity. What activities would be allowed or excluded? There is a need to evaluate the activities that would negatively impact ecosystem diversity so that they could be excluded. In many cases, then, these would be no-take zones, which would also best serve the scientific need for reference or control areas. It was suggested that a group of experts be established to define the ecosystem types in the ESSIM area, examine the human activities in these areas, and develop proposals for MPAs.

Monitoring Needs

The effectiveness of MPAs in the ESSIM area will critically depend upon monitoring of the indicators stated elsewhere in this report, associated with the six ecosystem objectives. Some new socio-economic indicators, specific to particular MPAs, may also be required.

Monitoring needs concerning the Gully will be developed as part of the current Gully Science Program and the resources and efforts required will be identified as part of the upcoming MPA management plan.

SUMMARY

Precautionary Approach Framework

A Precautionary Approach (PA) framework suitable to guide ecosystem-based management for the ESSIM initiative should have the following elements:

1. Long-term objectives for management

2. Strategies, which include the use of
   - limit reference points for unacceptable outcomes and target reference points for acceptable outcomes
     - reference points must be operational, meaningful, relevant, responsive, and comprehensive

3. Account of uncertainty, by
   - demonstrating that proposed actions have a good chance of achieving goals and avoiding limits
     - lack of scientific proof of causality should not be used as a reason for inaction (reversal of burden of proof)
     - stakeholders need to be represented and encouraged to provide input to the determination of "acceptable level of risk"
   - monitoring ecosystem and human activity (through indicators) and measuring uncertainty, as well as describing the interaction between ecosystem and human activity
     - proponents of a new ocean activity should be responsible for providing the necessary data to evaluate impact

4. Decision-making process, involving
   - pre-agreed actions or decision rules, which imply agreement on the indicators and actions to be taken depending on the state or magnitude of the indicators in relation to the reference points
   - proactive (e.g. have control rules) and reactive (e.g. ability to respond to unexpected events) decision-making
   - adaptive, conservative management for all new activities (including new fisheries, oil exploration, etc.)

5. Performance evaluation of entire management system, including the relevance of the objectives, and the applicability of the indicators and reference points
   - need to identify problem areas and whether actions are appropriate to solve the problems
   - performance evaluation must be outcome-oriented rather than process-oriented

In relation to the long-term objectives, it was felt that as a guide for the ESSIM initiative, human activities should be managed so as to maintain within acceptable bounds:

1. The diversity of ecosystem types
2. Species diversity
3. Genetic variability within species
4. Productivity of directly-impacted species
5. Productivity of ecologically-dependent species
6. Ecosystem structure and function
7. Marine environmental quality

As there were questions as to whether these were ecosystem objectives or attributes, it was agreed that a group of experts should be established to develop a series of descriptors for each of the seven objectives in order to clarify what they encompass. This team could also make the link between these objectives and the principles and approaches given in the Oceans Act.

For the strategies, the workshop considered indicators as being time series of estimates of attributes of the system. Limit reference points, associated with unacceptable outcomes, are specific values of these indicators. Current status of indicators in relation to reference points determines management actions. It was acknowledged that, in addition to indicators that reflect the performance of management measures, there are also indicators of system behaviour that, while not used for management actions, facilitate our understanding of the ecosystem.

In relation to taking account of uncertainty, ideally, a causal link between management action and resource response can be made. However, it is evident that correlation, which may not indicate causality, will have to drive decision-making in the foreseeable future, a fact that must be recognized by all involved in the decision-making. It then becomes important to state who determines the level of risk. Stakeholders must be involved in the decision-making process. To temper the amount of risk acceptable to any one sector, it is advantageous to broaden the stakeholder base in decision-making. This implies that the indicators and associated reference points would be agreed to by the stakeholders. Also, the proponents of an activity must be tasked with defining and collecting acceptable baseline information against which impacts can be judged.

Regarding the decision-making process, the workshop considered that the management system needs to be not only proactive, but also reactive, in the sense that it must be able to react to unforeseen events. The Traffic Light method has promise in facilitating communication and decision-making and the FMSWG was encouraged in its investigations. It was suggested that a simulation be undertaken to illustrate how the Traffic Light method would have performed using historical information. Also, it would be useful to try out the approach in a simulated decision-making setting cooperatively with a sample of stakeholders.

