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A Monitoring Framework for the St. Anns Bank Area of Interest

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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LIST OF ACRONYMS USED IN THE TEXT

AIS:	Automatic Identification System (for identifying ships)
AOI:	Area of Interest
AZMP:	Atlantic Zone Monitoring Program
BIO:	Bedford Institute of Oceanography
CESD:	Coastal Ecosystem Science Division
CIL:	Cold Intermediate Layer
CV:	Pre-adult stage in *Calanus* spp.
DFO:	Fisheries and Oceans Canada
DOC:	Dissolved Organic Carbon
ERAF:	Ecological Risk Assessment Framework
GSL:	Gulf of St. Lawrence
HOTO:	Health of the Oceans Program
IOS:	Institute of Ocean Sciences
IUU fishing:	Illegal, Unreported and Underreported fishing
LFI:	Large Fish Indicator
LRIT:	Long Range Identification and Tracking System
LSW:	Labrador Sea Water
MPA:	Marine Protected Area
MSFD:	European Union’s Marine Strategy Framework Directive
OCMD:	Oceans and Coastal Management Division
OESD:	Ocean and Ecosystem Sciences Division
OSD:	Ocean Science Division
PoE assessment:	Pathway of Effects assessment
TURFs:	Territorial User Rights in Fisheries
UXO:	Unexploded Ordnance
VHF:	Very High Frequency
VMS:	Vessel Monitoring System
WSW:	Warm Slope Water

ABSTRACT

Development of a Marine Protected Area (MPA) off Scatarie Island, Cape Breton, is in progress – the St. Anns Bank Area of Interest (AOI), having been announced during 2011. That Area extends from near-shore waters and the shallow crest of Scatarie Bank out to a portion of the deep floor of the Laurentian Channel. Effective, adaptive management of any MPA requires an extensive monitoring program to provide the information base for decision making. Such a program should be designed around the objectives of the MPA, the structures and functions of local ecosystems, anthropogenic pressures on those ecosystems, and the socio-economic benefits and costs of the MPA. Building on those foundations, this document sets out a recommended framework for the monitoring of a future MPA that may emerge off Scatarie Island, structured around 76 indicators. While data collection for some indicators would require surveys aboard Departmental research ships, others offer opportunities for collaborative monitoring work with local communities and institutes. Rationales for the selection of those indicators as well as an outline of the methodologies for their monitoring are provided, along with a proposed structure for program oversight and its continued development.

As a foundation for indicator selection, an initial account of the structures of the ecosystems in the AOI is offered, paying particular attention to its position astride both the Cape Breton Current and the major migration pathway, for fish, marine mammals and seabirds, into and out of the Gulf of St. Lawrence. However, much of the knowledge that should be critical to MPA planning and management has yet to be gathered, not least the details of the spatial distribution of benthic environments in the AOI. Hence, the account offered here can only be preliminary. Extensive baseline monitoring and research-oriented characterization studies are needed before every aspect of this framework could be developed further.

Un cadre de surveillance pour la zone d'intérêt du banc de Sainte-Anne

RÉSUMÉ

L'établissement d'une zone de protection marine dans la zone d'intérêt du banc de Sainte-Anne, située au large de l'île Scatarie, au Cap-Breton, est en cours et a été annoncé en 2011. Cette zone s'étend des eaux côtières et de la crête peu profonde du banc Scatarie jusqu'à une partie du lit profond du chenal Laurentien. Une gestion efficace et adaptative d'une zone de protection marine nécessite un programme de surveillance complet pour établir la base de renseignements éclairant la prise de décisions. L'élaboration d'un tel programme doit reposer sur les objectifs de la zone de protection marine, les structures et les fonctions des écosystèmes locaux, les pressions découlant des activités anthropiques sur ces écosystèmes et les coûts et avantages socioéconomiques liés à la zone de protection marine. À partir de ces fondements, ce document établit un cadre recommandé pour la surveillance d'une future zone de protection marine qui pourrait émerger du large de l'île Scatarie; le cadre repose sur 76 indicateurs. Bien que la collecte de données pour certains indicateurs nécessite des relevés à bord de navires de recherche du Ministère, d'autres collectes de données offrent des possibilités d'efforts de surveillance collaboratifs avec des collectivités et des instituts locaux. Les raisons derrière la sélection de ces indicateurs ainsi qu'un aperçu des méthodes de surveillance sont fournis, de même qu'une structure provisoire pour la supervision et le perfectionnement continu du programme.

À titre de base de sélection des indicateurs, un compte rendu initial des structures des écosystèmes dans la zone d'intérêt est fourni; celui-ci accorde une attention particulière à l'emplacement de la zone d'intérêt, laquelle est à cheval sur le courant du Cap-Breton et sur la voie de migration principale pour les poissons, les mammifères marins et les oiseaux de mer, à l'intérieur et à l'extérieur du golfe du Saint-Laurent. Bon nombre des connaissances essentielles à la planification et à la gestion d'une zone de protection marine n'ont toutefois pas encore été acquises, pas même les détails concernant la répartition spatiale des milieux benthiques de la zone d'intérêt. Par conséquent, le présent compte rendu peut uniquement servir de compte rendu préliminaire. Des études approfondies liées à la surveillance de base et à la caractérisation axée sur les recherches sont nécessaires avant toute élaboration supplémentaire d'un aspect de ce cadre.

INTRODUCTION

A search for new Marine Protected Areas (MPAs) to be designated under the *Oceans Act* led to the formal announcement, in June 2011, of an Area of Interest (AOI) straddling St. Anns Bank – off Scatarie Island, the easternmost tip of Cape Breton (Figure 1: see Figure 2 for locations of places named in text). Although it does not encompass all of the Bank and extends far beyond that one feature, covering approximately 5,100 km^2 in all from nearshore waters out to a portion of the deep Laurentian Channel, the Area has been dubbed the “St. Anns Bank AOI”. It was originally selected, as one of a score of potential MPAs on the eastern Scotian Shelf, through a network-planning exercise using the MARXAN analytical tool applied to a wide variety of data layers. As such, it was intended to protect both representative examples of some ecosystem types found more widely across the eastern Scotian Shelf and some particular biological features located within the AOI – a duality demanded of most MPAs by the need to use ocean space efficiently.

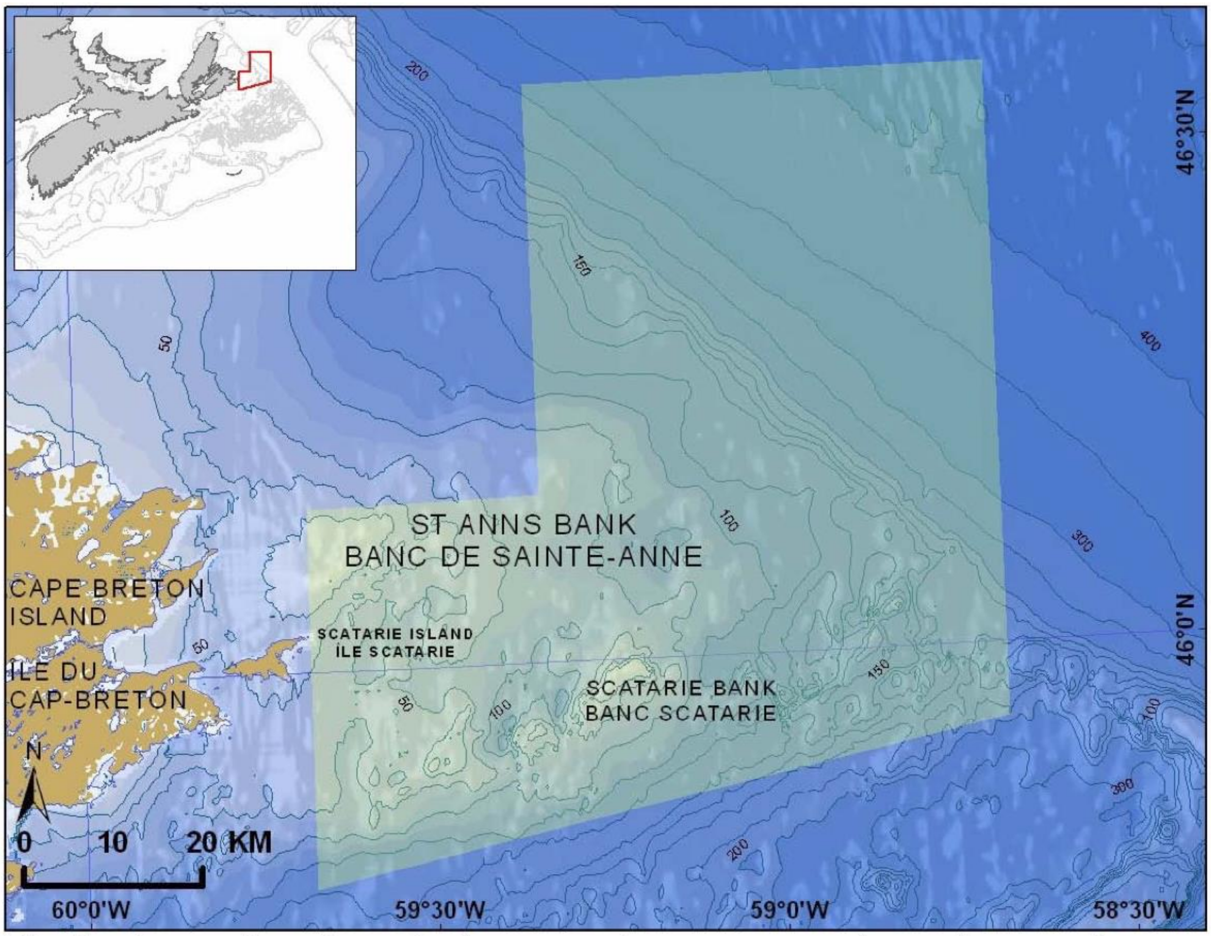

Figure 1: Location and extent of the St. Anns Bank AOI (in green tint). The boundaries shown are for information, study and consultation purposes only.

The process of designing an MPA in or around this Area is on-going. At the time of writing, late in 2012, its goals and objectives have been discussed (DFO 2012a,b) but are not yet set. Its boundaries remain fluid: a final MPA might extend beyond the AOI or might exclude wide portions of the current Area. The development of internal zoning and the drafting of regulations are awaited. Until those are finalized, it cannot be known which (if any) portions of the AOI might be closed to particular human activities, such as bottom fishing. The Ecological Overview and

Assessment Report, which should form the foundation of the design, is still in draft. The scientific research needed to characterize the ecosystems of the Area ahead of a potential MPA designation is on-going, while no attempt has yet been made to define future research requirements following the pre-designation work. Indeed, it is not certain that any MPA at all will eventually emerge off Scatarie Island.

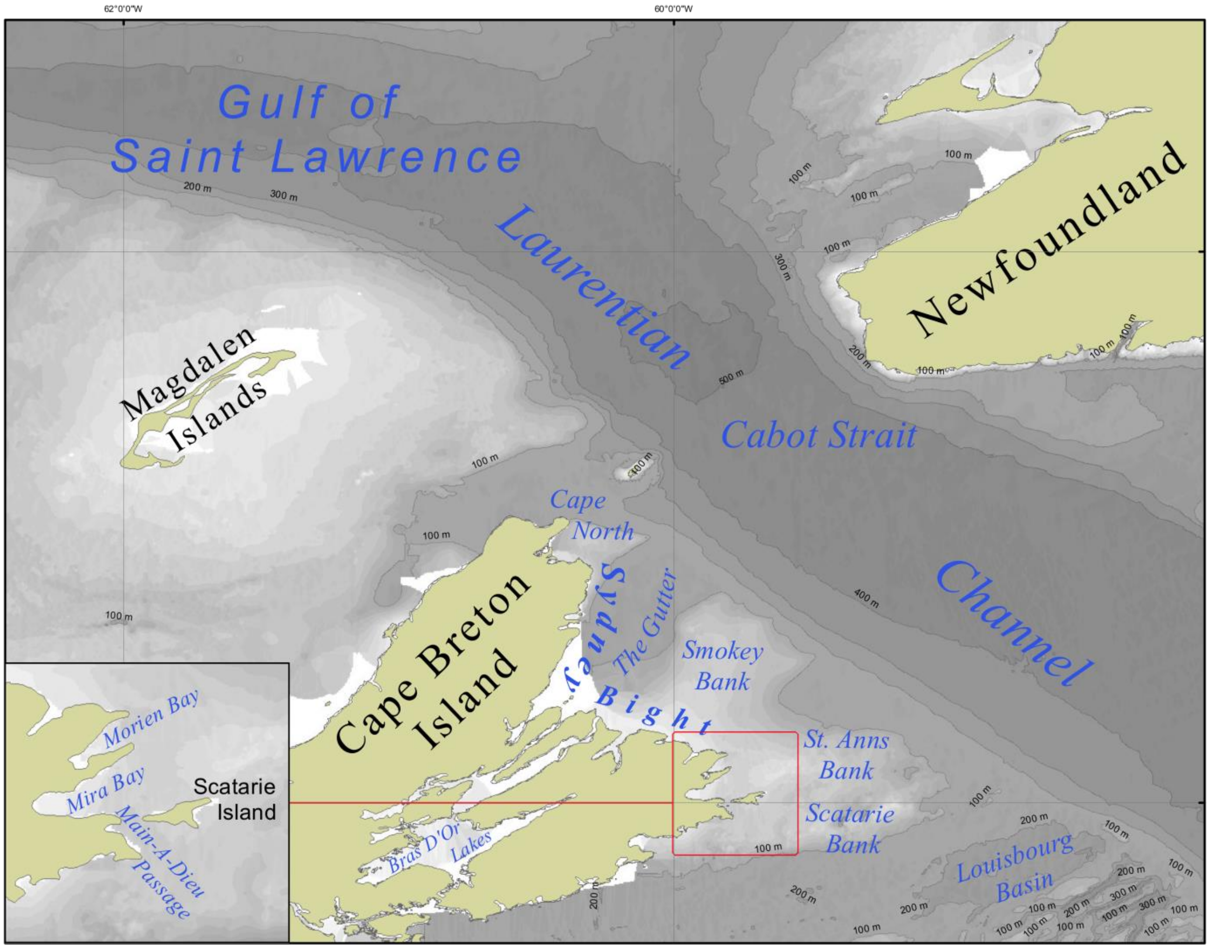

Figure 2: Locations of some places and sea areas named in the text. Sydney Bight is, strictly speaking, the area between the labelled coast and a line drawn from Cape North to Scatarie Island but the name is generally applied to the waters from the shore out to the Laurentian Channel.

If an MPA is designated, there will be the same necessity for a monitoring program embedded as an integral part of the Area's management as there is for any other MPA (*cf.* Pomeroy *et al*. 2004; Wilson and Tsang 2007). It cannot merely be assumed that drawing boundaries on a chart and establishing regulations restricting human activities within the area so delimited will achieve the MPA's objectives. Rather, each area requires management that is responsive to the state of, and particularly changes in, the protected ecosystems, while monitoring provides the information feedback on which management decisions can be based. That requirement is, perhaps, lessened in the case of MPAs which protect such unique features as The Gully, for which there may be broad public agreement that minimizing anthropogenic impacts is an appropriate objective in itself. However, where human use of a sea area is restricted because its features are representative (meaning "normal" or "average"), those interests that are excluded can be expected to demand evidence that their sacrifice has generated some benefits and has not been undermined by continued access to the Area by other users.

Under the *Health of the Oceans* (HOTO) program, the Science Sector of Fisheries and Oceans Canada (DFO) committed to providing the Department's MPA managers with a recommended environmental monitoring framework for each of Canada's *Oceans Act* MPAs, including those currently at the AOI stage of development. The intended nature of such frameworks remains somewhat fluid. Final monitoring plans will have to be extensive and detailed documents, including precise statements of the protocols to be used in on-going data collection, provided either by reference or as appendices. Those plans will also be, perhaps implicitly, statements of DFO's intent to carry out the monitoring and hence must follow after executive decisions concerning the use of the Department's budget, staff resources and research ships. Monitoring frameworks, in contrast, lack the detail and the commitment. Rather, they are science-based recommendations which outline how future monitoring plans could or should be structured. Even for an established MPA, a monitoring framework will not specify exactly how data should be either collected or presented to managers but a framework for an AOI that is still in an early stage of development must necessarily be highly generic and must tend towards being an outline of the steps needed to design a monitoring plan, rather than one of the plan itself.

The present document presents such a framework for the St. Anns Bank AOI, based on information available in December 2012. It largely follows parallel recommendations for the Gully MPA developed by Kenchington (2010), while addressing the very different possibilities and challenges of a coastal Area. The MPA managers' request for the Gully monitoring framework went beyond HOTO commitments to encompass a comprehensive monitoring program. In practice, Kenchington's (2010) recommendations fell short of that ideal by excluding socio-economic, governance, regulatory and compliance monitoring. I here seek to partially close that gap by offering preliminary suggestions for socio-economic indicators.

It is clear that, in the case of the St. Anns Bank AOI, the principal requirements for information in support of MPA management must be addressed through short-term, research-oriented characterization studies, as part of baseline monitoring efforts. While those are mentioned at intervals in the present document, they cannot be fully addressed in the absence of a research plan for the Area, which has yet to be prepared. Hence, the framework presented here is limited to recommendations for long-term trend monitoring. It is also limited to monitoring for MPA-management purposes and excludes the use of a future MPA off Scatarie Island for broader monitoring. Since the AOI extends from near-shore waters to 300 m depth over a distance of some 50 km, it has been suggested that the Area would be well suited as a location for a multi-faceted ocean observatory, with cabled instrumentation feeding data ashore (Dr. B. Hatcher, Cape Breton University, *pers. comm.*), but that would go far beyond the needs of management of the one MPA and hence is not further discussed here.

Kenchington (2010) provided a general account of MPA monitoring, including a typology of monitoring and the structuring of a monitoring program around a set of indicators. That material is only repeated here to the degree necessary for comprehension of the recommendations offered. The current document does follow Kenchington's (2010) format in offering some discussion of the likely objectives of an MPA in the area, an account of the ecosystems to be monitored over and around St. Anns Bank, and consideration of the anthropogenic pressures bearing on those ecosystems. A monitoring strategy is then proposed, rationales for the recommended indicators are provided, and approaches for their monitoring outlined. The present work concludes with an outline of some additional indicators that were considered during the preparation of this framework and the reasons for their rejection.

THE ST. ANNS BANK AOI

Any effective MPA monitoring program must be designed around the objectives of that MPA, the structures and functions of the ecosystems within it, and the types of anthropogenic pressures bearing on those ecosystems. Those topics, as they apply to the AOI, are examined in the following sections. Other factors, notably budget constraints and technical capabilities, are also important but do not require detailed exploration here.