In performance evaluation, it is important to ensure that overall system performance is reviewed and problems are resolved as needed. This will prevent faults in the functioning of the overall system, and not just those monitored by defined indicators. Focus on the latter may result in overall system failure. The system should be outcome, rather than process, oriented.

Management Considerations

The working paper by Herbert et al presented a series of recommendations by oceans sector on the changes required to incorporate ecosystem-based objectives into current planning. The workshop did not review these in detail but felt that they would serve as a useful base for further development. However, the workshop considered that the main conclusion was that there is a need for new institutions (e.g. management board) to coordinate activities of all existing agencies. The approach would be to initially develop a forum, anticipating that this may lead to the formation of a management board. Currently, interdepartmental coordination is mostly done by MOUs and similar mechanisms.

Integrated governance would solve many problems. A common set of ecosystem – based objectives could be adopted by all sectors in all management plans. With a common set of objectives, each ocean sector could judge where and how they may be having impacts or require specific actions. Where such management plans do not exist, they should be created.

The question was raised on the first day as to whether or not ESSIM should extend inshore. The present pilot initiative is restricted to seaward of 12 nautical miles. It was agreed that science should consider all relevant geographic areas influencing the eastern Scotian Shelf. Unfortunately, for the inshore, the knowledge base is not as solid as it is for the offshore. On the other hand, governance of the inshore, while intended, will have to occur gradually and will perhaps occur within the next 1-2 years.

Based on the presentations made on the second and third days, it was queried whether or not the ESSIM area should be divided into ecologically defined sub-areas. It was agreed that different systems and processes are scale-dependent and that, to determine impacts, it will be necessary to consider different areas depending on the activity. For example, oil and gas impacts may have to be examined on a shelf-wide basis. Oceanographers can divide or extend the area under study depending on the appropriate scale for the question being asked. Therefore, a nested approach to management should be taken, with the scale of study and management related to the human activity in question. Nevertheless, as much as possible, ecological areas should form the basis for evaluation of ecosystem-based management.

Trends

Based on the presentations made at the workshop, the following two sections were compiled which describe the trends in the various components of the Eastern Scotian Shelf ecosystem.

Oceanography, the Benthos and Biodiversity

A summary of the trends is provided in Table 2.

Physical Oceanography: From a physical perspective, the eastern Scotian Shelf can be characterized as an advective system, whose properties reflect inputs from other geographic areas. This, in turn, contributes to high seasonal and inter-annual variability in temperature, salinity and nutrients. Clockwise flows around the offshore banks and counter-clockwise flows around the deep basins typify circulation patterns within the region. Numerical models are providing important insights into the details of the circulation in the spatial domain and in the future it is hoped that such models will provide insights into year-to-year variability. Important physical differences exist within the eastern Scotian Shelf. In the northeast, the water column structure during summer is two-layered, there is restricted exchange with slope water, and the area is highly influenced by the Gulf of St. Lawrence. This is contrast to the central region where the water column structure is three-layered during the summer, slope water exchange is common and the Gulf of St. Lawrence only weakly influences the area.

Nutrients, Phytoplankton and Zooplankton: In general, large-scale connections exist between inter-annual patterns on the Scotian Shelf and other areas of the northwest Atlantic. Also, deep-water nutrients are strongly correlated with the hydrographic properties and may provide suitable proxies in the absence of direct measurements. In the northeast portion of the eastern Scotian Shelf, a large spring bloom is evident in addition to a less dominant fall bloom. In the central region, a moderate spring bloom is evident but there is an absence of a fall bloom. Data from the Continuous Plankton Recorder show that during the 1960s/70s, the greenness index was relative low compared to the 1990s. The abundance of copepods and krill was relatively high during the 1960s/70s. Collectively, this information, in combination with our knowledge about the current status of pelagic and groundfish resource levels in the region, suggests the existence of a trophic cascade. Groundfish levels are currently very low, pelagic biomass levels are believed to be very high, zooplankton is currently low and phytoplankton (greenness index) is high. The reciprocal difference in abundance among adjacent trophic levels is evidence for the trophic cascade.