OBJECTIVES OF A FUTURE MPA

The goals and objectives of a future MPA off Scatarie Island have yet to be finalized but scientific advice on the conservation objectives has been developed (DFO 2012a), while there are established national requirements that shape the individual goals for each MPA. That information is presented here as a foundation for the monitoring recommendations which follow. No refinement or modification of the wording is offered as those would lie outside the scope of the present work.

Statutory Objectives for MPAs Designated under the *Oceans Act*

The *Oceans Act* authorizes the designation of MPAs for any of five reasons:

1) The conservation and protection of commercial and non-commercial fishery resources and their habitats,
2) The conservation and protection of endangered or threatened species and their habitats,
3) The conservation and protection of unique habitats,
4) The conservation and protection of marine areas of high biodiversity or biological productivity, and
5) The conservation and protection of any other marine resource or habitat as is necessary to fulfil the mandate of the Minister of Fisheries and Oceans.

It is fully possible for a particular MPA to address more than one of those objectives. Indeed, at its designation, the Gully MPA was deemed to meet all five. It seems likely that the justification of an MPA in the St. Anns Bank AOI would be similarly broad.

Objectives for the National MPA Network

The five statutory goals have been supplemented by others adopted in 2011 as policy for the proposed national network of MPAs (DFO 2011a), *viz.*:

1) To provide long-term protection of marine biodiversity, ecosystem function and special natural features,
2) To support the conservation and management of Canada’s living marine resources and their habitats, and the socio-economic values and ecosystem services they provide, and
3) To enhance public awareness and appreciation of Canada’s marine environments and rich maritime history and culture.

While the first two of those widen the focus of the goals set out in the *Oceans Act*, they could be seen as mere re-wording, if protection of ecosystem function and services are taken to be inevitable outcomes of the conservation of resources, habitats and biodiversity. The third network goal, however, was a departure in being an explicit statement of the educational role of MPAs – itself an essential step towards building support for conservation efforts. Although that was adopted by DFO (2011a) as a goal of the overall MPA network, it must be supported by at least some of the individual MPAs within that network and may become part of the intentions for an MPA off Scatarie.

Specific Goals and Objectives for an MPA in the St. Anns Bank AOI

A Regional Science Advisory Process convened in January 2012 reviewed proposed conservation objectives for a future MPA in the St. Anns Bank AOI (DFO 2012a,b). The goals of such an MPA were then stated to be:

1) Conserve, protect and, where appropriate, restore the ecological health (biodiversity, productivity and habitat) of the St. Anns Bank AOI,
2) Contribute to the health, resilience, and restoration of eastern Scotian Shelf ecosystems,
3) Contribute to the recovery and sustainability of commercial fisheries, and
4) Promote scientific research and monitoring to further understand and protect the AOI1.

For that purpose, “conservation” was taken to mean management actions intended to minimize the risks from human activities while allowing for sustainable use or an acceptable level of interaction. Similarly, “protection” was defined as “a management action intended to reduce to the greatest extent possible the risk to a conservation priority from human activities” (DFO 2012a).

Within the first two of those goals, the Advisory Process generated science-based recommendations for conservation objectives[2]:

1) Conserve, protect and, where appropriate, restore the habitats of benthic, demersal and pelagic species occurring in the MPA, including the physical, chemical, geological and biological properties and processes of those habitats, in both the water column and the seabed,
   a) Specifically, conserve, protect and, where appropriate, restore the identified habitat types in the St. Anns Bank MPA, as representative examples of eastern Scotian Shelf habitats,
   b) In addition, if not protected as part of the representative habitats above, ensure that distinctive features are not altered or disrupted by human activities to the extent that they no longer have the characteristics that triggered their identification as conservation priorities within the St. Anns Bank MPA,
   c) Protect the important habitat of priority species,
   d) Protect the structural habitat provided by the identified sea pen and sponge concentrations,
2) Conserve, protect and, where appropriate, restore biodiversity in the St. Anns Bank MPA, including biodiversity at the community, species, population and genetic levels, so as to restore and maintain the structure and resilience of the ecosystems in the MPA,
   a) Specifically, support the survival and recovery of depleted species,
   b) Conserve and protect a portion of the identified area of high fish diversity, and
3) Conserve, protect and, where appropriate, enhance the productivity of the ecosystems in the St. Anns Bank MPA across all trophic levels, including the key trophic groups and the services they provide, so that they are able to fulfil their ecological role within the ecosystem.

When those recommendations were generated, the types of environments in the AOI had not yet been classified in any more detail than as “inshore bank shallower than 100 m”, “shelf,

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[1] The wording of these goals has here been modified from that in DFO (2012a) to incorporate a definition presented elsewhere in that source document and to correct grammatical errors. No comment is offered here on the technical merits of the wording offered to the Advisory Process. For a formal statement of these goals, future reference should be made to forthcoming documentation supporting the MPA designation.

[2] DFO (2012a) presented these recommendations in a discursive format. They have here been re-arranged as a list. Their wording is given *verbatim*, without comment on its technical merits, except that the examples associated with each objective have been grouped into the paragraph following the list.

approximately 100-200 m” and “slope/channel deeper than 200 m” and there was no more-detailed statement of which environment types are considered to be represented within the AOI. Hence, those three crude depth zones were specified as the “types” for Objective 1a, though DFO (2012a) called for further characterization and development of a more detailed habitat map. The only examples of the “distinctive features” of Objective 1b that were offered were equally bathymetric: the Big Shoal on St. Anns Bank, Scaterie Bank itself and some patches of high relief that extend the latter eastwards. Three “priority species” were suggested for Objective 1c: Atlantic wolffish (*Anarhichas lupus*), Atlantic cod (*Gadus morhua*) and Atlantic herring (*Clupea harengus*), without specification of particular intra-specific populations. For the purposes of Objective 2a, the “depleted species” were to include Atlantic wolffish, Atlantic cod (again without specification of populations), leatherback turtle (*Dermochelys coriacea*) and porbeagle shark (*Lamna nasus*). The supposed “area of high fish diversity”, invoked in Objective 2b, was identified as the wall of the Laurentian Channel. The “key trophic groups” of Objective 3 were named as including primary producers (including macroalgae), zooplankton (particularly *Calanus finmarchicus*), benthic invertebrates, forage fish (*e.g.* herring and mackerel, *Scomber scombrus*), demersal fish (including gadoids, flatfish and redfish, *Sebastes* spp.) and top predators (*e.g.* sharks, cetaceans and seabirds) – most of which units are not trophic groups at all.

At the time of writing, no objectives amplifying the third or fourth goals of a future MPA off Scatarie Island have been formally proposed. Some re-examination of the list of indicators recommended here may be necessary once those are determined.

It should also be noted that, while these goals and objectives are specific to an MPA developed out of the St. Anns Bank AOI, the Area was originally selected as a step towards a future MPA network – a network that has yet to be designed. The site-specific goals should be interpreted in that context.

ECOSYSTEMS OFF SCATARIE ISLAND

Any MPA monitoring plan should provide for the monitoring of the protected ecosystems and thus should be designed with an understanding of them. The St. Anns Bank AOI was, in part, selected as containing representative portions of ecosystems found on and around the wider eastern Scotian Shelf. Hence, the systems within the AOI can, in one sense, be assumed to be those known from the broader area, which are themselves not atypical of the ecosystems of temperate continental shelves in general, although with some particular features. The Shelf, however, is large enough that most of the processes within its ecosystems are primarily autochthonous, with limited (and often readily identifiable) external drivers. The AOI is very much smaller and lies in the unidirectional outflow from the Gulf of St. Lawrence (GSL). As such, its ecosystems are inherently open. Indeed, they are only managerially-discrete systems, being defined by the ecologically-arbitrary boundaries of the Area. Inevitably, much of the energy and biomass in those ecosystems are allochthonous in origin, while the external drivers are many, complex and important to system function. Moreover, it is a truism of ecology that ecosystems often change fundamentally depending on the scale over which they are examined. Hence, although those in the AOI resemble their analogues in any other small portion of the eastern Scotian Shelf, they may be expected to be simultaneously quite different from the ecosystems viewed at Shelf-wide scales. These differences between the whole and the part, the eastern Scotian Shelf and the AOI alone, will be critical to both monitoring and management of a future MPA off Scatarie. Such an MPA might, for example, offer protection to each trophic level but cannot protect an entire trophic pyramid.

A large volume of site-specific information on the AOI is being compiled in an Ecological Overview and Assessment Report as part of the MPA-designation process but, in the draft available to date, that has mostly been species-specific with little attention paid to how the many components interact in the local ecosystems. Broader primary studies and summary reviews of the ecosystems of the Scotian Shelf or its eastern portion (*e.g.* Breeze *et al.* 2002; Zwanenburg *et al.* 2006) are informative but require interpretation if the particular systems in the AOI are to be understood. This section of the present document, therefore, offers a first attempt to describe key aspects of the structure and function of the local ecosystems of the Area, as a foundation for the monitoring recommendations that follow. It touches on past temporal change in those systems, to provide an indication of both the degree of future change to be anticipated and the extent of anthropogenic degradation that might be reversed through establishment of an MPA. This section cannot, however, offer a final or definitive account of local ecosystems and it should not be relied upon for purposes external to the proposed monitoring framework.

Bathymetry

The eastern tip of Cape Breton, from Scatarie Island to Northern Head of Morien Bay, marks the junction of the Scotian Shelf proper with the rather different waters of Sydney Bight. Off Scatarie and stretching far to the southwestward, there is a distinct “Inner Shelf”, comprising a submarine extension of coastal Nova Scotia, with “Middle” and “Outer Shelf” regions further seaward (the Middle Shelf being dominated by deep basins and the Outer Shelf by shallow banks). That pattern extends into the southern portion of the AOI: the geomorphological feature which forms eastern-most Cape Breton Island dips to the eastward, reaching the shoreline in Morien, Mira and Main-à-Dieu bays. Across the narrow Main-à-Dieu Passage, the land rises again as Scatarie Island, beyond which there is a further channel and then the last rise: Scatarie Bank, with a least depth of about 30 m. That Bank, in effect, extends Cape Breton sub-tidally tens of kilometres eastward from the coast, while forming the northeastern-most extent of the Inner Scotian Shelf – the southern boundary of the AOI following the steep outer edge of the Bank, which drops into the deeper water (approximately 250 m) of the first of the “holes” that (with their intervening ridges) characterize the Middle Shelf between Cape Breton and Banquereau (Figure 3). Meanwhile, east of Morien Bay’s South Head, there is a similar channel and rise to those off Main-à-Dieu, but the parallel feature to Scatarie Island is the submerged St. Anns Bank, broader but somewhat less-shallow than Scatarie Bank.

While Scaterie Bank is part of the southeastward-dipping Inner Scotian Shelf, both it and St. Anns Bank (along with Smokey Bank, further to the westward in Sydney Bight) also dip gradually towards the northeast, where they meet the rim of the Laurentian Channel at about 150 m depth. Part of that gentle slope occupies the central portion of the AOI.

The Channel itself is one of the world’s largest shelf valleys. Extending from the upper continental slope between Banquereau and St. Pierre Bank, through the GSL and far into the St. Lawrence Estuary, it has the classic U-section of a glacial valley. The southwestern wall of the Channel cuts across the AOI from southeast to northwest, with depths of less than 150 m to greater than 250 m within a band a few kilometres wide. A length of approximately 60 km of that wall lies within the AOI. Beyond it, the northeastern third of the Area encompasses a portion of the floor of the valley, reaching depths greater than 300 m. Its furthest corner extends to one of the few ridges on the valley floor, the Laurentian Moraine (Fader *et al.* 1982).

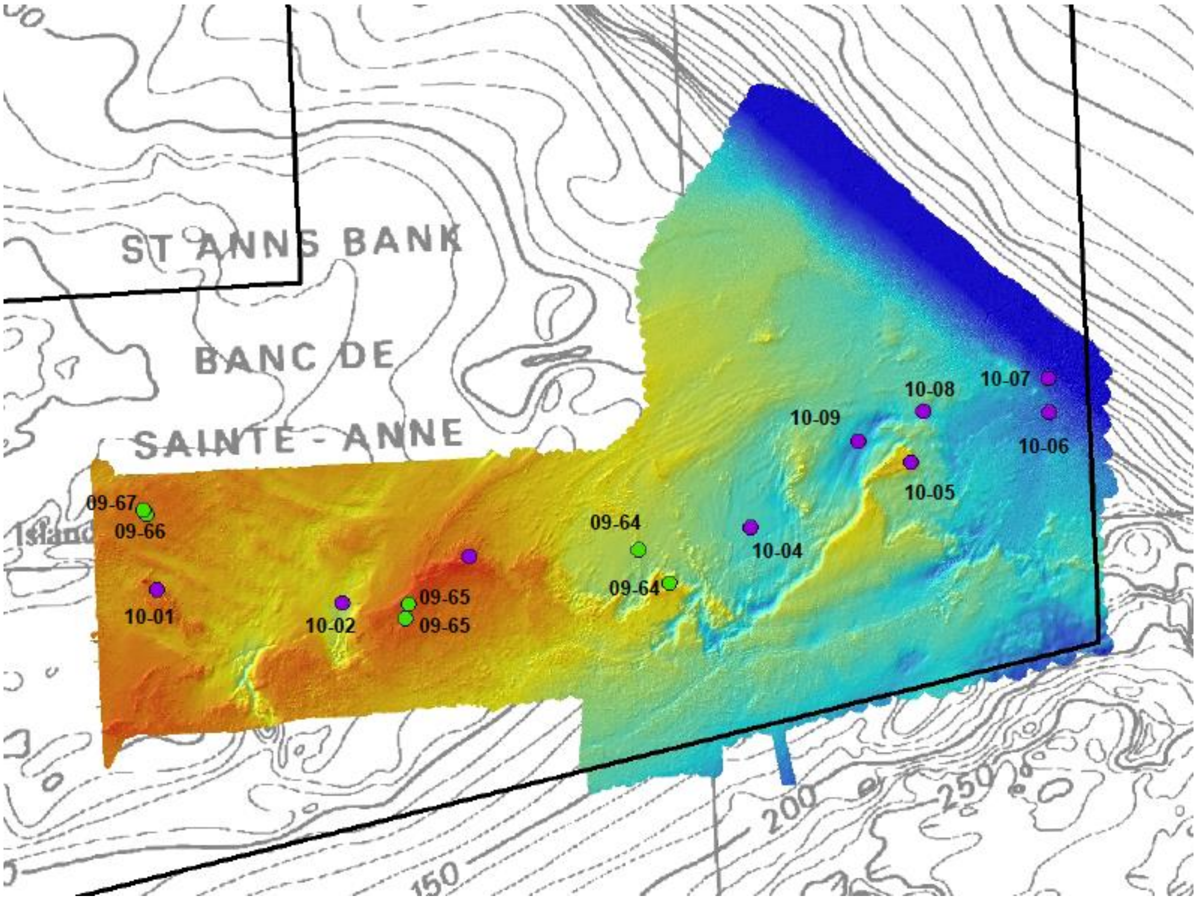

Figure 3: Detailed bathymetry of a portion of the AOI, including the results of a recent multibeam survey (colour shaded). The numbered dots represent benthic camera stations.

Surficial Geology

Seafloor geology is more location-specific than many other aspects of marine ecosystems and only the particular features of the AOI are of relevance here. Unfortunately, they are poorly known. The early mapping of surficial sediments off Nova Scotia by King and his co-workers (Fader *et al.* 1982) that is so valuable for the offshore Scotian Shelf is of limited utility for such a small, near-coastal area: too much was interpolated based on bathymetry alone, while the map units used (*e.g.* “Sable Island Sand and Gravel”, “LaHave Clay”) were defined more by the geological processes which formed them than by existing characteristics relevant to modern biota – a distinction that is of less importance offshore but which can be very significant close to the coast. As one example, Fader *et al.* (1982) noted that, on St. Anns Bank, the “Sambro Sand” map unit is actually a modified glacial till, which from an ecological perspective is likely to resemble what is elsewhere called “Scotian Shelf Drift”. Meanwhile, the modern mapping which will provide the detailed information required for MPA management is still in progress at the time of writing. Various datasets, such as observations from benthic sampling, do exist but those have yet to be compiled. In the interim, little can be said with any confidence.

There may be some exposed bedrock in the shallowest parts of the AOI, as there certainly are in nearby inter-tidal and shallow-sublittoral areas. More remarkably, some has been seen at 75 m depth on the last shoal of the geomorphological feature represented by Scatarie Island and Bank (see Figure 3, camera station 10-05), while on-going research confirms long-standing conclusions (Fader *et al.* 1982) that the extent of the exposure is considerably greater than that one point. It is very likely that, bedrock patches aside, the tops of the banks are covered in coarse sediments, from boulders to gravel and coarse sand, St. Anns Bank itself having a mix of sand and gravel fractions (Fader *et al.* 1982). The sediments may be expected to become generally finer with increasing depth, though deviations from a simple correlation with depth do occur, relatively coarser sediments being likely on local topographic highs and finer material in hollows, such as between St. Anns and Scatarie banks. The wall of the Laurentian Channel is likely rougher than its depth would suggest, though not as rough as further to the southeast, where it forms “The Stone Fence”, while the Laurentian Moraine is composed of glacial till which, despite its great depth, includes some coarse material (Fader *et al.* 1982).

Notably, there are gas-charged sediments within the AOI, particularly on the floor of the Laurentian Channel. The gas is likely methane. Parts of the Channel floor bear pockmarks, apparently formed by escaping gas, with one known field of them being associated with the Laurentian Moraine (Fader *et al.* 1982). Whether any pockmarks occur within the AOI is not currently known.

Water Masses and Water Movements

Specific field research into the physical and chemical oceanography of the AOI is in progress at the time of writing, but no results are yet available. Hence, this section must rely on extrapolations from regional studies.

The water column in the AOI is dominated by the outflow from the GSL, known as the Cape Breton Current, which occupies the southern side of the Cabot Strait, including parts of the deeper water of the Laurentian Channel to depths of 300 m (Koutitonsky and Bugden 1991). After passing across Sydney Bight, the waters of the Current flood the area off Scatarie Island.

The water in the GSL, and hence in its outflow, is derived from four inputs. In winter, there is an inflow of very cold, low-salinity Labrador Shelf Water through the Strait of Belle Isle, which extends across the Gulf at depths of around 75 m. It is supplemented by coastal water, ultimately of Labrador Current origin, that enters the GSL on the Newfoundland side of the Cabot Strait. The combination of those inputs is further diluted by river flow, primarily from the St. Lawrence itself but also from other drainage basins. In winter, surface cooling maintains the low temperatures and, in combination with storm waves, promotes the development of a mixed layer, with low salinities (31.5 to 33‰) and temperatures (approximately 0°C), extending to depths of about 100 m (Koutitonsky and Bugden 1991).

The surface dilution caused by freshwater discharge is particularly pronounced during the spring freshet. In the absence of either long, oceanic swells or fast tidal streams, there is only limited vertical mixing in calm weather. Summer solar heating thus creates a thin surface layer, from a few metres to 30 m deep, of very low salinity (27 to 32‰) but high temperature, especially in coastal shallows around the Southern Gulf. Annual variation in surface temperature can approach an exceptional 20°C. However, the cold conditions remain unchanged at depth throughout the year, such that the surface warming leads to the appearance of a distinct Cold Intermediate Layer (CIL), extending from about 50 to 100 m depth, though with broad thermoclines both above and below. When solar heating is reduced as summer turns to fall, storms stir the waters, homogenizing the surface layer and the CIL (warming the latter while cooling the former), before winter cooling and renewed inflow through the Strait of Belle Isle return the cycle to its beginning. One consequence of the patterns of variation in both temperature and salinity is the development of exceptional stratification of the water column through the summer (Koutitonsky and Bugden 1991; Chassé 2001).

The fourth input to the Gulf is one of subsurface oceanic water from beyond the shelf break that flows in along the Newfoundland side of the Laurentian Channel. Some of that water, with the nutrients it carries, is entrained into the shallower layers (especially at the head of the Channel, in the St. Lawrence Estuary), providing nutrient enrichment, but most of the volume recirculates within the Channel, either inside the GSL or before entering it. The portion which passes in through the Cabot Strait before turning back forms the deep layer of the Cape Breton Current, flowing primarily below the Channel's rim depth (approximately 150 m). It is both warmer and more saline (4–6°C, 34.5‰) than the overlying CIL (Koutitonsky and Bugden 1991).

As a consequence of the AOI's location within the GSL outflow, its waters show extreme temperature variations. Surface temperatures are below 0°C in winter and early spring but reach approximately 16°C in late summer. Seabed temperatures in most of the Area are relatively stable seasonally but are strongly dependent on depth, with the floor and wall of the Laurentian Channel, plus the outermost portion of the banks, being around 4°C. The rest of the banks (at the depths of the CIL: approximately 50 to 100 m) are very cold even in summer, though warmer in the fall when the surface water is mixed downwards, while the sublittoral slope (adjacent to the coastline and thus largely outside the AOI) experiences temperatures which follow the seasonal cycle of the surface layer. The minimum surface salinity, resulting from the spring freshet in the St. Lawrence, takes some months to cross the Gulf and passes through Sydney Bight and the AOI in late summer, which is also the season of highest surface temperatures – resulting in extreme density stratification, exceeding that seen anywhere else on the Scotian Shelf (Chassé 2001; Breeze *et al.* 2002).

All four inputs into the GSL, and hence the characteristics of its outflow, are subject to inter-annual and longer-period variations. River flow is affected both by precipitation over the catchment basins (including whether that falls as rain or snow) and by anthropogenic actions, such as hydropower developments, which tend to smooth out the seasonal cycle, reducing peak runoff and perhaps materially affecting entrainment of the nutrient-rich deep water (*cf.* Sutcliffe 1973; Sutcliffe *et al.* 1976). Changes in ocean climate have been seen to affect the Labrador Current, and hence the inflows both north and south of Newfoundland (*e.g.* Drinkwater and Gilbert 2004). In addition, the characteristics of the oceanic water at the mouth of the Laurentian Channel, and so the origin of the deep flow into the GSL, vary. Upper-slope depths off Nova Scotia are bathed by both Warm Slope Water (WSW: formed by mixing of Gulf Stream and coastal waters north of Cape Hatteras) and Labrador Sea Water (LSW), which is formed between Labrador and Greenland by winter surface cooling and the resulting deep convection. Off Nova Scotia, WSW is typically around 35.0‰ in salinity and can be as warm as 13°C at the surface, although much cooler at depth (Smith and Petrie 1982). Its oxygen content is rather low. In contrast, LSW is oxygen-rich, 3 to 4°C and about 34.8‰. The interaction between those two water masses has been described as a "coupled slope water system", in which the "maximum modal state" sees the LSW extending little further than the western flank of Grand Bank, while it can reach to the slope off Maryland when in the "minimum" state (Marsh *et al.* 1999; MERCINA Working Group 2001; Greene and Pershing 2003). Bugden (1991) reported a temperature of 4.5°C for the subsurface temperature maximum, at around 250 m depth, at the mouth of the Laurentian Channel in 1966. In 1985, however, it was 6.1°C, with a parallel change in salinity such that the density remained steady – presumably a consequence of a shift in the modal state of the coupled system. More recently, Gilbert *et al.* (2005) examined a long-term trend in oxygen levels at the head of the Laurentian Channel, within the St. Lawrence Estuary, and concluded that it was primarily driven by changes in the waters drawn in at the mouth.

Within the GSL, the Gulf outflow proceeds primarily along the southern side of the Laurentian Channel, although the current also draws in waters flowing northwards along the west side of Cape Breton from the Magdalen Shallows. Once past Cape North, the bulk of the current continues along the Channel, passing Sydney Bight, with some models suggesting a lesser southeastward flow over the banks within the Bight and others a clockwise gyre. In the AOI, much of the water proceeds on towards Banquereau, there to become a principal contributor to the southwest-flowing Shelf Break Current. Portions of the surface layer and CIL, however, turn around Scatarie to head down the coast as the Nova Scotia Current, although the details are never simple and there can be a northeastward flow along the Cape Breton coast, from

St. Peters towards Louisbourg, which feeds into the AOI from the south. None of these currents is fast: usually less than 0.25 $m.s^{-1}$ or 0.5 knots (Chassé 2001). Even such speeds are sufficient, however, for a typical water parcel moving from Cape North towards Banquereau to pass through the AOI in about three days.

The residual currents are overlain by tidal streams. The semi-diurnal streams are generally weak around Cape Breton, though model predictions of the M2 (lunar semi-diurnal) tide reach moderate speeds off some headlands, including 0.2 $m.s^{-1}$ over St. Anns Bank. In contrast, the usually-weak diurnal streams are relatively strong in the area. Modelled K1 (solar diurnal) streams reach 0.4 $m.s^{-1}$ over Scatarie Bank (Chassé 2001). Hence, at times when the lunar and solar, semi-diurnal and diurnal tides are all in phase, the flow over the shallows in the AOI may exceed 2 knots, particularly when the tidal stream and residual current are running together. Unlike the large banks of the outer Scotian Shelf, those in the AOI are too small to interact with the tidal streams to generate clockwise gyres (Dr. D. Hebert, Bedford Institute of Oceanography (BIO), *pers. comm.*).

The surface layer is also affected by aperiodic, meteorologically-driven flows. Between Cape Breton and Newfoundland, the wind can over-ride residual water movements (*e.g.* Trites *et al.* 1986). It should be noted that, while the bulk of the local water flow enters the AOI across its western boundary and exits across its eastern and southern ones, there will inevitably be some counter-flows, albeit limited in time and space. For many purposes, those will be quantitatively trivial but the ecologically-critical process of recruitment of meroplanktonic larvae to the benthos and the nekton depends on the inherently-improbable survival of a very few eggs through to adulthood. If those larvae that are caught in the counter-flows, perhaps aided by active swimming behaviours, are disproportionately represented amongst the survivors, then local populations could be primarily self-reproducing, through effective larval retention, even though the great majority of the water in the AOI passes across its width in much less time than the duration of a species' larval stage.

Finally, while the Gulf's stratification is greatly reduced in winter, near-surface haloclines are still frequent enough for much of the GSL to become ice-covered in typical winters. Some of that ice is carried out into Sydney Bight by the Cape Breton Current. The extent of cover is variable, inter-annually as well as seasonally, but most years have seen ice in the AOI in February and March, and sometimes in January and/or April as well (Canadian Ice Service 2011). That pattern may be changing, however, as there has been very little ice in the Area in the recent past (Dr. D. Hebert, BIO, *pers. comm.*).

Primary Production, Primary Producers and Other Energy Sources

Very few data on photosynthetic plants have been collected within the AOI itself, but much can be confidently predicted from knowledge of the surrounding region and of temperate continental shelves generally. Primary production in the Area, as always in the open sea, is undoubtedly dominated by phytoplankton, although (unusually for a location away from the immediate coastline), it is known that there are macroalgae on the boulders of Scatarie Bank. The limited seabed imagery yet available from that area (specifically from Station 09-65 at 40 to 45 m depth, see Figure 3) shows not only encrusting coralline forms but also a red-algal turf and some specimens of the kelp *Agarum clathratum* (Dr. E. Kenchington, BIO, *pers. comm.*).

Phytoplankton production in the AOI, as on the eastern Scotian Shelf, follows the classic cycle of temperate waters, with a bloom (dominated by large diatoms) beginning in the spring as increasing sunlight and stratification (resulting from solar heating and reduced wind-driven vertical mixing) combine to keep the phytoplankton within the near-surface euphotic zone. The bloom lasts until the nutrients (primarily nitrate and silicate) have been exhausted in that zone. On the eastern Scotian Shelf, the timing of the bloom varies inter-annually and inter-decadally but falls into the March to May period (Head and Pepin 2008). Far lesser production continues through the summer, when small flagellates dominate phytoplankton populations. There is sometimes a fall bloom, of lower magnitude than that in the spring, if increasing wind stress mixes deeper, nutrient-rich water into the euphotic zone without causing a complete breakdown of stratification (*cf.* Breeze *et al.* 2002).

There are high concentrations of both nitrate and silicate in the outflow from the GSL (Petrie and Yeats 2000), enriching the blooms in the AOI, as well as generally across the Inner and Middle portions of the eastern Scotian Shelf. The extreme summer stratification in Sydney Bight, however, probably greatly reduces the summer nutrient supply to the euphotic zone, relative to other areas on the Scotian Shelf. Along the Atlantic coast of Nova Scotia, southwest winds combine with the Coriolis force to drive surface water away from the shore, allowing upwelling of deeper layers. A similar effect should occur along the southern side of Sydney Bight with easterly winds and on the western side of Cape Breton in northerlies, both potentially increasing summer nutrient supplies to the surface layer in the AOI. Meanwhile, the current flowing over the rough and shallow seabed around Scatarie may also be sufficient to mix nutrients upwards into the euphotic zone. While there is no firm evidence, the combination of those inputs may serve to maintain some local phytoplankton production through the summer, although presumably not at the levels of the spring bloom.

Despite the place of phytoplankton photosynthesis as the principal energy-capture process in the AOI, there are multiple other sources of energy supporting the local ecosystem:

- Much energy must come from photosynthesis immediately upstream, entering the Area as either drifting phytoplankton or phytodetritus (*e.g.* flocculated but uneaten diatoms from the spring bloom), though that flux will be roughly balanced by losses across the downstream boundary of the AOI.
- The macroalgae on Scatarie Bank will provide additional local carbon fixation, though the amount is likely small and net production may be confined to summer: the plants are growing at extreme depth for macrophytes, where they will receive sufficient light for net production only when the sun is high in the sky and after the shading caused by the spring plankton bloom ceases. While doubtless utilized by the zoobenthos of the Bank, that production can only make a very minor contribution to the total energy in the AOI's ecosystems.
- There must also be a supply of non-living organic detritus derived from marine macrophytes (including macroalgae, eelgrass and marsh grasses) growing on nearby coasts, possibly including the shores of the Bras D'Or Lakes.
- A likely far greater flux of detritus entering the AOI is that derived from marine animals upstream which produce faecal material and assorted other organic matter containing energy fixed by photosynthesis outside the Area.
- A further supply of detrital material could be from terrestrial sources, although the lack of large rivers on the eastern side of Cape Breton suggests that that source may be less important than in some other coastal areas.
- Besides the detritus, the Cape Breton Current will carry Dissolved Organic Carbon (DOC) into the AOI, some of which will support the microbial loop within the Area, the energy then being passed up the trophic pyramid.
- Minor hydrocarbon seeps, including those associated with pockmarks on the floor of the Laurentian Channel, likely occur in the AOI or at least close outside its boundaries. The released methane or other hydrocarbon will be utilized by microbial communities, which in turn feed the benthos.
- Much the largest flux of energy across the boundaries of the AOI and into its ecosystem, however, almost certainly takes the form of the bodies of migrant nekton – a topic taken up below. The greater part of the migrant biomass entering the AOI will, however, leave soon after, either passing swiftly through or else departing after overwintering.

While those energy sources can be listed and the relative magnitudes of some fluxes can be suggested, it is not known whether the AOI is a net source, exporting more energy than it receives, or conversely a net sink. Even less clear are the magnitudes of the net fluxes and of the energy utilized or exchanged between trophic levels within the ecosystems of the AOI. For example, the net energy flux into (or out of) the Area in the form of nektonic biomass is unknown but may be no more than a small fraction of the total allochthonous portion of the energy supporting the AOI's ecosystems, despite the very large quantity of migrant nekton.

Residence times for water parcels within the surface layers of the AOI are longer than the doubling times for phytoplankton and unicellular grazers but much shorter than the life spans of most multi-cellular herbivores, such as copepods. Thus, it is reasonable to speak of energy being captured by phytoplankton photosynthesis within the AOI and of the phytoplankton as being local to the Area but much of the energy that is taken up in the AOI will be exported downstream, in the biomass of the bodies of the grazers, while the mesozooplankton biomass within the Area will mainly be derived from primary production that occurred upstream, in Sydney Bight or even in the GSL. It follows that upwelling around Cape North may be at least as important to the zooplankton production of the AOI as that which occurs around Scatarie and elsewhere within the Area, while the copepods do not truly belong to the AOI but merely pass through. Some sunlight energy captured within its boundaries will pass from phytoplankton to copepod before leaving but very little will be passed on to a herring or other planktivore before departing. Other pathways within the Area are likely shorter, with much of the energy present only taking at most one step up the trophic pyramid while inside its boundaries. This dominance of trans-boundary fluxes over local processes is a consequence of the small size of the AOI, by the standards of open-sea ecosystems) exacerbated by the prominence of the unidirectional GSL outflow.

Pelagic Ecosystems

In the vicinity of Sydney Bight, phytoplankton are consumed by a wide array of zooplanktonic herbivores, including larvae of some benthic organisms, and also by certain shallow-living benthic species (*e.g.* scallops: *Placopecten magellanicus*) where seabed depth lies within the surface mixed layer. The most important grazers are, however, the copepods, especially the large calanoids *Calanus finmarchicus*, *C. hyperboreus* and *C. glacialis* (*cf.* Breeze *et al.* 2002; Head and Pepin 2008). Those three species overwinter at depth in a dormant state and they, or their offspring, rise in late winter–early spring to feed on the phytoplankton bloom. Because they require deep water during the cold months, most individuals that appear in the AOI in spring will have spent the previous winter in the Laurentian Channel, either locally or within the GSL, or else they will be the offspring of adults that did so (*cf.* Sameoto and Herman 1992). *C. hyperboreus* and *C. glacialis* are Arctic species, which leave the surface layers of the Scotian Shelf in late spring as the water warms, accumulating at depth in the Channel and the shelf basins (*e.g.* Louisbourg Basin, immediately south of the AOI). In contrast, *C. finmarchicus* is found in near-surface waters from late winter until fall. That species reproduces in the surface layer but the adults that survive the winter and ascend to the surface must feed first. They therefore start to release eggs into the water when the spring bloom begins. From early summer onwards, as individuals reach the pre-adult ("CV") stage, most migrate down to begin their dormant "overwintering" phase. Those that do not descend mature to adulthood in the surface layer, producing a second generation and possibly a third, if food supplies are adequate, before migrating down. From mid-summer onwards, however, while some *C. finmarchicus* are active in the near surface layers, most of the first (and largest) generation is dormant, at depth, along with the Arctic *Calanus* species. Once they make their seasonal, downward migration, all *Calanus* species can go to depths of several hundreds of metres if they are transported off the shelf. Those that are swept into the shelf basins or the Laurentian Channel can reach biomass densities of tens of tons per square kilometre (equal to tens of grams per square metre). All three *Calanus* species are particularly abundant in the Laurentian Channel in and near the Cabot Strait, with water column densities approaching 60,000 individuals m^{-2} (8 g dry weight m^{-2}) for *C. finmarchicus*, 35,000 m^{-2} (22 g dry weight m^{-2}) for *C. hyperboreus* and 3,000 m^{-2} (1 g dry weight m^{-2}) for *C. glacialis* (Head and Pepin 2008, Dr. E. Head, BIO, *pers. comm.*).

Like the copepods, euphausiids are herbivorous during the spring bloom period and the two groups compete for food during bloom periods. Some species (*e.g. Thysanoessa* spp.) remain herbivorous as they develop and grow, but others, notably *Meganyctiphanes norvegica,* become carnivorous or omnivorous, preying on copepods when phytoplankton is not available. Adult euphausiids make extensive diel migrations, feeding near the surface at night but spending the day at depths below 200 m (Sameoto and Cochrane 1996). Thus, within the AOI they are confined to the Laurentian Channel and perhaps the southern slope of Scatarie Bank.

The trophic pathways from phytoplankton through copepods to larval, juvenile and adult fish are key routes via which energy travels up the food chain. *C. finmarchicus* eggs and nauplii are important food sources for the larvae of spring spawning groundfish and sandlance (*Ammodytes* spp.), while the later stages of the copepods are consumed by juveniles of those fishes and others, including mackerel. The principal predator of crustacean zoopankton in near-surface waters of the Sydney Bight region in summer is, however, almost certainly the herring, which eat large amounts of both copepods and euphausiids, as well as small decapods (Cook and Bundy 2010) and is itself a key forage species, supporting the many piscivores. Copepods, small euphausiids and the larger *M. norvegica* are also eaten at similar depths by a variety of other animals, including baleen whales and some seabirds.

Meanwhile, the concentrations of calanoids and euphausiids at depth in the basins and the Laurentian Channel provide important food sources for some deeper living fish species, including small silver hake (*Merluccius bilinearis*, a species that is notably piscivorous at larger sizes: Cook and Bundy 2010) but especially the redfishes. *Sebastes fasciatus* and *S. mentella*, have long been exploited by a substantial trawl fishery in the Laurentian Channel, including in the vicinity of the AOI. There are shallow-dwelling populations of *S. fasciatus* elsewhere, notably around the mouth of the Bay of Fundy, but in Sydney Bight they seem to be confined to the deeper water of the Channel. While the largest individuals of *Sebastes* spp. include fish in their diet, most eat primarily planktonic crustaceans, especially euphausiid krill and small decapod shrimps (*e.g.* Savenkoff *et al.* 2006). Since adult redfishes experience little predation, as confirmed by their low rates of natural mortality, but have been intensively fished, the trophic pathway phytoplankton> copepod> krill> *Sebastes* spp.> human may be a notable one along the wall of the Laurentian Channel.