Larval fish diversity: The most comprehensive source of information to assess larval fish diversity on the Scotian Shelf comes from the Scotian Shelf Ichthyoplankton Survey. This program was active only during the late 1970s/early 1980s and therefore any characterization of patterns may only be applicable to that period. On the eastern Scotian Shelf, larval fish diversity and abundance was at a relatively stable high from April to September/October, but the taxon composition changed. Also, the majority of taxa were not dependent on the spring/fall bloom of calanoid copepods, rather it appears that a diversity of food webs supports the production of larval fish. Larval fish diversity was particularly high on Western and Sable Island Banks and low diversity typified the northeast portion of the shelf. Given the perceived changes in relative composition of adult fishes in the area, it is possible that changes in both species richness (taxon composition) and the evenness component of diversity may have changed.

Benthos and contaminants: The benthos is almost unknown component of the eastern Scotian Shelf. Very little empirical data exists to characterize spatial and temporal patterns of the benthos, with the exception of commercially important species such as scallops. Sediment type provides an approximation of the benthic community composition but does not give any information about productivity. The highest concentration of contaminants is observed inshore, particularly in Halifax and Sydney harbours. The Gulf of St. Lawrence is the biggest upstream source of contaminants and suggests that the northeastern part of the Shelf may be more impacted than other areas.

Table 2. Characterization of Oceanographic, Planktonic and Benthic Components of the Eastern Scotian Shelf Ecosystem

Physical Oceanography

Northeast	*Central*
Similarities: • both areas advective and exhibit high seasonal and inter-annual variability in T, S, and nutrients • associated with general flows are clockwise circulation around offshore banks and counter-clockwise flows around deep basins • modeling is providing important insights into the details of the spatial domain and in the future the temporal domain	
• 2 layered in summer	• 3 layered in summer
• Restricted exchange with slope water	• Slope water exchange is common
• Highly influenced by GSL	• Weakly influenced by GSL

Nutrients and Phytoplankton

Northeast	*Central*
• Large spring bloom	• Moderate spring bloom
• Fall bloom evident	• No fall bloom
General patterns: • nutrients in deep water are strongly correlated with hydrographic properties • large-scale connections exist between inter-annual patterns on Scotian Shelf and other areas of the NW Atlantic (seen also in hydrography and zooplankton)	

Zooplankton

Northeast	Central
General patterns: • ratio of *C. hyperboreus* to *C. finmarchicus* higher in ESS • abundance and timing of C.f. show differences between the two areas • large differences in the greenness index between the 1960s/70s (low) vs. the 1990s (high) • large differences in C.f. and krill between the 1960s/70s (high) vs. the 1990s (low) • suggestion of possible trophic cascade: greenness ↑, zooplankton ↓, pelagics ↑, groundfish ↓ Note: no examination of patterns within NE and Central Scotian Shelf; only comparisons between Eastern SS and Western SS	

Larval fish diversity

<table>
<tr><th>Northeast</th><th>Central</th></tr>
<tr><td>• Based on data from the early 1980s, larval fish diversity relative low</td><td>• Larval fish diversity relatively high, particularly on Western and Sable Island Banks</td></tr>
<tr><td colspan="2">• Diversity and abundance was at a relatively stable high from April to Sept/October, but taxon composition changed
• Majority of taxa not dependent on spring/fall bloom of calanoid copepods, rather diversity of food webs support larval fish production</td></tr>
<tr><td>• Possible assemblage differences given influx of cold water species</td><td>• Possible changes in evenness component of diversity given perceived dominance of pelagics</td></tr>
</table>

Benthos

<table>
<tr><th>Northeast</th><th>Central</th></tr>
<tr><td colspan="2">Facts :
• almost an unknown component of the ecosystem
• likely that sediment type will provide approximations of community composition (but not abundance)</td></tr>
</table>

Contaminants

<table>
<tr><th>Northeast</th><th>Central</th></tr>
<tr><td colspan="2">High concentrations seen inshore (e.g. Halifax and Sydney harbour)</td></tr>
<tr><td>• Given that GSL is the biggest source of contaminants (i.e. heavy metals), expect higher concentrations in the NE</td><td></td></tr>
</table>

Fisheries and the Ecosystem

Over the past 30 years, DFO has carried out trawl surveys of the Scotian shelf that allow us to track changes in the species and size composition of fish communities, and to track changes in the physical environment. Bottom temperatures on the eastern Scotian shelf became very cold during the late 1980's and have remained cold until very recently. During this cold period, the eastern shelf was invaded, and in some cases colonized, by a number of cold-water fish and shellfish species like capelin, turbot, northern shrimp, and snow crabs. During warmer period, these species are more prevalent in the colder waters of the Gulf of St. Lawrence or the Grand Banks to the north. The reduced numbers of cod and other predators (which feed on these species) may also have contributed to these population increases. Since the 1970s, average weights of commercially targeted demersal fish decreased by 51% on the eastern shelf and by 41% on the western shelf. For both systems, the integrated community size frequency showed long-term declines in proportions of large fish, and trawlable biomass of most targeted species is presently at or near the lowest observed. In the east, these changes were coincident with a doubling of fishing effort, and a decline in bottom temperature to the lowest in 50 years. In the west, fishing effort more than doubled while bottom temperatures reached the highest in 50 years. In both systems, declines in biomass and average weight were more prevalent for commercially targeted species than for non-target species. Since the closure of the cod fishery on the eastern shelf in 1993, and the restrictions on landings on the western shelf, average weights and the integrated community size structure have stabilised. In the east, this stability is associated with increasing bottom temperatures and reduced effort while in the west, it is concurrent with reduced landings and high bottom temperatures. Both fishing and changes in bottom temperature have influenced demersal fish size but that the relative effects cannot be determined from current observations.

Indicators

The Precautionary Approach framework requires the development of indicators and reference points associated with each of the ecosystem objectives. The workshop made some progress on this but much is still to be done. The potential indicators discussed for the oceanography, benthos and biodiversity are summarized in Table 3.

Table 3. Potential Indicators for the Physical and Biological Oceanography, the Benthos, and Contaminants related to the ESSIM initiative (presently have no indicators for larval fish diversity nor abundance estimates of individual species)

- volumetric T and S analysis (defining quantities of specific water mass types)
- stratification
- current patterns (hind-casting and fore-casting of)
  - strength
  - direction
  - retention indices
  - etc.
- sea ice
- contaminants
  - heavy metals
  - oils
  - PCB's
  - etc.
- location, amplitude, timing and duration of the spring bloom
- species composition (e.g. diatom/dinoflagellate ratio)
- CPR abundance of dominant species and their relative proportions
- habitat diversity based on bottom type

Maintenance of the diversity of ecosystem types

The diversity of ecosystem types refers to assortment of ecosystem communities that one observes rather than the diversity of species within each ecosystem. For example, the benthos is composed of a number of different communities, dependent upon water depth, substrate, temperature and other factors. The workshop considered each component of the ecosystem and where possible suggested potential indicators for each.

In relation to the diversity of planktonic communities, some of the talks presented indices of diversity trends but these were not linked to the diversity objective, or management measures. The degree of understanding of this component of the ecosystem is too limited to provide indicators and associated reference points. On the other hand, the indices discussed give insight into the structure of the ESSIM ecosystem and how it compares to systems elsewhere. In the case of the ichthyoplankton community, diversity indices for this community might better reflect that in the ecosystem, as compared to those calculated using more selective gear types (e.g. bottom trawls).

In relation to the diversity of the benthos, while no indices were presented, there was a need identified to define the number of ecosystem types (based on bottom type, depth, water flow, etc), evaluate the amount of total area of each type which is being used or impacted by various categories of human activities, and monitor changes in diversity. In this case, diversity indicators could be the number of benthic ecosystem types and the total area by ecosystem type that is impacted by human activity. Reference points would need to be established on the percent usage by ecosystem type, which requires knowledge of the impacts. To judge these, the idea raised during the MPA discussion of using control areas was considered useful.

The situation in relation to the pelagic fish communities was discussed. Enumerating the number of ecosystem types here would be very difficult. The workshop did not pursue this further.

Maintenance of species diversity

Species diversity refers to the number and type of species within each ecosystem type. If one wishes to determine species diversity at all levels (virus to whale), a considerable amount of work is required, some of which may be impractical. It was recognized as important to know the species composition, as each species has a potentially different function within the ecosystem.