Importantly, the diel vertical migrations of *M. norvegica* and the seasonal ones of *Calanus* spp. do not simply serve to concentrate food for those commercially-exploited predators. In a more general sense, they also carry some of the energy captured by phytoplankton in the surface layer downwards into the depths of the Channel, in the form of the biomass of migrating animals. The flux represented by that active migration is likely much greater than that caused by passive sinking of organic detritus (*cf.* Vinogradov 1997). Along the continental slope of the Scotian Shelf, the downward transport role is also filled by sergestid shrimps and by myctophid fishes, with *Benthosema glaciale* being overwhelmingly predominant among the latter (Themelis 1996; Kenchington *et al.* 2009). In those deeper waters, the energy thus transported supports a complex mesopelagic ecosystem, including predatory fish and squids, an abundant fauna of gelatinous plankton, predatory and commensal crustaceans, plus a “mesopelagic microbial loop” through which non-living organic material derived from the migrants is reprocessed. It is not currently known whether that ecosystem is replicated within the Laurentian Channel, and hence within the AOI, since no appropriate sampling seems ever to have been attempted. The available depths, never much more than 500 m and usually less than 400 m, are rather shallow for the full development of mesopelagic migrations. Bottom-trawl surveys conducted in the

Channel within the GSL have, however, found the fish species that are typical of the mesopelagic ecosystem along the continental slope (*e.g.* Dutil *et al.* 2009a; Chouinard and Dutil 2011), making it very likely that both they and some other components of that ecosystem do occur within the AOI.

Gulf Migrants and their Resident Conspecifics

While the fluxes of drifting plankton and non-living material across the AOI's borders are important to the functioning of its ecosystems, as noted above, the largest movements of biomass and its energy equivalent into and out of the AOI almost certainly result from active animal migration – primarily out of the GSL in the fall and back in through Cabot Strait in the spring. That migration incorporates a share of the accumulated primary production of the entire Southern Gulf over multiple years, while annual plankton drift into the AOI comprises little more than a part of the production of Sydney Bight during a single season.

As outlined above, the extreme stratification of the water column in the GSL results in an equally extreme seasonal temperature cycle in the surface layer. Most of those species which can withdraw from the winter cold (and away from the corresponding lack of prey) do so by moving into the warmer, deep layer in the Laurentian Channel. Many also move southeast along the Channel, concentrating near Cape North or else passing out into Sydney Bight and sometimes onward to the Scotian Shelf or the flanks of the banks along the Newfoundland side of the Channel. Species which are tied to the sea surface necessarily migrate still farther to overwinter far to the south. With a few exceptions, such as herring and cod, the full extents of those migrations are not well known but some of the biomass of moving animals almost certainly passes into or through the AOI.

The long-distance migrants, those which overwinter to the south or east of the Scotian Shelf, include charismatic megafauna such as baleen whales, giant bluefin tuna (*Thunnus thynnus*) and some species of large sharks. There are also seabirds which follow a flyway clockwise around the coast of Cape Breton in the fall. The greater tonnage, however, is currently (if not necessarily historically) composed of small pelagics, most notably mackerel and saury (*Scomberesox saurus*). The 2007 spawning biomass of the former species in the GSL has been estimated at 76,000 t, although it was around 1,750,000 t in the mid-1980s (DFO 2008). In the spring, mackerel pass westward through the Cabot Strait while remaining within 6 km of the Cape Breton shore (Castonguay and Gilbert 1995). They leave the Gulf in the fall, overwintering far to the south (Sette 1950). Saury have never been commercially exploited in the northwest Atlantic and that, along with complications arising from their near-surface distribution, has prevented reliable biomass estimation. They are known to feed extensively across the northwest Atlantic in summer, before aggregating along the edge of the Scotian Shelf and thence migrating southwestwards (Nesterov and Grudtsev 1980; Dudnik *et al.* 1981). Based on Soviet resource explorations, Nesterov (1979) estimated the biomass of the fall migration at 900,000 t. That figure was highly uncertain, while not all of those fish will have fed in the GSL. It is, however, likely that the saury migration through Cabot Strait is of the same order of magnitude as that of mackerel. The routes taken by these fish as they pass between Scatarie and Newfoundland are unknown, but it is reasonable to suppose that much of the biomass traverses the AOI, at least on the outward migration in the fall when the fish would enjoy the assistance of a favourable current.

A further form of long-distance migration, though of far smaller magnitude in biomass terms, concerns diadromous species. Adult Atlantic salmon (*Salmo salar*) that spawn in rivers draining into the Gulf, such as the Miramichi and Margaree, must migrate annually to and from feeding grounds off Greenland. While many use the Strait of Belle Isle, some pass through the Cabot Strait (Reddin 2006) and perhaps the AOI. The catadromous American eel (*Anguilla rostrata*) undertakes ontogenetic migrations, "silver eels" leaving the rivers where they have fed and grown *en route* to their spawning ground in the Sargasso Sea, while the young “glass eels” pass westward through Cabot Strait in the spring (Dutil *et al.* 2009b). Whether any of these diadromous fish have much ecological consequence in the waters off Scaterie is, however, doubtful. Their biomasses are low by the standards of the strictly-marine resource populations while the adults may not feed while migrating, eels in particular ceasing to eat at about the time of their downstream migration.

There is greater diversity in the intra-regional migrants that overwinter in or along the rim of the Laurentian Channel. Those include the herring (*e.g.* Stobo and Simon 1982) and redfish (*e.g.* Campana *et al.* 2007), already referred to above, but also several species of groundfish, such as American plaice (*Hippoglossoides platessoides*: Swain *et al.* 1998). As late as the early decades of the 20th century, those used to be joined by large numbers of haddock (*Melanogrammus aeglefinus*: Needler 1931; McKenzie 1946), although that species has since withdrawn from the GSL for reasons as yet unknown.

Current estimates of summer herring spawning biomass in the Southern Gulf approach 350,000 t, most of it in the fall-spawning component (DFO 2010a). Those fish generally move into Sydney Bight by mid-fall and do not pass back through the Cabot Strait until early spring (spring spawners) or early summer (fall spawners). Meanwhile, herring from groups which spawn along the Atlantic coast of Nova Scotia and as far away as Scots Bay, in the Bay of Fundy, also overwinter in the Bight (Stobo and Simon 1982). To further complicate the picture, there are local spawning groups in the Bight, with one known area for the roe fishery (suggestive of a spawning ground) being “The Big Shoal”, on the crest of St. Anns Bank (Power *et al.* 2010) and hence within the AOI, though the actual spawning location has not been confirmed and might fall outside the Area. There is additional spawning in the Bras D’Or Lakes, by fish which migrate in from the Bight (Crawford *et al.* 1982). However, most herring in and around the AOI are overwintering migrants.

The greatest migration of former times, however, was likely that of cod. Back-calculated biomasses of Southern Gulf cod [formerly managed as “Division 4TVn (January-April) cod” – now “Div. 4TVn (November-April) cod”] have been estimated at around 500,000 t as late as the 1950s and again at a peak in the mid-1980s, before declining to much lower levels today (Swain *et al.* 2009). Probably the best studied of the groundfish species (*e.g.* Frank *et al.* 1994; Campana *et al.* 1995, 1999; Swain *et al.* 2001; Comeau *et al.* 2002a,b), they can serve as a model of the complexities. Not all of the migrant individuals from the southern GSL follow the Laurentian Channel as far as Cape North. Of those that do, a few cross to the Newfoundland side of the Channel, balanced by some northern Gulf fish crossing in the other direction, while many more remain within Sydney Bight and do not reach as far to the southeast as the waters off Scatarie Island. January surveys in the vicinity of Cabot Strait from 1994 to 1997 found the fish broadly distributed in the Channel, with a particular concentration off Cape North. While there were cod in the AOI each of the four years, high densities were only seen there in 1996, when there was a patch of the fish straddling the Area’s western boundary. That concentration was very largely composed of Southern Gulf fish, which group was also found further to the southeast along the southwestern wall of the Channel, as far as Banquereau, implying that they had moved through the AOI (Campana *et al.* 1999; Swain *et al.* 2001). Those of the cod which pass out through the Cabot Strait mostly do so in November or even December, returning to the Gulf around the beginning of May (Comeau *et al.* 2002a). A small proportion of the Southern Gulf cod are in Sydney Bight as early as September, however (Swain *et al.* 2001).

Meanwhile, there are resident cod in Sydney Bight. The species is particularly renowned for having multiple, small, coastal, resident sub-populations, as well as more abundant, migrant populations that pass through the same inshore waters on migration circuits which also carry them offshore. Evidence for genetic distinctions between such populations is fragmentary (but see Ruzzante *et al.* 1996, 2000) but attempts have been made to map the former inshore groups in the Gulf of Maine (Ames 2004), and a similar pattern along the Nova Scotian coastline has been both reported by fishermen (*e.g.* Kenchington and Halliday 1994) and recognized by scientists (*e.g.* Campana *et al.* 1995). The terms "migrant", "resident" and "stock" should not be taken too literally, however, since there is considerable mixing and dispersal of cod, while their classification is largely a human attempt to impose order onto the realities of fish behaviour (*cf.* Kenchington 1984). This local structuring of cod populations has generally been ignored by fisheries management and, in the northwest Atlantic, only the largest of the resident groups was accorded a separate "stock" designation and then only seasonally: the Sydney Bight cod being denoted in 1974 as "Div. 4Vn (May-December) cod" [now "Div. 4Vn (May-October) cod": Campana *et al.* (1995)]. That group is known to move into The Gutter, between Smokey Bank and the western shore of the Bight, beginning in late April and to spawn there in May and June, before dispersing to the east, across Smokey Bank and towards Scatarie (Lambert and Wilson, in Campana *et al.* 1995), where they are recorded by sentinel longline surveys. It may be noted that the adults must penetrate the cold water of the CIL in order to spawn. In the 1970s and 1980s, by the season of the summer groundfish surveys, around the beginning of July, these cod were spread widely across the Bight, with a patch of relatively high biomass density extending through the AOI and to the southeast of Scatarie, mostly at depths typical of the CIL. Since the 1990s, however, those resident cod taken in the Bight by the summer surveys have largely been caught in the warmer water along the rim of the Laurentian Channel, with particular concentrations off Cape North, on the edge of Smokey Bank and within the AOI (Horsman and Shackell 2009). Nothing in that seasonally-restricted survey record hints that the adult cod have already been inshore to spawn and have retreated from there to feed.

Like their GSL conspecifics, the resident cod also withdraw towards the Laurentian Channel and thence to the southeast for the winter, but their movements are much less extensive than those of the Southern Gulf fish, such that some Sydney Bight residents may overwinter along the wall of the Channel within the AOI. In June 2000, Comeau *et al.* (2002b) tagged 126 mature cod on their spawning ground in The Gutter, using acoustic transmitter tags, while an array of receivers was placed along the upper wall of the Laurentian Channel from off Cape North to east of Scaterie at an average depth 140 m, meaning somewhat deeper than the aggregation observed by the summer trawl survey. Of the tagged fish, 67 passed close enough to a receiver to be recorded, which led to estimates of two-thirds of the adult population migrating out to the depth of the receiver line. Curiously, their outward movement revealed two groups of individuals, one of which reached the line before the end of August, while the other only began to be detected there in mid-October. The former group lingered along the receiver line for an average of 68 days each, when they were presumably feeding, whereas the latter group was only within detection range of the receivers for an average of 21 days per fish, perhaps having fed at lesser depths through the summer. Most of the fish first encountered the line in the vicinity of The Gutter, with some individuals being detected off Cape North and others on the seaward flank of Smokey Bank. Only about a dozen reached the line as far east as the AOI and half of those did so near its western boundary. However, once within the detection range of the receivers, most of the fish moved southeast along the wall of the Channel (though a minority moved northwest), with the maximum displacement approaching 150 km or nearly the full length of the line (Comeau *et al.* 2002b). The records of the tagged fish have not been analyzed with reference to the AOI but, if it is assumed that the cod continued along the wall after moving deeper than the receivers, then many, perhaps most, will have entered the AOI and may be passed on through it towards Banquereau. Only four of the tagged fish were detected during the winter, by a survey using a towed hydrophone. They were then in deep water (380 m) off Cape North, where they were mixed within a large aggregation of cod, likely mostly of Southern Gulf origin (Comeau *et al.* 2002b). It is possible that the other tagged fish were then far to the southeast but there is no empirical confirmation of that speculation.

The survivors of the tagged fish returned to shallower depths in spring 2001, most of them crossing the receiver line in April. Again, most reached it in the vicinity of The Gutter, only about one in three doing so in the AOI. They made less movement along the line than in the fall, perhaps swiftly crossing it towards their spawning ground, though such along-slope displacement as they made was more often to the northwest. Three of the ten individuals for which the first spring record was in the AOI moved nearly 100 km, placing them at the mouth of The Gutter before they headed inshore (Comeau *et al.* 2002b).

What happened to the one third of the fish which did not cross the receiver line in the fall is unclear. They might have entered the AOI, passed Scatarie inshore of the line and descended into the Channel further to the southeast. Some could have similarly passed between Cape North and the northernmost receiver. It is, however, possible that some fish overwinter in the cold shallows of Sydney Bight. During the years around 1980, groundfish trawl surveys were conducted across the Scotian Shelf in spring and fall, in addition to the summer surveys which have been on-going since 1970. Ice cover severely restricted the spring survey effort in the Bight and the resulting data have limited usefulness. In contrast, the fall surveys, which fell in October to December, found adult cod widely spread throughout the Bight, including in the AOI (Frank *et al.* 1994). It cannot be certain that those were resident fish but, in that era and at those depths, it does seem likely. While they may have moved deeper later in the season, much as the second group observed by Comeau *et al.* (2002b) did, some of them could have remained on the inshore banks.

Little is yet known of the possible use of the AOI by juveniles of the Sydney Bight cod, small individuals being de-emphasized when mapping biomass based on resource-survey data (*e.g.* Horsman and Shackell 2009), while young cod apparently prefer seabeds too rough and too shallow for survey trawls. Frank *et al.* (1994) did find that small numbers of Age 1 fish had been taken from points throughout the Bight, including in the AOI, by both the summer and fall trawl surveys between 1979 and 1984, but those may not represent the main aggregations of the fish. Indeed, a considerable body of literature has been built up addressing the habitat preferences of young cod of other coastal populations, extending chronologically from Keats *et al.* (1987) to Thistle *et al.* (2010) and beyond, while encompassing laboratory experiments as well as field observations. It is now well established that post-settlement young-of-the-year coastal cod live in very shallow water, particularly in areas with three-dimensional “cover” – cobbles and boulders, eelgrass or other emergent epibenthos. It appears that the survival of the young fish is materially enhanced by the complexity of vertical structure (*e.g.* Lough *et al.* 1989; Tupper and Boutilier 1995; Lindholm *et al.* 1999), at least where predation is dominated by hunting predators. Where they have been studied, older juveniles are distributed at progressively greater depths, at least in summer. No part of the AOI extends to the shallows preferentially utilized by young-of-the-year coastal cod, but it may prove that the rough crest of Scatarie Bank, with its macroalgal turf, is disproportionately important to older juveniles of the resident population. To date, however, the greatest densities of small juveniles recorded in the Bight were taken by inshore surveys in the Bird Islands area, close to the spawning ground of the adults, and only limited numbers of older juveniles have been seen on the banks eastward to Scatarie (Lambert and Wilson, in Campana *et al.* 1995) – although it must be remembered that those observations also came from trawl surveys, which necessarily avoid the rough habitat favoured by the young fish.

The available information on other species of migrant or resident nekton is far less detailed than that for cod and herring, though it may be expected that similar complexities would be found by detailed study. It is known that the summer (and so presumably primarily resident) trawl-vulnerable groundfish community shows a band of relatively high richness along the wall of the Laurentian Channel, including that portion within the AOI but more especially in the vicinity of Cape North. The same fish community has relatively low richness over the inshore portions of Smokey, St. Anns and Scaterie banks, including the southwestern third of the AOI (DFO

2012a). No similar analysis of the spring or fall trawl-survey data appears to have been attempted.

The east-going flux of intra-regional migrants across the western border of the AOI in the fall is thus far more complex than simply a movement along the wall of the Laurentian Channel by the fish that spend their summers in the southern GSL. Its magnitude cannot simply be calculated by summing the estimated biomasses of those resources but must nevertheless be in the hundreds of thousands of tons per year at least and may exceed a million tons.

What is even less clear is the ecological role of these many migrants within the AOI. The flux of mackerel or saury biomass into the AOI across its western boundary in the fall may total over 500,000 t but it will be matched by an almost-equal outward flux across the eastern boundary, lagged by perhaps a day. Fish that overwinter within the AOI may be expected to make a larger contribution to local ecosystems but it is unlikely to be a season of high activity levels and the amount of predation (either by or on the migrants) may be very low: GSL cod, for example, eat little during the winter (Schwalme and Chouinard 1999; Comeau *et al.* 2002a). It is not even sure whether the migrants make a net positive contribution to the energy in the AOI's ecosystems or whether they carry away more than they bring. Still less can the gain or loss be quantified or apportioned across the many constituent components of the local ecosystems.

Resident individuals necessarily feed, and are preyed upon, within Sydney Bight, some of them presumably in the AOI specifically. As a generalization, cod typically feed on zooplankton when very young but then transition to a benthivorous diet, often including a wide variety of foods. Later, they shift towards eating more fish as they reach larger individual sizes. As an average across years, across the Scotian Shelf and across predator sizes, the leading prey taxon in cod stomachs (in weight terms) is the Clupeidae, likely meaning principally herring, a pelagic. That is followed by the Ammodytidae, meaning sandlance, which can be regarded as part of the benthic ecosystem or at least a substantial contributor to the linkage between the benthos and the water column, since it feeds largely on euphausiids, decapods and other crustaceans yet burrows into the seabed. For the cod, however, those two prey taxa are surpassed by the combination of all of the invertebrates eaten, even though not by any one non-fish taxon (Cook and Bundy 2010). While relevant data do exist, no analysis of location-specific diets in Sydney Bight appear to have been attempted.

While the details certainly differ from one species to another, the tendencies towards highly diverse diets and diets that change with age and increasing size seen in cod are broadly applicable to most groundfish.

Benthic Ecosystems

In contrast to the organisms of the water column, with their fluxes across the boundaries of the AOI, as adults the individuals of the benthos are very largely resident within the Area, the sessile forms being entirely immobile. Hence, the benthos shows the greatest promise of benefitting from area-based management measures, such as the establishment of an MPA. However, many of the benthic species, including almost all of the macro- and megabenthic species, have meroplanktonic egg and / or larval forms, such that their local sub-populations in the AOI are to some degree dependent on upstream sources of recruitment, leaving them vulnerable to anthropogenic stressors outside the specially-protected area. Conversely, if the enhanced protection should lead to increases in biomass and spawning within an MPA, the Area may become a valuable source of recruitment for locations downstream. In short, while the fluxes of benthic larvae across the AOI's boundaries are only a minor part of the zooplankton biomass flux, they will be critical to the success of a future MPA.