Notwithstanding this, it was agreed that, to achieve the ecosystem-based objective related to species diversity, it is necessary to prevent the extinction of species, and introductions of new species, as a result of human activities. The issue of endangered species was raised on the second day of the workshop, during which, it was noted that Canada has and will be using the IUCN criteria, along with relevant life history information to determine whether or not a species is vulnerable, threatened, endangered, etc. Numerous concerns regarding the IUCN criteria were raised and there was a need identified for Canada to adopt alternate ‘species at risk’ criteria for marine organisms.

The presentation by Kenchington provided a number of potential indicators (e.g. range contractions, population fragmentation, number of spawning units, critical habitat, exotic species, etc) applicable to the species diversity objective. These could be used as a set of scanning criteria to develop a list of potential 'species of special concern' - species that could qualify for special monitoring needs. The workshop considered that a group of experts should be established to both develop the criteria further and prepare a report on the application of these criteria to the species in the ESSIM area.

Account needs to be taken of marine introduced species as well. The effects of invasive and introduced species may be extremely important. For example, on the eastern Scotian Shelf, there may have been major changes in the benthos due to invasion by *Codium* (a green alga) & others. Regarding landbased and freshwater introductions, these need only be considered if they impact the ESSIM objectives.

Maintenance of genetic variability within species

Genetic variability within species relates to the population structure - the number of stocks or stock components of a species in an area and the genetic makeup of each. During the discussion on the second day, a number of potential indicators were proposed to measure genetic variability within a species. Along with those mentioned in the species diversity section, these include:

- Survey Numbers/Biomass
- Sex ratio
- Fecundity
- Selection Differentials

Further work on these indicators was recognized. It was considered that a group of experts should develop the indicators further and apply these on a case study basis to the resources in the ESSIM area.

Maintenance of the productivity of directly-impacted species

Directly impacted species are those that some ocean use activity directly effects in some manner. For example, in the case of fisheries, these would be the species targeted for harvest, whereas in the case of oil and gas exploration, these would be the species that would be directly impacted by the products of seismic, drilling or production activity.

The workshop acknowledged the on-going work in Marine Fish Division on indicators and reference points for Scotian Shelf finfish and encouraged these efforts. Some of this work has already been tabled in RAP as part of the fisheries management planning process. Eventually, it would be useful to prepare a list of all species (commercial and non-commercial) in the ESSIM area, along with associated indicators and, where possible, reference points.

Maintenance of the productivity of ecologically-dependent species

The definition of ecologically dependent species is important. The workshop generally considered these species to be those that are directly linked through the food chain (immediate predator and/or prey) to those species directly impacted by human activities.

A number of potential indicators were discussed, all of which need further development.

The biomass of forage species at a specific trophic level could be calculated and a limit reference point (biomass below which one should not fall) defined as 75 percent of the virgin biomass. Indicators based on fish condition were also suggested.

For marine mammals, potential indicators include:

- optimal sustainable population size
- potential biological removal (PBR)
- foraging trip duration of lactating female
- weaning mass of young
- juvenile growth rate
- pregnancy rate
- age at maturity

For birds, indicators, such as the number of deaths that will prevent a population from recovering, could be developed using a PBR approach. Other indicators could be based on breeding success. It will be necessary for scientists in DFO and Environment Canada to develop these indicators further.

Maintenance of ecosystem structure and function

The workshop considered indicators and reference points in relation to the overall structure and function of the ecosystem. For instance, are there some characteristics of the ecosystem that can be measured that indicate its state and how it is changing? This is an active area of research globally but the issues are very complex.

During the workshop, a number of potential indicators of ecosystem structure and function were presented. The one that showed the most promise was the slope of the size spectrum, perhaps calculated by guild or trophic level. Pauly's FIB index is another possibility. Unfortunately, our level of understanding of ecosystem structure and function is very limited and it is not possible to recommend reference points in relation to these indicators.

It was suggested that, as part of the ESSIM initiative, impacts (e.g. fishery removals) by trophic level should be monitored as a first step towards ensuring the maintenance of ecosystem structure and function.

Maintenance of marine environmental quality

The workshop noted that contaminant guidelines apply primarily to the inshore area. Their application to the offshore needs to be rethought. Some information exists that could be compiled to provide guidance to the ESSIM initiative. The workshop suggested that a working group of the appropriate experts be established to compile the existing information on indicators and reference points for the offshore area. Also, the Green Plan Toxic Chemicals Program report should be finalized and published.