Since benthic ecosystems are nevertheless primarily place-based, they cannot be described without site-specific data, which are largely lacking for the AOI. There have been some camera observations but only on two transects across the southern part of the Area. Data on selected types of benthic invertebrates are available from research-vessel trawl surveys but the gear is unsuited to sampling of most of the benthos. Nor can much be extrapolated from knowledge of the wider Scotian Shelf: Breeze *et al.* (2002) have summarized the available, though limited, knowledge on the benthos of that region. There are extensive (although still incomplete) species lists, maps of distributions and descriptions of community compositions, but the maps have low spatial resolution and knowledge of the functional relationships among the species is weak. In consequence, useful information is available on some special features of the AOI, such as the macroalgal beds which have already been described, but not on the structure and function of the local benthic ecosystems – the very ecosystems which might be positively affected by the protections afforded by any future MPA designation.

Although current knowledge of the details may be weak, it is highly probable that the benthos and benthic ecosystems play key roles in the AOI, as they do almost everywhere on continental shelves, with their biogeochemical processes linking non-living sediments and the benthic biota to the organisms in the water column. The benthos is also a primary food source for demersal fish, while the macro-epibenthos can provide three-dimension structure, shaping the habitats of other species, as noted above for juvenile cod.

It is also clear that benthic ecosystems below the photic zone, which means across all of the AOI save for the shallow crest of Scatarie Bank, receive the bulk of their energy in the form of DOC and organic detritus, the latter comprising phytodetritus (fragments of macrophytes, flocculated but uneaten diatoms from the spring bloom and various exudates), faecal material and animal carcasses (*cf.* Desrosiers *et al.* 2000), derived from the water column. Some living phytoplankton will reach filter feeders on the seabed but, with the intense stratification of the water column in Sydney Bight in the spring and summer, that supply is likely to be minimal at the depths across most of the AOI, except perhaps downstream of Scatarie if local vertical mixing resulting from the fast tidal streams carries phytoplankton down to the seabed there. Across all depths, some live zooplankton will be consumed by benthic animals, including by the abundant sand lance already mentioned. Also as already noted, there may be minor hydrocarbon seeps, particularly at the pockmarks on the floor of the Laurentian Channel, supporting microbial communities which in turn feed the benthos. Nevertheless, the detrital and DOC supply from the water column must provide the greater part of the energy reaching the benthos. Above the rim depth of the Laurentian Channel, a considerable portion of the vertical flux likely takes the form of passive sinking, particularly of copepod faecal pellets, some locally produced and the rest advected across the upstream boundary of the AOI. In the deeper waters of the Channel and as noted above, that slow supply is presumably much exceeded by the amounts of detritus generated at depth after material and energy has been carried down in the form of actively migrating animals, through both the diel movements of krill and myctophids and the seasonal ontogenetic migrations of *Calanus* spp. (*cf.* Vinogradov 1997). Those may be supplemented by the downward movement of groundfish in the fall. At three stations on the Channel floor, including one in the Cabot Strait, Desrosiers *et al.* (2000) found a higher abundance of macrobenthos (captured in 100 mm-diameter cores and retained by a 0.5 mm sieve) in November–December than in June, which they suggested might have resulted from increased fish predation during the summer. An alternative explanation of a benthic response to the energy pulse provided by the downward fall migration cannot be dismissed.

The energy in that fraction of the detritus that reaches the seafloor is exploited by a wide diversity of biota: varying in size from the microbial flora to large sponges and coral “trees”; taxonomically including members of most animal phyla; in habitat from burrowers (both errant and sedentary) and inhabitants of the interstices among sediment particles, to both attached and mobile epibenthos; in terms of trophic guild from filter feeders and deposit feeders to omnivorous scavengers. Next to nothing is known of how those many species interact within the AOI. On the Laurentian Channel floor further to the northwest, deposit feeders predominate amongst the macrobenthos (Desrosiers *et al.* 2000), but areas with faster water flows can be expected to favour suspension feeders, while the megabenthos should be mostly comprised of mobile scavengers (*e.g.* echinoderms, gastropods, crabs) and sessile filter feeders (*e.g.* bivalve molluscs, sponges, corals). Once the energy and organic material supplied as detritus have been captured by benthic organisms, both will be recycled within the seabed ecosystems, as well as exchanged with the water column through predation and a return to the detrital pool. Potential predators range in size from meiofauna to large crabs, including both grazers and active hunters, with individuals switching between scavenging and predatory behaviours as opportunities offer.

While the varied components of the benthic ecosystems, in all their complexity, are intimately connected to one another, labelling of their systems as “benthic” and hence distinct from the water column, with the connections between being treated as “bentho-pelagic coupling”, are largely convenient abstractions, driven by the very different sampling tools available for seabed and midwater studies. Exchanges of inorganic nutrients between water and sediment are complex but often of great quantitative importance. The dependence of much of the benthos on recruitment by planktonic larvae and the supply from the water column of almost all the energy driving the ecosystems have already been stressed. Most groundfish are clearly members of the nekton, many of them migratory, and yet for much of their lives they are benthivores, reliant on the benthos for food but also apparently important as consumers of that benthos, while supplying detritus to the seafloor ecosystems. Other demersal finfish, including sculpins, liparid seasnails, zoarcid pouts and perhaps the wolffishes, are relatively sedentary and can be more firmly seen as part of the benthic systems, if not exactly as benthos themselves. The benthopelagic crustaceans, including mysids and decapod shrimps amongst others, similarly span the artificial distinction. The particular case of the sand eels has already been noted but an example of another kind of interaction is the mesopelagic pout, *Melanostigma atlanticum*, which spends most of its life in midwater, at hundreds of metres depth over the continental slope, but burrows deep into the seabed apparently to brood its eggs – such burrows having been found in the floor of the Laurentian Channel (Silverberg *et al.* 1987). In short, the resident, even static, benthos of the AOI is intimately coupled to the water flowing above and hence to the many fluxes across the Area’s boundaries.

All of that generalization is, however, based on plausible extrapolations from what is known of other areas. Aside from raw data still awaiting analysis, most of the site-specific details available for the benthos of the AOI concern the commercial resource species and a few special and distinctive features. Among the former there are reasonable numbers of snow crab (*Chionoecetes opilio*) in the Area and likely stone crab (*Lithodes maia*) deeper on the wall of the Channel. Otherwise, benthic resource species are scarce. Lobsters (*Homarus americanus*), rock crab (*Cancer irroratus*) and whelks (*Buccinum undatum*) are fished around Scatarie Island, while there are inshore scallop beds in the vicinity, but those species are primarily confined to the warmer, shallower areas, which are largely outside the AOI.

Several distinctive seabed features have already been mentioned: the macroalgal patch on Scatarie Bank, the herring spawning bed somewhere in the vicinity of “The Big Shoal” and the bedrock outcrops to the east. Otherwise, Kenchington *et al.* (2010), using kernel density analyses to interpolate between bycatch records from groundfish surveys, identified a handful of small patches on the Scotian Shelf that each holds a significant concentration of sea pens (Pennatulacea). One of those patches lies near the top of the wall of the Laurentian Channel, just inside the eastern boundary of the AOI, while another lies on the slope of Scatarie Bank immediately outside the AOI’s southern border. Each was defined on the basis of a single catch of more than 200 g in a standard survey tow but subsequent camera observations have shown the patch within the AOI to be extensive and to have a higher density of sea pens than has been seen elsewhere on the Scotian Shelf (Dr. E. Kenchington, BIO, *pers. comm.*). Much as for juvenile cod interacting with the habitat complexity provided by shallow-water emergent epibenthos, the sea pens of the Laurentian Channel have been identified as valuable habitat for redfish larvae in the spring (Baillon *et al.* 2012). Kenchington *et al.* (2010) similarly identified an area of significant sponge catches on the flank of St. Anns Bank, above the rim of the Channel, based on multiple survey catches of a few kilograms per tow. The snow crab trawl surveys have also taken relatively large sponge bycatches in the same area. To have been retained in the trawls, those were presumably large, erect sponges but they are as yet unidentified. The sponge patch has not, to date, been examined using appropriate survey or sampling methods and hence its extent and nature remain poorly known.

One final species within the benthic ecosystems on St. Anns and Scatarie banks merits some special attention here: the Atlantic wolffish is a species of conservation concern which is relatively more abundant in groundfish trawl survey catches in the southeastern corner of the AOI than in most other parts of the eastern Scotian Shelf, although there are large patches of similar density off southwest Nova Scotia. A future MPA off Scatarie might, therefore, help support the species' recovery. The importance of the AOI to wolffish should not be over-emphasized, however: The adult fish appear to prefer hard-bottom habitats that are inaccessible to bottom trawls, while the dominance of the local area in the survey catches of (presumably primarily) smaller individuals only emerged in the 1990s, as aggregations elsewhere declined (Horsman and Shackell 2009).

Wolffish are widely regarded as non-migratory, though they do follow seasonal circuits (*e.g.* Kohler 1968; Nelson and Ross 1992) which, off Iceland, can amount to displacements of hundreds of kilometres annually (Jónsson 1982). It remains possible that, in Sydney Bight, they do no more than change depths, without swimming further than a few tens of kilometres. Within the AOI, the July trawl surveys find wolffish primarily along the flanks of St. Anns and Scatarie banks at depths of 100 to 150 m but sentinel surveys, using longline gear, have found their largest catches of the species at lesser depths and hence closer to land. That might be a seasonal change in distribution but it could additionally, or alternatively, reflect differences in individual fish sizes, with small wolffish being vulnerable to trawl nets towed over relatively smooth seabeds, while longlines set on hard bottom take mostly adults. A tendency for smaller wolffish to be caught at greater depths than are the larger individuals (a reversal of the "larger deeper" rule common to many fish species) has been found in both Newfoundland waters (Keats *et al.* 1986) and the Gulf of Maine (Nelson and Ross 1992) and hence may be expected off Cape Breton also. Moreover, large adult wolffish preferentially use very rough, shallow habitats, seeking shelter amongst rocks and other vertical relief, sometimes in immediately sublittoral depths (*e.g.* Keats *et al.* 1985; Pavlov and Novikov 1993; Kulka *et al.* 2004; Larocque *et al.* 2008), at least seasonally (Jónsson 1982; Keats *et al.* 1985, 1986) and in daylight. Thus, the crest of Scatarie Bank and the shallow waters between the AOI and Cape Breton Island may be of particular importance to the species. However, much more detailed studies of the movements of the species in the Sydney Bight area would clearly be needed before the degree of protection potentially afforded by an MPA could be determined.

Charismatic Top Predators and Trophic Cascades

The approach to a description of the ecosystems of the AOI followed above tends to emphasize the most abundant species and the principal trophic pathways. Future MPA management will probably also consider the rarities, with an emphasis on those charismatic species that will draw public attention and aid in achievement of an MPA's educational goals. While there are exceptions, such as the corals, charisma tends to be associated with top predators.

Data are scarce but the AOI appears to be used, at least as a migratory route, by a number of species of large sharks and by bluefin tuna. There is, however, no evidence that the Area is particularly important to any of them, save for its straddling the pathways into and out of the GSL. A suspected mating ground of porbeagle shark extends from Sydney Bight to Grand Bank

(Campana *et al.* 2003) and there may be some mating within the AOI, though there is no reason to think that Area especially important. Whether any of those large fish materially affect local ecosystems remains quite unknown.

The AOI is also used by the only marine reptile to occur routinely on the Scotian Shelf: the critically endangered leatherback turtle (*Dermochelys coriacea*). Whether the Area is any more important for that species than many other locations on the Scotian Shelf is unclear, as the available data come from satellite tags applied to individuals caught in a few locations, one of which is off Cape Breton (James *et al.* 2005; DFO 2012c) and thus show a disproportionate number of records in the vicinity of Sydney Bight. Such as they are, those data suggest that the turtles make particular use of a swath of sea from northwest of the Magdalen Islands to east and south of Scatarie, mostly along the southwestern edge of the Laurentian Channel. While a portion of that broad area lies within the AOI, it sees no more presence of leatherbacks than do the waters westwards to Cape North (DFO 2012c). Since the turtles are now so scarce, they can have little effect on the ecosystems in which they feed, though it remains possible that their past depletion has released their prey, primarily gelatinous plankton, from significant predation pressure.

A wide variety of marine birds feed within the AOI, although current estimates of their biomasses and consumption rates suggest that they do not eat enough to much affect their prey populations (Bundy 2005). The food within the AOI is, however, very likely important to the members of breeding colonies along the easternmost coast of Cape Breton, at least seasonally, since there is an energetic imperative for adult birds to forage near their colonies while they have nestlings to feed. Thus, an MPA off Scatarie Island might contribute to conservation of nearby colonies, including those of black-legged kittiwake (*Rissa tridactyla*), Leach's storm petrel (*Oceanodroma leucorhoa*), black guillemot (*Cepphus grille*), great cormorant (*Phalacrocorax carbo*) and both great black backed and herring gulls (*Larus marinus* and *L. argentatus*), which between them nest on the North and South Heads of Morien Bay, on Scatarie Island itself and on the nearby Cormorandiere Rocks and Hay Island. There are also colonies of common tern (*Sterna hirundo*) at some of those locations and elsewhere in the vicinity.

It can additionally be surmised that the AOI is used by a variety of cetaceans, including both large baleen whales and the smaller odontocetes, at least as a short segment of their migration routes to and from the GSL. Local data are, however, all but absent and nothing is known of cetacean feeding in the Area, either now or before their historic, anthropogenic depletion. Potentially, dolphins and pilot whales might be locally significant predators of fish even in modern times, though it is unlikely that there are enough baleen or sperm whales for them to currently have much influence on the ecosystems in the AOI. There are also pinnipeds in the Area, which can include members of the Gulf herd of harp seals (*Pagophilus groenlandicus*) when their breeding ice is carried out through the Cabot Strait in spring, and likely harbour seals (*Phoca vitulina*). The principal pinniped of the region is, however, the grey seal (*Halichoerus grypus*), which has a small breeding colony on Hay Island, near Scatarie, though the bulk of the individuals in the AOI likely come from the much larger Gulf and Sable Island colonies.

Charisma aside, it is generally supposed that, before the advent of the commercial fishery, the dominant top predators across the continental shelves of the northwest Atlantic were very large, and hence presumably piscivorous, cod. Individuals of *circa* 1.5 m length could still be found on the eastern Scotian Shelf into the 1980s (*personal Observation*), although by then they were far too scarce to be of ecological significance. As a consequence of fishing pressure interacting with poorly-understood ecological factors, even the smaller size-classes of most populations are now severely depleted (*cf.* Halliday and Pinhorn 2009). There is a growing literature on the ecological consequences of that recent extreme depletion of the eastern Scotian Shelf cod specifically, which change has been wrapped up with the apparent replacement of cod by grey seals. There is a possibility that the loss of the cod has led to a trophic cascade, with effects extending throughout the ecosystem [see O'Boyle and Sinclair (2012) and references therein]. Much of that recent research is relevant to the ecosystems of the AOI. Whatever its causes, however, the cod decline of the past 25 years has been a loss of fish that would have been considered small until the mid-20th Century – fish that probably occupied a niche distinct from that filled by the much larger cod of a former era, with their diets of larger fish.

Those big cod may have been driven to ecological irrelevance long ago. Before European contact, exploitation of cod by the native peoples of what is now Atlantic Canada was limited by their low population densities. Commercial fishing in Sydney Bight apparently began with a Portuguese seasonal fishing station at Ingonish, established in the 1520s (Pope, unpublished[3]). Data from the following three centuries are scarce but the expected effect of even light fishing pressure is to markedly depress the largest size-classes of the fish. Assuming the conventional exponential mortality model, isometric von Bertalanffy growth, recruitment to the exploited population at 25% of asymptotic length and no change in population-dynamic parameter values, sustained fishing at an "optimal" $F_{0.1}$ level should reduce the equilibrium biomass of individuals larger than 75% of asymptotic weight by about 98% – all but eliminating that size fraction of the resource. Even sustained fishing mortality of one tenth of $F_{0.1}$ should reduce the equilibrium biomass of those same sizes of fish by some 50% from its virgin level[4]. Indeed, the very limited available evidence (Kenchington and Kenchington 1993) suggests that there were already too few really big cod for them to be targeted by the banks schooner fishery in the 1750s. Hence, although great uncertainty remains, it appears that the dominant natural top predator of both the AOI and the surrounding region may have been very significantly depleted centuries ago. To date, there has been no scientific investigation of the ecological effects of that depletion, although it may well have transformed local and regional ecosystems.

The degree of similarity between the ecosystems in the AOI as they are now and as they would have been, had the commercial fisheries of the last five centuries never emerged, remains essentially unknown though it seems likely that the differences are profound. Moreover, since cod and the other principal resource species are migratory, the depletion of large fish and its ecological consequences cannot be mitigated through area-specific measures such as an MPA, which cannot influence region-wide levels of fishing mortality. Thus, even if anthropogenic activities were strictly controlled within an MPA established off Scaterie, it should not be expected that the protected ecosystems would return to the state they would have had in the absence of fishing.

Summary of the Ecosystems

In short, the ecosystems of the AOI are not atypical of those of temperate continental shelves, though the limited size of the Area, supplemented by its location in the unidirectional Cape Breton Current, magnifies the importance of transboundary fluxes of various kinds. Indeed, the AOI is best regarded as an "open" or "flow-through" system that is particularly remarkable for straddling the major migration route which passes through the Cabot Strait. The fluxes of nekton biomass across the AOI, westward in spring and eastward in fall, may be key in the shaping of its ecosystems. The presence of an exceptionally-large shelf valley, the Laurentian Channel, also has a determining influence on those ecosystems. Together, they drive biotic patterns which span the AOI, such as overwintering concentrations of both Gulf groundfish and zooplankton herbivores, summer feeding by both seabirds and leatherback turtles. Like the

[3] Unpublished report "A sixteenth-century Azorean Portuguese colony in Cape Breton: A speculative analysis" prepared for the Nova Scotia Department of Tourism and Culture (1992).
[4] Percentages drawn from author's research in progress.

Channel and the migration route, however, those patterns are much larger than the AOI and can only receive limited protection from area-based management measures such as an MPA.

Distinctive features that are captured within the AOI include the deep patches of exposed bedrock east of Scatarie, the offshore macrophyte patch on Scatarie Bank, plus the sea pen field and sponge bed that have been identified. There may also be a herring spawning bed within the AOI, while an MPA there might materially contribute to the conservation of Atlantic wolffish. Even those features remain at risk of negative effects of anthropogenic pressures exerted outside the AOI, the effects being carried in as fluxes across the Area's boundaries. Indeed, even should the consequences of past overfishing be repaired in the future, continued fishing at optimal levels in Sydney Bight and the GSL would hold large groundfish to abundances far below their natural levels. The ecological consequences of that harvest would enter the AOI through an absence of big, migratory fish – consequences that no MPA could exclude.

ANTICIPATED ANTHROPOGENIC PRESSURES ON THE ECOSYSTEMS

The literature on MPA monitoring distinguishes human "activities" from the "threats" that they pose to ecosystems. While that distinction is sometimes clear, in other cases it can lead to semantic arguments with no unique solutions. Furthermore, to label any anthropogenic stressor as a "threat" is to draw a value judgement and an extreme one. Hence, in contrast to the terminology used by Kenchington (2010), the "activities" and "threats" of the monitoring literature are here merged and, following DFO precedents, are termed "pressures" on ecosystems. Some of those act directly on the biota within a specific area but others are mediated through sometimes-complex pathways, the distinction between pressure and pathway being another topic of irreconcilable debate. To avoid the latter, pressures and the pathways through which they act are here combined.

At the time of writing, no comprehensive analysis of the anthropogenic pressures on the ecosystems within AOI, nor of the pathways through which their effects are mediated, is available. By extension from considerations of other areas (*e.g.* Kenchington 2010), however, they might be thought to include (not necessarily in priority sequence):

1) Extractive use of fish and invertebrate populations by:
    a) Commercial fisheries,
    b) Recreational fisheries, and
    c) Research and monitoring,

    whether the extraction occurs within the area or, in the case of species that are mobile across scales larger than the MPA, also outside,
2) Disturbance of seabed habitats and the benthos in the AOI by:
    a) Bottom fisheries,
    b) Research and monitoring sampling on the seabed,
    c) Deployment on the seabed of other research and monitoring equipment,
    d) Laying of pipelines, power cables or telecommunications cables,
    e) Vessel anchoring, and
    f) Industrial development in the Area, including petroleum exploration or development activities, offshore renewable-energy projects and the like,
3) Entanglement of whales, seabirds, turtles and perhaps other animals, of those populations which pass through the area, by:
    a) Commercial fishing gear, particularly longlines and the lines used with traps, and
    b) Research and monitoring gear,
4) Vessel strikes on whales and turtles by:
    a) Research and monitoring vessels,
    b) Naval vessels,

   c) Other government vessels,
   d) Commercial fishing vessels,
   e) Ecotourism vessels,
   f) Other mercantile vessels, particularly large cargo ships, cruise ships and ferries, and
   g) Vessels servicing any future industrial development in or near the Area, including petroleum exploration or development activities, offshore renewable-energy projects and the like,

5) Sound emitted by vessel traffic both in and near the AOI (primarily engine noise, propeller noise and sonar emissions), including by:
   a) Research and monitoring vessels,
   b) Naval vessels,
   c) Other government vessels,
   d) Commercial fishing vessels,
   e) Ecotourism vessels,
   f) Other mercantile vessels, particularly large cargo ships, cruise ships and ferries,
   g) Vessels servicing any future industrial development in or near the Area, including petroleum exploration or development activities, offshore renewable-energy projects and the like, and
   h) Recreational vessels,
6) Release of chemical (*e.g.* oils), biological (*e.g.* organic garbage) and other (*e.g.* plastics) contaminants, including routine emissions, illegal discharges and occasional major accidents, from
   a) Research and monitoring vessels,
   b) Naval vessels,
   c) Other government vessels,
   d) Commercial fishing vessels,
   e) Ecotourism vessels,
   f) Other mercantile vessels, particularly large cargo ships, cruise ships and ferries,
   g) Vessels servicing any future industrial development in or near the area, including petroleum exploration or development activities, offshore renewable-energy projects and the like, and
   h) Recreational vessels,
7) Release of invasive species during ballast-water exchange by mercantile vessels, particularly large cargo ships,
8) Aircraft noise,
9) Noise from seismic surveys,
10) Release of contaminants, including but not limited to drill muds, cuttings and produced water, from industrial development in or near the Area, including petroleum exploration or development activities, offshore renewable-energy projects and the like,
11) Retention and concentration of contaminants from outside the AOI (other than from marine vessels or offshore industrial development), including:
   a) Run-off and discharges or spills from the adjacent coastline including discharges and spills in nearby harbours,
   b) Run-off, discharges, spills or disturbed marine sediments in the coastal waters of Sydney Bight, including outflows from Sydney Harbour, Little Bras D’Or and Big Bras D’Or,
   c) Contaminants in the outflow from the GSL, through the Cabot Strait, including contaminants originating in the Great Lakes and St. Lawrence catchment area, and
   d) Long-range transport of air pollutants,
12) Imbalances in the trophic structures of the ecosystems, resulting from past anthropogenic disturbances, potentially including excess abundance of some top predators (*e.g.* grey seals) and insufficient numbers of others (*e.g.* large Atlantic cod, large sharks),

13) Introduction and spread of aquatic invasive species, and
14) Anthropogenic changes in the oceanographic climate of the northwest Atlantic, including those mediated through global climate change and those resulting from alterations to the inflows to the GSL.

The listed items are to be understood as the anthropogenic pressures acting on the ecosystems within the AOI, whether or not the human activities that cause them occur within that Area. It has been suggested that MPA monitoring should only consider pressures resulting from activities within the MPA, since only those are subject to MPA regulations and management, though the Gully MPA regulations apply to any activities under Canadian jurisdiction which have negative impacts within the MPA, wherever the activity occurs, and the same principle may be invoked for other MPAs. Besides, when deciding on rational management responses to change in the ecosystems within an MPA, it is necessary to understand the causes of the observed change, which may well involve anthropogenic pressures exerted outside the Area's boundaries. Of perhaps greater importance, the proposed development of a Canadian MPA network is built on the supposition that an MPA can, to some degree, protect the ecosystems within its bounds. That tenet is challenged by the existence of anthropogenic pressures that reach into an Area from human activities outside. If the design of the network is to learn from experience with the first MPAs, then monitoring must provide the data for tests of that challenge.

In the absence of a more thorough analysis, it would be premature to suggest the relative degrees of threat posed by each of the many pressures. It is, however, all but certain that the principal past anthropogenic impact on the ecosystems in the AOI was the result of commercial fishing depleting its target resources and thereby disturbing the balance of the ecosystems (items 1a and 12 in the above list). Another pressure of note off Scatarie is vessel noise, especially that emitted by large merchant ships. During 2010, the various ports in Québec handled nearly 6,600 movements of ships in international trade, totalling some 170,000,000 gross tons (Statistics Canada 2012). While some of those ships will have passed through the Strait of Belle Isle in summer, there was additional traffic to and from ports in Ontario, via the Seaway, and some from Atlantic Canadian Gulf ports. Hence, it appears that, on average, approximately one large merchant ship per hour passed either in or out of the Cabot Strait, steaming through or near the AOI in the process. Unfortunately, there has been almost no study of the impacts on marine life of the pervasive noise emitted by such densities of ships but they have become an issue of mounting concern (*e.g.* OSPAR 2009) and merit future attention.

The as-yet unexplained withdrawal of haddock from the GSL in the mid-20th Century should, however, serve as a warning that there may be additional, unknown and yet substantial anthropogenic impacts on marine ecosystems. It is sometimes suggested that MPAs serve as "insurance against ignorance" in marine management (*e.g.* Rice and Houston 2011). If so, it is important that their effectiveness not be undermined through ignorance of the potential for external pressures to bear on the supposedly protected ecosystems within.

A RECOMMENDED MONITORING FRAMEWORK

INTRODUCTION

Why Monitor?

Kenchington (2010) summarized the purposes and need for a monitoring program as an integral component of MPA management. Monitoring is required to provide the information necessary for effective management, meaning management that is responsive to the state of and trends in the protected ecosystems, in human uses of and responses to the MPA and in the anthropogenic pressures exerted on the ecosystems. The core focus should be on progress towards or attainment of the MPA's objectives, thereby evaluating the effectiveness of management measures to date. In contrast to some other Areas, the draft conservation objectives for an MPA in the St. Anns Bank AOI are broad, as are the formal objectives of the Gully MPA. Hence, objective-focused monitoring amounts to monitoring the state of the ecosystems as a whole.

It is sometimes argued that monitoring should be more narrowly focused onto variables that would inform the use of those adaptable management measures which can be adjusted in response to the flow of information. That proposal is rejected here. Unlike quota-controlled fisheries, MPAs do not commonly have immediately-responsive, variable measures that could be identified in advance. Rather, MPAs are designed as long-term measures which can only be adapted through alterations in design, such as adjustments in their boundaries, in internal zoning, in the activities permitted (perhaps through attaching more stringent conditions to permits) or, ultimately, through a decision to delete the protected status of an MPA which fails to advance its objectives. Such adjustments need to be designed in response to broad-ranging information gathered by the monitoring program, not triggered by changes in single variables. Thus, monitoring should not be tailored to some pre-conceived set of management adjustments. Indeed, the most readily adaptable management response may not concern a monitored MPA at all but would rather be alterations in the design of forthcoming MPAs as the proposed national network is rolled out. The overall Canadian MPA program needs to learn from its own experience and that requires broad monitoring of the individual MPAs. In most of them, the principal economic activity that is or will be markedly restricted is fishing. Stakeholder tolerance of those restrictions is sometimes enhanced by a supposition that the fisheries outside the boundaries will be enhanced by the restrictions applied within – a supposition which seems to be supported by the third draft goal for a future MPA off Scatarie. If the establishment of additional MPAs is not to be strongly opposed, evidence for their fishery benefits will be needed and must be gathered through monitoring.

While a core monitoring focus on the objectives of the MPA calls for measurement or estimation of variables or indices representing environmental quality, biodiversity and productivity within the Area, it would not be sufficient to detect change (or its absence) in those alone. If there is to be a rational management response, it is also necessary to know why the ecosystems are changing. To do so, the anthropogenic pressures on the ecosystems must be monitored. Since marine ecosystems are strongly influenced by oceanographic climates and conditions (themselves responsive to both anthropogenic and natural drivers), it is essential to also monitor relevant variables, allowing interpretation of trends in the core measurements that are not driven by local human activities alone.

For efficiency, MPA monitoring should also be coordinated with the Department's regional, zonal and national monitoring programs, such that the MPA monitoring both utilizes the on-going work, instead of duplicating it, and contributes to the wider programs. For example, the signature species of the Gully MPA include deepwater corals, which are vulnerable to the effects of ocean acidification at considerable depth. It would be desirable to monitor acidification in the corals, as an aspect of MPA monitoring, but there would also be value in monitoring deep-ocean acidification in support of monitoring of global climate change. A monitoring station established within the MPA could serve both purposes simultaneously (*cf.* Kenchington 2010).

Indicators in MPA Monitoring

A typical *Oceans Act* MPA has goals that relate to the protection of ecosystem structure and function. Ecosystems, however, are intrinsically complex, while their emergent properties are not usually directly measurable. Efficient and effective monitoring of such systems cannot be carried out through casual observations, nor as a series of disconnected research studies. In particular, trend monitoring (designed to detect temporal change or its absence: *cf.* Kenchington 2010) must be based on repeated determination of the same variables using the same methods, so as to maximize the “signal to noise ratio” of the data streams. The results of that work are not reported as voluminous and incomprehensible raw data but as temporally-repeated values determined for each of a set of “indicators” which together capture the information needed for MPA management. Indicators serve to reduce the unbounded complexities of real ecosystems to a relatively small set of measures that are, hopefully, affordable, comprehensible, quantifiable, standardized across time in the case of trend monitoring, and communicable to MPA managers and the interested public. Ultimately, those indicators must be precisely, if narrowly, defined: the definition frequently being dependent on the details of the data-collection methodology, since the best that can be achieved in the face of natural spatial and temporal variability is monitoring change in measured or derived variables, as indications of change in an ecosystem.

There is a risk that the reductionist approach to monitoring inherent in the use of indicators will produce confident measurements of temporal trends in highly-specific aspects of the ecosystems of an MPA, while missing the interactions among those system components – the interactions that generate the overall characteristics of the ecosystems. Yet any other approach to the monitoring of temporal trends would create such massive uncertainties in the information gathered as to render the exercise useless as a support for management decision-making. Thus, routine trend monitoring must focus on precisely-defined indicators but must also be supported by a research program that will generate an understanding of the ecosystems of the MPA and hence a context for interpretation of the monitoring results. Meanwhile, minimizing the number of indicators will aid understanding and communication, as well as lowering costs, but will also increase the loss of information and the risk that critical changes will not be detected. Hence, a careful balance is required or would be if budget considerations did not override other criteria and compel a minimalist approach.

An unrecognized confusion has arisen between two very different concepts, to each of which the term “indicator” has been applied. One notion, which will here be designated an “index”, sees an “indicator” as almost a scale of measurement, often defined by a simple equation that reduces a data vector to a single scalar value and which can be quantified using any applicable data set. Examples of such indices include the familiar Shannon Diversity Index and the Large Fish Indicator (“LFI”) of Greenstreet *et al.* (2011). Given suitable data, an index in that sense is globally applicable. The term “indicator” has been used for such indices in the context of marine ecosystem monitoring by Samhouri *et al.* (2009) and Shin *et al.* (2010) among others. The “indicators” required in an MPA monitoring plan (*cf.* Pomeroy *et al.* 2004; IOC 2006; Wilson and Tsang 2007), in contrast, are items to be measured (rather than scales of measurement) and, once specified in sufficient detail to ensure comparability over time for trend monitoring, will typically be specific to a particular MPA. An example might be: “The annual average total length of all individuals of the fish species listed in Appendix A that are taken within the MPA by standard sets made in accordance with the survey protocol given in Appendix B”, with the appropriate appendices being attached to the monitoring plan. Such an indicator (*sensu stricto*) could use an index as its scale of measurement, as in the case of the Shannon Index being used in an indicator of diversity or the LFI in an indicator of fish sizes, but other indicators might use simple counts or averages of raw data, even semi-quantitative verbal summaries in some cases. Hence, the concept of an “indicator”, as the term is understood here, is much broader than that of an index, though a particular indicator used in an MPA monitoring plan must be much more specific.

Since any future MPA off Scatarie is, at the time of writing, still in a vestigial state of development, all that can be offered in the present framework are generic approaches to the required highly-specified indicators. That is not, however, a reason to substitute indices for indicators. Indeed, the choice among the multiple available indices that might be utilized in some of the indicators is not one that need be made early in the development of a monitoring plan. It need not even be rigidly maintained through the duration of a trend-monitoring program:

provided that the relative abundances of species and the lengths of individuals in the catches of a standardized survey are recorded, reporting of the value of a diversity indicator could be changed from the Shannon Index to one of Simpson's alternatives at any time, while the reporting of fish sizes could switch from an overall mean to the LFI. Such changes would have to be justified and explained to users of the indicator reports, while values of the new measures would have to be back-calculated for earlier years, using archived data, but those are normal activities within any scientific advisory process and pose no special challenges. What is needed from the start of any trend-monitoring program is consistency and continuity in the data collected, including the details of the data-collection methodologies employed. That is essential so that trends over time can be detected without confusion caused by methodological artifacts, despite staff turnover, changing research interests, and evolving Departmental priorities. The need for methodological constancy demands that a final monitoring plan specify the methods to be used in great detail, much as the manuals for the current groundfish surveys do.

The prime requirements in initial planning for such monitoring are therefore, firstly, anticipation of which data streams will be needed for the calculation of indices or other measures that are likely to be important to managers and analysts in decades to come and, secondly, consideration of affordable means to gather those data in standardized ways that minimize unnecessary "noise". Since the cost of data collection far exceeds other aspects of most offshore monitoring programs, while the differential costs of using alternative indices are trivial, early attention to the required data streams is also essential as support for budget requests. In preparing generic approaches to the detailed indicators that will be needed in a monitoring plan for a new MPA, the focus should thus be on data streams and not on the indices which may one day be calculated from those data – save to the extent that the types of data required for the calculation must shape the streams to be captured.

That is not to dismiss the work of Samhouri *et al.* (2009), Shin *et al.* (2010) and those many other authors who have examined the variety of indices available for ecosystem monitoring. Their reviews will have value as the monitoring plan for a particular MPA matures and appropriate indices must be selected for use in some indicators. Similarly, ICES (2012) devoted attention to the choice of indices to be employed in indicators when charged with providing advice on monitoring achievement of the objectives of the European Union's Marine Strategy Framework Directive ("MSFD"). That work was, however, confined to the use of existing data and thus had no need to consider which data streams should be gathered. For the monitoring of an MPA off Scatarie, the equivalent step may be reached at some future time but not in the initial framework recommended here.

A further clarification may be appropriate here: when selecting indicators, it might be ideal to identify some component or aspect of an ecosystem that would be especially sensitive to one class of anthropogenic pressures and that would simultaneously be easy to monitor with adequate precision and at low cost. If monitoring showed no unacceptable change in the sensitive measure, one could conclude that the rest of the ecosystem was even less affected. Such an indicator, serving a "canary in a coalmine" function, could perhaps centre on a particularly sensitive "indicator species". Where it is possible, that approach to monitoring can be very efficient and it is routinely used in, for example, monitoring the toxicity of effluents from outfalls. In MPA monitoring, however, the prime interest lies in ensuring protection of broad ecosystem attributes from a variety of anthropogenic pressures. Appropriate sensitive variables will rarely be available, let alone both available and capable of being affordably monitored. Hence, the concept of an indicator employed here is very much broader than that of an "indicator species" or even an "indicator variable".

Finally, some theoretical treatments suggest that each indicator should be accompanied by pre-set reference limits for use in "rule-based decision-making". Where MPA monitoring is concerned, that would be a mistake. The approach has been widely used in fisheries management, where it leads to unimaginative responses that may meet the oversimplified objectives of analysts but which are often seriously deficient in advancing the broader policy goals of the fisheries affected. It may nevertheless be a justifiable choice in such a setting since stakeholders are better placed to consider long-term optimal management when they are not facing imminent imposition of exceptional short-term restrictions, so that swift responses to declining resources are often better planned in advance and triggered by some indicator falling below a reference value. In contrast, MPA monitoring deals with vastly more complex systems than those which confront fisheries managers, meaning that the significance of a change in the value of any one indicator cannot be determined in advance. Moreover, MPA designs are not normally adaptable over short timeframes. There is a need for management to learn from experience and to adapt accordingly, but the process should be slow, leaving ample time for interpretation of monitoring results and for considered management responses to be designed. What is needed in any MPA monitoring plan is a mechanism that ensures that the interpretation, consideration and response do follow when trends are detected. Pre-determining that an MPA would be automatically deleted and the area returned to the conservation regime applicable in surrounding waters simply because monitoring had shown a failure to achieve some defined objective within an arbitrary time limit would be seriously misguided.