Monitoring Requirements

The list of monitoring requirements, that is provided in Table 4, is a compilation of all the stated needs made throughout this report. This monitoring will generate data products, which may or may fill the requirements of specific indicators. Therefore, the monitoring requirements shouldn't be finalized until the indicators are fully identified. The workshop agreed that once the indicators have been identified, the list should be revisited. The eventual prioritization of monitoring requirements should be based on their relevance to the indicators - will the data products provide sufficient monitoring of the indicator? It was recognized that some data products might not directly relate to indicators relevant for management but will be helpful in interpreting changes in the ecosystem.

The collection of this information will not be possible without assistance from the ocean industry. The increased costs of monitoring will have to be borne by the users of the environment. This is consistent with Canadian Environmental Assessment (CEA) requirements. It is important to consider, then, a process whereby the ocean's industry both provides funds and has input into how it is spent. The concept of a joint government/industry fund was discussed. There are already negotiations and agreements in place with the oil and gas industry on this issue. These discussions might profitably be expanded to include other ocean sectors.

If industry funding can cover most of the routine monitoring needs, government funding might best be primarily directed at auditing activities and research issues. The workshop noted the existence of the DFO Science Strategic Science Fund, whereby funding for national and zonal research questions is made available. DFO needs to ensure that internal funding mechanisms are in place to support the research questions emerging from the new ocean mandate.

If the proponent pays, who owns the data? A policy on data ownership following these monitoring or characterization activities is required. As part of this, data archiving and availability needs to be considered.

The above issues implicate the stakeholders. It is suggested that the ESSIM initiative form a working group with ocean sector involvement to discuss monitoring requirements, funding and data ownership.

Table 4. Monitoring Requirements of the ESSIM Initiative

Component	Historical information?	Current monitoring?	Adequacy?	Specifics
Hydrography	>50yrs	Yes	Yes	Additional CTD stations at shelf edge (200 – 1000 m) on AZMP Halifax & Louisbourg sections Additional CTD stations on Groundfish Surveys Additional CTD section across Gully & east of Sable Is. Extend St. Pierre AZMP CTD section
Circulation Modeling	>50yrs	Yes	Yes	Current measurements at 'key' locations and seasons (central ESS, end of Halifax Line, deep Gully, slope), drifters off western Cabot Strait (see text for details)
Contaminants	Sparse	No	No	Inshore: Load in shellfish, closure stats, eutrophication trends Offshore: Seasonal Cabot Strait outflow, decadel survey of sedimentary basins, dissolved/dispersed oil in water-column
Nutrient/ phytoplankton	>20yrs, non-continuous	Yes	Yes	Winter nutrient distributions Community structure & diversity changes
Meso/ macrozooplankton	>30yrs, non-continuous	Yes/no	Yes/no	Adjustment of AZMP sampling for mesozooplankton Periodic macroZ surveys in basins (integrate into AZMP?); need better net sampling than acoustic sampling Community structure & diversity changes
Ichythyoplankton	1978 – 85/Shelf 1972 +/ BoF	No	No	Contemporary surveys (integrate within AZMP?)
Benthos	Sparse	No	No	Large-scale macrofauna distributions Time-series sampling of infauna/Epifauna Trawl survey analysis for Megafauna Micro-scale spatial survey for macrofauna distributions (details in text)
Species at Risk	Various surveys	Yes	Yes	Calibration surveys for catchability
Genetic Diversity	Various surveys	Some	Some	Range contraction, Pop fragment., spawning units, critical habitat Population size, sex ratio, fecundity
Directly impacted species				
Compliance	Limited	Limited	No	Discard & compliance monitoring of fishing regulations
Fishing effort	1963+	Yes	Yes	Assurance of reliable location info for all ocean use activities by gear type
Finfish	1960s/1970s+	Yes	No	Complementary small pelagics & juvenile/forage spp. surveys Calibration surveys for catchability
Invertebrates	Surveys since mid-80s and mid-90s, non-continuous	Yes/Not always for by-catch Yes-large vessel	No	Omnibus survey (would require different sampling gear than currently used in Groundfish Surveys) Calibration surveys for catchability