Monitoring Strategy

Once fully developed, the recommended monitoring program for an MPA in the St. Anns Bank AOI is envisioned as comprising:

1) the set of monitoring indicators, each accompanied by a manual specifying the data-collection protocols to be followed,
2) the data collection itself (though much is “data gleaning” from within the Department, rather than requiring new fieldwork),
3) an archive holding copies of all the monitoring data, plus
4) a review, analysis and reporting step that would pass the information gathered, and scientific interpretations of that information, to MPA managers, who could respond with appropriate adaptations of the management plan.

The latter is essential to the functioning of the first three, including in its role as a replacement for the notion of pre-set reference limits.

Comprehensive Monitoring Program: MPA monitoring takes many forms. A variety of types has been defined (*cf.* Kenchington 2010), though they tend to be theoretical abstractions that can at best summarize the structure of pragmatic monitoring plans designed for practical application. The work extends beyond the monitoring of ecosystems, their impacts on humans and the anthropogenic impacts impinging on them, to include “compliance monitoring” (monitoring of an activity to ensure that it is in compliance with MPA regulations and permits), “regulatory monitoring” (monitoring of sufficient rigor that it can generate evidence for enforcement actions) and “administrative monitoring” (monitoring MPA management, to record numbers of permits issued, enforcement actions undertaken and the like). All should be structured as sub-units of MPA management, since they serve a common end, even though very different personnel may be involved: natural scientists in monitoring animal abundances, social scientists in quantifying public attitudes to the MPA, enforcement officers in regulatory monitoring and MPA management staff in administrative monitoring. It is further recommended that all, or at least most, of the different facets of monitoring be grouped into a single, comprehensive program – the possible exception being regulatory monitoring, which requires a degree of confidentiality and which must sometimes focus on other monitoring staff as its subjects of inquiry. Otherwise, drawing together the many data streams from the various monitoring efforts would facilitate interpretation, with analysts of each type of data drawing understanding from the information in other kinds, while discouraging their colleagues from misinterpretation of their own results. If the indicators have been well chosen, there should be much useful knowledge generated, all of which should be brought together and provided to management decision-makers in packaged form.

The framework proposed here is not, however, as comprehensive as that ideal. It does not directly consider compliance monitoring, though some of the recommended pressure indicators may serve that function. No attempt has been made to address regulatory monitoring, which would require different expertise. Administrative monitoring has been passed over in these recommendations since MPA managers are better placed to design that for themselves. Once regulations and an administrative structure for an MPA off Scatarie have been designed, however, managers should return to those other kinds of monitoring.

The principal facet that is missing from this framework, however, is baseline monitoring of the AOI. As is clear from the gaps in the summary of ecosystems above, there is a pressing need for a wide variety of short-duration studies, some of which could best be described as strategic research, others would be characterization work ahead of on-going trend monitoring, while most would have aspects of both. Some of the work will be needed to support interpretation of observed trends and their causes. Those baseline studies are, arguably, more urgent and important than the first steps in gathering long-term data streams. Planning for such work, with all the added complexity of a series of short but varied studies, needs extensive discussion among the scientists involved, which fell outside the scope of the work leading to the framework presented here, which is thus largely confined to trend monitoring, though some suggestions for baseline studies are offered. In particular, some aspects of the AOI's ecosystems require baseline work before decisions can be made about future trend monitoring. The lack of a more detailed treatment of baseline studies in this framework should not be misread as being any indication of their relative importance.

One aspect of the overall information requirements of MPA management that is covered by the recommendations presented below, and which should be included in a comprehensive monitoring plan though it is rarely discussed in theoretical treatments, is the gathering of data primarily because it already exists in Departmental hands. The proposed national MPA network will re-allocate a substantial portion of Canada's ocean space to new uses and it may be expected that many questions will be asked about that process and its consequences. They may be asked of MPA staff by DFO senior management, of the Minister in Parliament or more generally by press and public. Where the answers to those questions require new data, the monitoring program must either provide them or be able to justify the absence of ready answers, whether on grounds of cost or otherwise. Where the answers, or data from which they could be generated, do exist in government hands, the Department should be able to produce them swiftly. To facilitate that, it is recommended that this information gathering be merged with the remainder of the MPA monitoring program. Several such indicators are offered below.

Data Collection: Aside from baseline studies, most of the work involved in the monitoring program will comprise the collection of the data needed for routine evaluation of the set of trend-monitoring indicators. Recommendations and justifications for those, along with outline suggestions for methodological approaches, form the bulk of this framework document. At the time of writing, however, knowledge of the ecosystems in the AOI and the development of a future MPA off Scatarie are neither sufficiently developed for final drafting of indicators. Hence, only generalized ones are offered within which detailed indicators, often multiple sub-indicators for each enumerated indicator presented here, remain to be developed.

Management of a Monitoring Data Archive: Much of the data called for by this recommended monitoring framework already resides in, or is flowing into, existing databases within the Department or elsewhere. Nevertheless, and as has been recommended for the Gully MPA

(Kenchington 2010), a web-based data-management system should be developed, perhaps modelled on that used by the Atlantic Zone Monitoring Program (AZMP)[5], which should serve as the MPA's monitoring archive and as a portal through which the data (in both raw form and as processed summaries) are made available to managers, to scientists working in the MPA and to stakeholders.

Even with the AZMP model to follow, development of the website will require a substantial commitment of resources, though much of that expense could be shared among multiple MPAs. Continuous support will also be needed for the on-going management of the website, not least for quality-control checks on uploaded data. Once again, the AZMP precedent provides a model to be followed.

While the costs of data management should be minor, when compared to those of its collection, they will not be trivial. The task should not pose any major challenges but it will require staff time. The further development of a monitoring plan should give consideration to those resource requirements.

Analysis, Review and Reporting: Collecting and archiving data are necessary parts of any monitoring program but, alone, they merely generate reams of unintelligible numbers. The solution of defining reference points in advance, after which a simple calculation can determine whether they have been breached, has been rejected above. If useful, rational advice is to be provided to MPA managers, then an intelligent consideration of the data streams must be inserted between the data archive and the advice.

Following Kenchington (2010), it is recommended that a committee be convened, comprised of the project leaders of the various programs which contribute monitoring data, perhaps with some additional scientists as members and co-chaired by an MPA manager. That committee should meet in an annual Monitoring Workshop, charged with reviewing the data and any analyses based on it, providing quantitative evaluations of the indicators and alerting the MPA managers to any pressing issues or emerging problems that may be revealed by the monitoring. The committee should bear a particular responsibility to investigate the causes of any observed trends (recommending supplementary studies as necessary), since that requires scientific expertise and cannot, in general, be determined from any simple examination of the incoming data. The Workshops may best be set within the CSAS context, to provide for rigorous review while avoiding the creation of an additional advisory system. If so, data summaries and initial analyses should be prepared as *Research Documents*, much as is currently done for the AZMP (*e.g.* Harrison *et al.* 2009; Petrie *et al.* 2009), while an annual *Proceedings* volume would record Workshop discussions of the data and of any monitoring methodology issues. Formal recommendations to MPA management would then appear as *Science Advisory Reports*, though an additional format, suited to communication with stakeholders, may also be required. The challenge of reducing voluminous data, often on variables of limited direct interest to managers or stakeholders, into understandable and yet meaningful summaries will remain. AZMP has made effective use of anomaly plots and graphic "score cards" which point to useful means for communicating monitoring results, though some evolution of the data products needed for MPA monitoring is to be expected as managers and stakeholders respond to initial offerings.

An alternative, if far more ambitious, model for reporting the results of the monitoring is provided by the Great Barrier Reef Marine Park Authority's five-year *Outlook Report* series, which began with a 2009 volume (GBRMPA 2009). That addresses the Authority's very extensive monitoring

[5] For an example of their web-based data management system, please visit the AZMP's website at http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html.

program, which incorporates biodiversity, ecosystem “health”, resilience, human use, threat, background environmental and management indicators.

In conjunction with the Monitoring Workshops, the Committee might usefully conduct Research Workshops to review progress on the baseline understanding of the MPA’s ecosystems and to promote interactions among the scientists working in the area, thus contributing holistic understanding appropriate to an Area dedicated to broad ecosystem goals. Periodic joint meetings of the monitoring committees for the various MPAs would facilitate deeper understanding of monitoring issues.

Evolution of the Monitoring Plan: Even after the preparation and implementation of a detailed monitoring plan, some indicators will need methodological refinement, while others cannot be fully implemented without extensive prior baseline characterization of the ecosystems to be monitored, which work will be on-going for an extended period. Hence, an MPA monitoring plan must evolve over time, at least through its first years. It is therefore recommended that on-going scientific oversight of the monitoring program, including its evolution, be entrusted to the same monitoring committee.

DESIGNING A MONITORING PROGRAM FOR AN MPA OFF SCATARIE ISLAND

Development of the framework proposed here began with the parallel recommendations for the Gully MPA that were developed by Kenchington (2010). That earlier, and fundamentally pragmatic, process commenced with an initial draft, prepared in close collaboration with the MPA’s managers and after consideration of the recommendations of Pomeroy *et al*. (2004), IOC (2006), Worcester (unpublished[6]) and Wilson and Tsang (2007), plus examination of other monitoring plans, while giving full attention to both the objectives of the MPA and what is known of its ecosystems. Those initial proposals were then discussed with scientists who could offer appropriate expertise, leading to a substantially revised version that was presented to peer and stakeholder review, from which the published framework (Kenchington 2010) was refined. Its recommendations have yet to be implemented and, at of the time of writing, have not been further developed. The monitoring framework for the St. Anns Bank AOI offered here was built following a similar, though somewhat abbreviated, approach. Despite the similarities, however, the present framework has been much modified to match the objectives, opportunities, ecosystems and anthropogenic pressures of a proposed MPA that would extend into near-coastal waters.

The design task centres on the preparation of a suite of indicators that together meet the requirement of adequately monitoring progress towards, or attainment of, the MPAs goals. The preparation can be seen as requiring both the development of a longer list of potential indicators and its refinement into a shorter list, the reduction being needed partly because of budgetary concerns but also to prevent the intended recipients of the information from being overwhelmed by the sheer number of reported results. Contrary to some abstract, theoretical treatments (*e.g.* Rice and Rochet 2005), however, those are not separable stages: a comprehensive list of potential indicators for the AOI would run to many hundreds, perhaps thousands, of items, only a small fraction of which could conceivably be applied in any monitoring program. Drawing up such a list would therefore be a large and unjustifiable expenditure of effort. Instead, the drafting of the list and its refinement must be performed concurrently or at least iteratively. Of the two, it is the refinement that is challenging. To guide that, Kenchington (2010) used a set of criteria, based on the recommendations of Kabuta and Laane (2003), Pomeroy *et al.* (2004) and Wilson and Tsang (2007), which called for each indicator preferably to be:

[6] Unpublished discussion draft “Research and monitoring strategy for the Gully Marine Protected Area” prepared for Department of Fisheries and Oceans, Dartmouth, NS (2006).

- Capable of being monitored by non-invasive methods – causing neither harm nor disruption to the MPA's ecosystem,
- Readily, swiftly and directly measurable, using simple, existing, proven instruments and analytical methods,
- Capable of being monitored at an appropriate frequency to detect changes over time scales relevant to management,
- Able to provide a signal that is detectable amidst the inevitable natural variability, without excessive cost,
- Sensitive to the effects of management actions, with responses that are specific to known causes,
- Relevant to management objectives or stakeholder concerns,
- Cost efficient, maximizing the information gained while minimizing costs to Canadian taxpayers,
- Solidly founded in scientific theory,
- Supported by the scientists who will conduct the fieldwork and analyses,
- Understandable to the public,
- Selected in partnership with stakeholders,
- Integral to the management process, and
- Accompanied by a pre-existing baseline.

The full suite of indicators should, ideally, encompass the issues that require monitoring in a particular MPA, capturing an overview of the state of the ecosystem that is adequate for management purposes, while describing the effects on it of human activities. Pomeroy *et al.* (2004) suggested that it would be desirable for the suite to have some in-built redundancy, such that major changes in the ecosystem would be detected even if one indicator proved non-informative, though others have objected to the resulting dispersion of monitoring resources and the extra contribution to information overload (*e.g.* Rice and Rochet 2005; ICES 2012).

Those same considerations were taken into account in developing the present recommendations, though the experience with the framework for the Gully MPA had shown that budget constraints all but over-ride other criteria and go far towards shaping a monitoring program (*cf.* Kenchington 2010). Scientifically-justifiable, comprehensive monitoring of the ecosystems in an offshore area would require entirely unreasonable budgets, beginning with the construction and operation of additional research vessels dedicated to the task. Even a minimal program, marginally sufficient to gather required information for the support of management decisions, perhaps including routine seasonal surveys of migratory fish and regular mapping of the benthos, would imply costs far beyond anything likely to be available. Preparation of a purely science-based monitoring framework, without regard to budget constraints, would thus be a waste of effort. Conversely, accepting the current (negligible) MPA-monitoring budget as a given would mean tolerating a near-absence of monitoring and hence of meaningful management, which would be inappropriate as a recommendation from DFO's Science sector. Development of Kenchington's (2010) monitoring framework for the Gully MPA thus became largely a search for potentially-affordable indicators that, taken together, might serve to monitor progress towards the MPA's objectives adequately. In the process, it became clear that some indicators should be monitored because the incremental costs of doing so were low, even though the information obtained would have only secondary interest, while other aspects of the ecosystem would have to go unmonitored, despite their importance to MPA management, for lack of an affordable means of collecting the required data. Meanwhile, accepting the high costs of monitoring one indicator would sometimes lower the incremental burden of adding others (*e.g.* monitoring anthropogenic debris on the seabed at great depth would not be cost effective on its own but can become so if a video survey is run for monitoring the mega-epibenthos). It was also immediately evident that, in an offshore area, the variables of greatest interest (*e.g.*

abundances of an MPA's signature species) will be at least as much affected by natural change and by region-wide or larger-scale human activities as they will be by those anthropogenic pressures that are potentially controllable under the MPA's regulations. Hence, if trends in the indicators of principal interest are to be interpreted as a foundation for management advice, it is essential that many other variables also be routinely monitored. Thus, an effective and efficient monitoring program for an offshore MPA should only be examined as a unified whole, with as much attention being given to the potentially-available monitoring resources as to the ecosystem being monitored or the objectives of the management program.

While all thirteen of the above criteria were considered when selecting indicators for the monitoring of an MPA off Scatarie, the task thus became largely a search for potentially affordable means by which to approach effective monitoring of progress towards the proposed MPA objectives (with particular emphasis on those special features of the AOI named alongside the objectives) and the factors, both anthropogenic and oceanographic, that were expected to influence that progress. In general, existing and on-going data streams from routine surveys that can be utilized for MPA-monitoring purposes are available at minimal cost, while minor extensions of existing routine surveys (whether additional stations or extra tasks at each station) may be affordable. Entirely new deployments of dedicated research vessels, however, appear unlikely to be supportable and are only recommended here when information of critical importance to MPA management can be obtained in no other way. To a considerable extent, the design of an offshore MPA monitoring program is less a matter of selecting what is most cost-effective as it is one of calling for monitoring of everything affordable and hoping that no key issues are left unmonitored (*cf.* Kenchington 2010). In contrast to The Gully, however, the proximity to shore and the relatively shallow depths of much of the AOI open the possibility of utilizing simple and light-weight gears, deployed from local vessels (probably inshore commercial fishing boats but potentially other craft also) for certain portions of the monitoring. Such collaborative fieldwork opens the possibility of using local volunteer or student labour for sample processing, potentially via partnerships between fishermen, universities and First Nations resource agencies. Not only could the costs of some kinds of monitoring be reduced but the work would provide opportunities for Cape Bretoners (fishermen, scientists and others) to engage with their MPA, thus enhancing its value. Hence, there is some scope for adding new data streams which would not be affordable offshore.

Ideally, indicators would be preferentially selected to capture information on key pathways or components in the ecosystems of the AOI, thus facilitating monitoring efficiency. As outlined above, however, current understanding of the structure and function of the Area's ecosystems is still limited. Hence, the proposed framework recommends a moderately large suite of basic indicators, with nearly a score of generic ones needed to capture the state of the ecosystems. Once each of those is replaced with multiple, specific sub-indicators, there would be a potential for significant information over-load in monitoring reports. To some extent, that is inevitable: ecosystems are almost always highly complex and it is their complexity that forms the biodiversity which MPAs are intended to protect, while attempts to reduce the complications to a few metrics have been dismissed as an "obscenity in reductionism" (Willby 2011). The monitoring strategy recommended here places the filter of a committee of scientists between the indicators and their end users. It is to be hoped that the committee's reports would highlight those indications in the monitoring data that are of greatest management concern, thus reducing the bombardment of detail. Nevertheless, if the Department is to pursue ecosystems-based oceans management, its managers will need to cope with the complexities inherent to those systems.

Other authors, have suggested rather different approaches to similar tasks. For ecosystem monitoring in support of fisheries management, Rice and Rochet (2005) proposed an eight-step process:

1) Determine user needs,
2) Develop a list of candidate indicators,
3) Determine screening criteria, for which they proposed:
    a) Concreteness,
    b) Theoretical basis,
    c) Public awareness,
    d) Cost,
    e) Measurement,
    f) Historical data,
    g) Sensitivity,
    h) Responsiveness, and
    i) Specificity,
4) Score the indicators against the criteria,
5) Summarize the scoring results,
6) Decide how many indicators are needed,
7) Select the indicators to be used, and
8) Report on the observed indicator values.

Selecting a parsimonious set of indicators, based on user needs, evaluating those indicators and reporting the results are obvious steps. For MPA monitoring, however, practical experience (*e.g.* Kenchington 2010) shows that Rice and Rochet's (2005) steps 2 to 6 do not offer a useful basis for making the selection. The nine screening criteria are sensible and are all included within the longer list developed from Kabuta and Laane (2003), Pomeroy *et al.* (2004) and Wilson and Tsang (2007), though Rice and Rochet (2005) do not appear to have comprehended how the cost of monitoring dominates and shapes the selection. Preparation of a comprehensive list of potential indicators without consideration of the screening criteria would, however, be an onerous task of little value, as has been explained above. More serious are Rice and Rochet's (2005) steps 4, 5 and 6, through which they propose quantitative scoring of each candidate indicator against each criterion. The first difficulty with that approach is that it is doubtful whether any scoring scheme can be truly quantitative, while there is little merit in devoting effort to a pseudo-quantitative exercises. Secondly, too many of those scores would be conditional: the incremental costs of gathering one kind of data depending on what vessels may be mobilized to collect others, while deleting one indicator can raise the importance of the information from a second. It is necessary to progress from Rice and Rochet's (2005) step 1 to their steps 7 and 8, but the process that they proposed would not be helpful if applied to MPA monitoring indicators.