Component	Historical information?	Current monitoring?	Adequacy?	Specifics
Ecologically-dependent species	Surveys of some spp.	Limited	No	Complementary surveys Systematic stomach content monitoring
Ecosystem Structure & Function	Various	Limited	No	Improved estimates of by-catch profiles based on observations of catch onboard rather than landings Complementary surveys
Mammals	Sparse for most spp. Grey Seals – >30yrs	Yes (Greys)	Some	Pinnipeds (Greys): currently, 3 year survey. If density-dependence established, annual surveys will likely be required Cetaceans: 5-10 year comprehensive survey recommended; annual surveys not useful & 'Year of the Whale' approach better
Seabirds	>20yrs (temporal/ geogr. gaps)	No	No	Selective ship-based observations and aerial surveys to fill spatial/temporal gaps Sensitive sites (breeding/molting areas) PAH monitoring of mussels at selected remote island sites Winter (non-breeding season) diets Breeding performance (outside ESS region)

Use of Marine Protected Areas

The workshop was given the following three questions to answer:

1. To what degree does the Sable/Gully proposed MPA meet potential ecosystem objectives of ESSIM?
2. What ocean use activities are consistent with meeting the objectives?
3. Are additional MPAs needed within 4VW to meet ecosystem objectives?

In relation to the first question, the workshop noted that MPAs are a valuable tool to use in meeting the objectives relating to ecosystem and species diversity, and have implications for meeting the other objectives as well. For instance, unless there are appropriate regulatory safeguards, closures can displace human activity elsewhere and cause localized negative impacts, particularly in regards to the productivity of commercial and non-commercial species. The proposed Gully MPA, for instance, will be designed to protect vulnerable species and a range of seabed habitats, but the degree of protection may be limited if it does not include a no-take/ no impacting activity zone. It was not possible to evaluate how the Gully MPA fit within the context of the broader protection of the ecosystem types within the ESSIM area without knowing the location of these. There are for instance basin and shallow marine ecosystem types not included in the designated area. Other sensitive and important ecological areas would need to be identified and set aside for restricted ocean use activity to maintain benthic ecosystem type diversity.

In relation to the second question, the answer depends on the objective of each particular MPA, but it is evident that some activities (i.e. those that physically disrupt the seabed and those that degrade the quality of the water column) are less likely than others to be consistent with the ecosystem objectives. The workshop noted the need to evaluate the activities that would negatively impact the ecosystem diversity so that these could be excluded from MPAs. In many cases, then, MPAs would be no-take/no-activity zones, which would also best serve the scientific need for reference or control areas.

In relation to third question, the workshop proposed that MPAs be used more broadly in the ESSIM area to maintain benthic ecosystem diversity, and to protect distinctive ecological and biological features. It suggested that, based on present knowledge, the spatial distribution of benthic ecosystem types be mapped within the ESSIM area. Present ocean use activities could then be superimposed on this map to determine the proportion of each type that is disturbed. This analysis would lead to the definition of additional areas that require special protection. 10 percent was suggested as a minimum area of each type that needs to be undisturbed, but it was recognized that this percent would vary by ecosystem type (e.g. deep corals may require a higher percent of protection than sand – based communities). A working group of experts would be required to undertake these analyses.

During the workshop, there was considerable discussion on whether or not MPAs should be used as reference areas. It was felt that, besides protecting the resource, they do have a valuable function to play in providing reference areas to which human impacts elsewhere can be compared and evaluated.

CONCLUDING REMARKS

This workshop was another step towards ecosystem-based management in the Maritimes Region. It proposed a precautionary approach framework for the Eastern Scotian Shelf Integrated Management pilot initiative, considered the changes needed to existing management measures and plans, reviewed the scientific information available and required to support ecosystem-based management, and examined one particular management tool, the Marine Protected Area. It was a challenge to the scientific community to not only consider the concepts and needs ecosystem-based management, but also to work as a team towards achieving these. A number of suggestions and proposals were made which will, if acted upon, lead to a considerably enhanced capability by the scientific community to support ecosystem-based management. The challenge is to DFO to make the changes required to meet the new demands of the Oceans Act.

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APPENDICES

Appendix 1. Workshop Remit

The general aim of the workshop was to provide a synthesis of scientific and technical information of relevance to the Eastern Scotian Shelf Integrated Management (ESSIM) pilot initiative. The specific objectives for the workshop were:

1. To provide a Precautionary Approach framework for ecosystem-based management

2. To describe conservation objectives and regulatory measures for existing management plans, policies, and programs of government and ocean industries in the ESSIM area (including fisheries, oil/gas, etc.) and consider the changes needed to incorporate ecosystem objectives.

3. To describe long-term trends in the ESSIM area of the

    - Physical and chemical oceanographic conditions
    - Plankton
    - Species richness
    - Size spectrum
    - Exploited and by-catch species
    - Fishing effort by gear type and geographic area
    - Benthos
    - Marine mammals
    - Birds

4. To define indicators for the following potential ecosystem-based management objectives:
    - Maintenance of ecosystem type diversity
    - Maintenance of species diversity
    - Maintenance of genetic variability within species
    - Maintenance of directly impacted species
    - Maintenance of ecologically dependent species
    - Maintenance of ecosystem structure and function

5. To identify monitoring needs for selected indicators of the potential ecosystem-based management objectives.

6. To determine to what degree the Sable/Gully proposed MPA meets the potential ecosystem objectives of ESSIM, what ocean use activities are consistent with meeting the ecosystem objectives, and what additional MPAs are needed in the ESSIM area to meet these objectives.

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Appendix 3. Workshop Schedule

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Time	**19 June**	**20 June**	**21 June**	**22 June**	**23 June**
09:00 – 09:30	**Travel**	Oceanographic Trends / Drinkwater	Trends-Community Metrics / Zwanenburg	Monitoring Needs for ESSIM / Harrison & O'Boyle	Summary Discussion
09:30 – 10:00		Circulation Modeling / Han	Trophic Balance / Zwanenburg	Discussion	
10:00 – 10:30	Introduction / O'Boyle ESSIM Overview / Rutherford	**Break**	**Break**	**Break**	**Break**
10:30 – 11:00	Ecosystem Objectives / Sinclair	Trends-Contaminants / Yeats	Trends in Directly Impacted Species / Fanning & Smith	Discussion	Summary Discussion
11:00 – 11:30	Framework for ESSIM & Precautionary Approach / O'Boyle	Trends-Plankton / Harrison	Indicators / Fanning & Mohn	Objectives of Gully MPA / Fenton	
11:30 – 12:00		Trends-Plankton / Sameoto			
12:00 – 12:30	**Lunch**	**Lunch**	**Lunch**	**Lunch**	**Lunch**
12:30 – 13:00					
13:00 – 13:30	US Experience / Mace	Diversity-Mesoplankton / Head	Trends in Effort / Black	Additional Areas for Conservation/ Protection / Fenton	Summary Discussion
13:30 – 14:00	Australian Experience / Sainsbury	Diversity-Ichthyoplankton / Shackle			
14:00 – 14:30	Existing Mgt Plans / Potter	Benthic Patterns and Diversity / Hargrave	Marine Mammals / Bowen	Discussion	
14:30 – 15:00			Birds / Lock		
15:00 – 15:30	**Break**	**Break**	**Break**	**Break**	**Travel**
15:30 – 16:00	Existing Mgt Plans / Potter	Species at Risk / Bradford	Ecosystem Overview / Zwanenburg	Discussion	
16:00 – 16:30			CDEENA Overview/ Bundy		
16:30 – 17:00	Discussion	Diversity - Within Species / Kenchington	Discussion		
17:00 – 17:30					

Appendix 4. List of Documents (Copies of the presentations can be obtained directly from the Authors)

Fanning, P. 2000. Canadian Workshop on LMR-GOOS: Objective # 4 Exploited Species. Working Paper.

Halliday, R.G. 2000. Notes on Terminology. Working Paper.

Herbert, G. S. Coffen-Smout, R.G. Halliday, T. Potter, and N. Witherspoon. 2000. Ocean Activities and Ecosystem Objectives on the Eastern Scotian Shelf: Are Changes in Governance Required? Working Paper

Mohn, R. 2000. Maintenance of Ecological Dependent Species. Working Paper