ICES (2012) advanced a rather different set of criteria for selecting metrics to be used under the European Union's MSFD. Their proposals can be re-arranged as:

1) Data quality:
    a) Tangible (easily and accurately measured or determined, using feasible and quality-assured methods),
    b) Quantitative, rather than qualitative,
    c) Existing and on-going data available, and
    d) Relevant spatial coverage of data,
2) Responsiveness:
    a) Indicator should respond predictably and sensitively to change in ecosystem,
    b) Indicator should respond unambiguously and predictably to change in a particular anthropogenic pressure, and

   c) Low "signal-to-noise-ratio" in data,
3) Management:
   a) Relevant to management objectives,
   b) Linked directly to a management response,
   c) Comprehensible by non-scientists,
   d) Preference for indicators familiar to decision-makers over new variants,
   e) Cost effective, making effective use of limited financial resources, and
   f) Preference for indicators which provide an "early warning" before ecosystems are harmed, and
4) Conceptual:
   a) Theoretically sound,
   b) Avoiding redundancy,
   c) Clearly either monitoring a state or a pressure,
   d) Relevant to MSFD requirement, and
   e) Applicable to more than one requirement or directive.

It was recognized that no one indicator could fully meet all of those criteria and hence they are desirable attributes, rather than strict requirements. Each was either included in, implied by or at least consistent with items in the list used by Kenchington (2010), excepting only the preference for or against redundancy. ICES (2012) even included the requirement to address the task at hand (item 3a) within budgetary constraints (item 3e). They did not note that the combination of those can drive the selection process but it may not when selecting metrics for use with existing data streams, which was their focus, since the differential costs of various alternatives may be small.

The parallel efforts to develop monitoring frameworks for Canada's other *Oceans Act* MPAs also merit consideration here. Some of those areas (*e.g.* Gilbert Bay MPA, Labrador: DFO 2010b) have such specific conservation objectives that selection of their monitoring indicators was straightforward but can provide little guidance to the development of monitoring frameworks for more generalized MPAs, like the one proposed off Cape Breton. Selection of indicators for the Tarium Niryutait MPA in the western Arctic (DFO 2010c; Loseto *et al.* 2010) followed a rather similar approach to that adopted by Kenchington (2010) for the Gully MPA. In the case of Tarium Niryutait, however, the conservation objectives revolve around a single signature species, the beluga whale (*Delphinapterus leucas*), which is readily available for monitoring, while the comparatively-simple Arctic ecosystem lowers the cost of routine tracking of trophic relationships to the point that Loseto *et al.* (2010) could recommend a suite of techniques for monitoring food webs. Few of their proposed indicators can be adapted for use in the St. Anns Bank AOI. The Manicouagan AOI, in the St. Lawrence Estuary, faces many of the same issues as are seen downstream off Cape Breton, although in more concentrated form and a smaller space. The general approach being taken to monitoring that area (DFO 2010d) is closely similar to the one advanced here, although the different on-going monitoring programs in and around the two AOIs result in limited overlap of the indicators themselves. Development of a monitoring plan for the Musquash Estuary MPA, in New Brunswick, has commenced (DFO 2011d) but at the time of writing has not yet proceeded far enough to provide lessons that could be applied off Cape Breton.

The Department's Pacific Region has taken a unique approach to the monitoring of the two deepwater MPAs off British Columbia: Sgaan Kinghlas Bowie Seamount and Endeavour Hydrothermal Vents – an approach so different from precedents elsewhere that some explanation for not recommending its application off Cape Breton is required. To date, the Science sector has stopped short of recommending monitoring indicators for either Pacific MPA because no measurable conservation objectives have yet been proposed for them (DFO 2011b,c). In place of monitoring frameworks, an Ecological Risk Assessment Framework (ERAF), in which Valued Ecosystem Components, human activities and anthropogenic stressors are first identified and then linked through “pathway of effects” (PoE) assessments, has been applied (DFO 2011b,c, 2012d; Davies *et al.* 2011a,b). Equivalent identifications were inherent to the process used here for the St. Anns Bank AOI, even though not drawn up as explicit lists, but they were not followed by any equivalent of PoE assessments, except to the extent that *a priori* knowledge pointed to some anthropogenic pressures as being matters of particular concern. Much of the point and purpose of MPAs designed to encompass representative examples of ecosystem types is to protect against scientific uncertainty (Rice and Houston 2011), particularly in coastal waters where multiple anthropogenic impacts with unknown ecological consequences can be anticipated. In that setting, reliance on rational, reductionist approaches, such as PoE assessments, risks a failure to monitor the unexpected. Further, the over-riding effect of budget constraints mean that even confident knowledge of the effects of particular pressures on the ecosystems would not advance indicator selection very far beyond what can be achieved in the absence of formal assessments. The ERAF approach may have more value when prioritizing new field survey programs, specifically designed to gather data for MPA monitoring, but there is minimal budgetary scope for such initiatives in Maritimes Region MPAs, where existing programs yield useful data streams. Meanwhile, as with any scientific task in support of management, it is the role of a monitoring program to aid in achieving an MPA’s conservation goals. It is not the task of managers to select objectives to aid monitoring, if that comes at the cost of distorting the goals of the Area – goals which, for an *Oceans Act* MPA, will often be broadly inclusively and ecosystem-focused. While well-defined, quantitative objectives would certainly make the design of a monitoring plan easier and its delivery more efficient, indicators can be developed in the absence of such objectives and that has been done here, for the St. Anns Bank AOI.

In contrast to all previous Canadian MPA monitoring frameworks, the one offered here explicitly addresses the requirement for socio-economic monitoring, alongside the ecological and threat-oriented indicators. In doing so, it goes beyond the HOTO commitments of the Department’s Science sector but responds to the requests of MPA managers. The socio-economic section of the framework was built on the recommendations of Bunce *et al.* (2000), Pomeroy *et al*. (2004) and IOC (2006).

It should perhaps be stressed that the end result of the selection process, the list of indicators offered below, is not a “menu” from which items can be further selected. It is intended as a recommended suite of indicators that would capture the information required for MPA management in a cost-effective manner. While the list could doubtless be improved and some indicators could perhaps be dispensed with in the interests of economy, any deletions would require that the amended list be reviewed to ensure that it still meets the minimum requirements for management purposes.

MONITORING INDICATORS

The various recommended indicators are here grouped into convenient classes as an aid to comprehension but that classification is not intended to have any greater significance.

Background Indicators

1) Temperature, salinity, oxygen concentration, light levels, chlorophyll, pigments, nutrients and zooplankton within the AOI and both upstream and downstream, as measured on the AZMP’s Cabot Strait and Louisbourg lines, plus an additional line in the AOI,
2) Physical (e.g. temperature, salinity, wind, sea-surface height) and biological (e.g. ocean colour) sea surface properties in the MPA and the surrounding region,
3) Weather conditions at the Sydney Airport and Fourchu Head weather stations, including wind direction and speed, air pressure and sea-level air temperature,
4) Extent of ice cover within and around the MPA,

5) Fluxes, other than those of nekton, across the boundaries of the MPA,
6) Bentho-pelagic exchanges,
7) Phytoplankton production and the timing and intensity of the spring bloom in the MPA and the surrounding region,
8) Mesozooplankton community composition within the AOI and both upstream and downstream, as measured on the AZMP's Cabot Strait and Louisbourg lines, plus an additional line in the AOI,
9) Blooms of harmful algal in or near the MPA,

Effectiveness Indicators

Benthic Environments:

10) Diversity and community composition of the benthos, abundance or biomass and size composition of selected benthic taxa, and characteristics of surficial geology at selected sampling stations, distributed across the seabed environment types represented in the MPA (with particular emphasis on the habitats of species named in the objectives of the MPA, such as wolffish), as determined from selected dredge, grab, core, video and/or diver sampling methods,
11) Diversity and community composition of the benthos, abundance or biomass and size composition of selected benthic taxa and characteristics of surficial geology at comparable sampling stations outside the MPA, as determined from the same sampling methods used within the MPA,
12) Diversity and community composition of the benthos and characteristics of surficial geology at selected sampling stations located in the identified distinctive seabed features of the AOI, plus abundance or biomass and size composition of the defining benthic taxa of those features, as determined from selected dredge, grab, core, video and/or diver sampling,
13) Spatial extent of identified distinctive seabed features of the AOI,

Fish and Fishery Resources:

14) Population-wide abundances and size distributions of those populations of resource species which utilize the MPA, as determined by fishery stock assessments,
15) Relative abundances, biomasses, size distributions and population fecundities of selected groundfish and invertebrates, plus diversity and community composition of trawl-vulnerable species, in appropriate portions of the MPA, as determined by groundfish and snow-crab trawl surveys,
16) Relative abundances, biomasses, size distributions and population fecundities of selected longline-vulnerable species in appropriate portions of the MPA, as determined by sentinel-fishery and halibut surveys,
17) Relative abundances, biomasses and size distributions of selected mesopelagic nekton and micronekton species in the Laurentian Channel portion of the MPA, as determined by midwater-trawl surveys,
18) Relative abundances, biomasses, size distributions and population fecundities of selected groundfish and invertebrates, plus diversity and community composition of trawl-vulnerable species, in comparable areas outside the MPA, as determined by groundfish and snow-crab trawl surveys,
19) Relative abundances, biomasses, size distributions and population fecundities of selected longline-vulnerable species in comparable areas outside the MPA, as determined by sentinel-fishery and halibut surveys,
20) Abundance of large wolffish in sub-tidal rocky areas along the coastline adjacent to the MPA, as determined by diver transect surveys,
21) Fluxes of fish and other nekton across the boundaries of the MPA,

Marine Mammals, Seabirds and Marine Reptiles:

22) Distributions, relative abundances, diversity, community composition and activities of mammals, birds and reptiles in the MPA, as determined by visual observation from boats, using standardized survey methodology,
23) Cetacean presence and activity in the MPA, year-round,
24) Grey and harp seal breeding in the vicinity of the AOI,
25) Seabird nesting in the vicinity of the AOI,

Other Effectiveness Indicators:

26) Trophic relationships in the MPA,
27) Ecosystem function in the MPA,
28) Data inputs to the MARXAN analysis,

Anthropogenic Pressure and Impact Indicators

29) Number and speeds of transits of, or past, the MPA by vessels other than pleasure craft, broken down into naval vessels, fishing vessels not fishing in the MPA, and other vessels,
30) Hours of operation within the MPA by vessels other than commercial fishing vessels or pleasure craft, broken down into research and monitoring vessels, other government vessels, ecotourism vessels, and all others,
31) Commercial and recreational fishing effort within the MPA,
32) Commercial and recreational fishing effort in close proximity to the MPA boundary,
33) Unauthorized fishing activity within the MPA,
34) Seabed area within the MPA swept by bottom-tending mobile commercial fishing, research and monitoring gears, both as a total and subdivided by zone or seabed habitat type,
35) Seabed area within the MPA occupied by bottom-set commercial fishing, research and monitoring traps, both as a total and subdivided by zone or seabed habitat type,
36) Length of bottom-set fixed commercial fishing, research and monitoring lines set within the MPA, both as totals and subdivided by zone or seabed habitat type,
37) Number of vertical lines and length of midwater lines set within the MPA as part of commercial fishing, research or monitoring gears, both as a total and subdivided by zone,
38) Quantities and types of baits introduced to the MPA as part of commercial fishing, research or monitoring gears, both as a total and subdivided by zone,
39) Quantities of target and bycatch organisms removed from or discarded within the MPA by commercial, recreational, research and monitoring fishing, subdivided by type of organism and the nature of the human activity,
40) Number and types of seabed cables, offshore-petroleum exploration and development activities, other mineral exploration and development activities, channel dredging projects or other large-scale engineering works in the general vicinity of the MPA, including any within the MPA itself,
41) Incidents of vessels anchoring within the MPA,
42) Number of ballast-water exchanges within or in proximity to the MPA,
43) Number, quantities and types of other discharges from vessels of all kinds[7] or from offshore installations within or in proximity to the MPA,
44) Number, quantities and type of discharges from coastal sources within or in proximity to the MPA,
45) Types and concentrations of contaminants (including organic chemicals, heavy metals and plastics) in the biota, water column and seabed of the MPA, including contaminants derived from unexploded ordinance,

[7] In the context of Indicator 43, “vessel” has the same meaning as in the International Collision Regulations, where it refers to any watercraft from small boats to large ships.

46) Quantity of large floating anthropogenic debris in the MPA,
47) Quantity of anthropogenic debris on the seabed of the MPA,
48) Incidents of whale or turtle entanglement, ship strikes or other interactions with humans in the MPA,
49) Incidents of whale or turtle strandings adjacent to the MPA,
50) Reports of known invasive species in the MPA and spread of established invasive species towards the MPA,
51) Characterization of deep-water natural and anthropogenic noise within the MPA,

Socio-Economic Indicators

52) Overall economic value of marine activities in and around the MPA,
53) Landed and export values of seafood harvested in and around the MPA,
54) Direct investment in marine activities in and around the MPA,
55) Marine-related employment in and around the MPA,
56) Overall economic value of the MPA,
57) Landed and export values of seafood harvested in the MPA,
58) Direct investment in MPA-related activities,
59) MPA-related employment,
60) Social and economic dependence on marine activities in and around the MPA,
61) Social and economic dependence on the MPA,
62) Nature and extent of recreational and tourism activities within or related to the MPA,
63) Value of recreational and tourism activities within or related to the MPA, including associated on-shore expenditures (*e.g.* hotel-nights, restaurant meals),
64) Public awareness and knowledge of the MPA's ecosystems,
65) Extent of public involvement in monitoring and managing the MPA,
66) Influence of MPA on public attitudes towards marine conservation,
67) Spatial and temporal distribution of marine-resource use in and around the MPA,
68) Costs and benefits of exclusion of fishing and other economic activities from the MPA,
69) MPA costs, including management, enforcement and monitoring costs.
70) Social and cultural significance of the MPA,
71) Perceptions of the MPA and its management,
72) Perceptions of the effects of the MPA on marine ecosystems,
73) Perceptions of the MPA's effects on traditional resource access,
74) Perceptions of public access to the MPA,
75) Perceptions of health and safety issues relating to the MPA, and
76) Socio-economic characteristics of MPA users and other stakeholders.

RATIONALES FOR INDICATORS

Background Indicators

While the details remain largely unknown, the ecosystems within the AOI must be primarily shaped by oceanographic conditions – particularly by conditions in the water which flows through the Area. With limited exceptions related to local anthropogenic activities, those conditions are at best impractical (and often impossible) to influence through MPA regulations. Nevertheless, MPA management must be responsive to oceanographic change, while an understanding of other monitoring data is apt to depend on knowledge of upstream conditions.

MPA budgets are unlikely to support extensive data collection outside the immediate area but relevant existing and on-going surveys and monitoring should be incorporated into this monitoring framework. The information already being gathered will thus be readily available to MPA managers and consideration of that information in MPA decision-making will be enhanced, while the implications for MPA management are the more likely to be pondered before any changes are made to the monitoring programs.

Indicator 1: Ship-Board Oceanographic Monitoring: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

Regional and zonal monitoring of a broad suite of oceanographic variables is already provided by the AZMP, which routinely surveys a line of stations across Cabot Strait, from Cape North to Newfoundland. That line provides effective monitoring of the inflowing waters, upstream of the AOI, except for any modifications that occur in Sydney Bight, which might include the effects of outflows from the Bras D'Or Lakes and Sydney Harbour. The AZMP's Louisbourg Line (the inshore end of which lies only a few kilometres outside the AOI) likewise serves to monitor that portion of the outflow from the AOI which forms the Nova Scotia Current. The combination of the information from the two lines may provide sufficient information on the waters overlying St. Anns and Scatarie banks for the purposes of MPA management.

As explained below, however, consideration should be given to adding to the routine AZMP tasks another line of a few stations within the AOI itself, particularly for mesozooplankton monitoring. If that line is established, the standard suite of oceanographic measurements should be made at those stations also. They would serve to monitor the principal outflow from the AOI, which follows the Laurentian Channel to Banquereau. The waters that follow that route are not presently sampled by the AZMP, following their passage of Cabot Strait, until after they have merged into the Shelf-Break Current.

Indicator 2: Satellite-Based Oceanographic Monitoring: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

Remote oceanographic observations from space are limited to the surface waters and to a few aspects of the ecosystem. They can, however, provide frequent, synoptic, region-wide mapping of variables such as sea-surface temperature and sea surface colour (a proxy for phytoplankton concentration). Moreover, the data are already freely available and are routinely archived at BIO, such that they can be added to MPA monitoring at minimal incremental cost. The variety of data collected changes over time, without reference to the needs of any one MPA, and is generally increasing. This indicator is therefore explicitly intended to allow for on-going development of new information products, utilizing the data that may be available at any given time.

Indicator 3: Meteorological Monitoring: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

The relative importance of meteorological forcing to the ecosystems in the AOI is not well known but may be significant. Available data from the Environment Canada weather station at Sydney Airport (the nearest comprehensive monitoring station) and the lesser facility at the Fourchu Head lighthouse (on the coast in general proximity to the AOI) should be included in the MPA monitoring for its potential value in understanding changes in the ecosystems. Once again, the incremental cost of including those data will be minimal.

Indicator 4: Ice cover: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

The extent of ice cover in Sydney Bight and around Scatarie is highly variable, not only seasonally but also inter-annually. While it may have little direct effect on the marine ecosystems of the area, it could influence the timing of the onset of the spring phytoplankton bloom and most certainly shapes the use of the area by fishermen, seals and indeed research ships. An awareness of changes in the ice should be of importance to MPA management, while the relevant information should be available at negligible cost.

Indicator 5: Fluxes across the MPA boundaries, excluding nekton: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

As has been emphasized in the above summary of the AOI's ecosystems, they are very strongly influenced by the many inward fluxes (of water, nutrients, other chemicals, plankton, detritus, DOC etc.) across the Area's boundaries. Moreover, much of the role of a future MPA as a member of a network and as a supporter of the ecosystems across the eastern Scotian Shelf generally will depend on outward fluxes. Failure to monitor them would render most of the management of an MPA moot. Direct monitoring of fluxes would involve too great a technological and budgetary burden but, following baseline studies, it should be possible to approach the task by modelling water movements and then driving the model using data collected under Indicators 1 to 4. Animal biomass does not move as passive particles but zooplankton drift can be adequately modelled given information (from local baseline work if necessary) on vertical distributions and migrations. Fluxes of nekton biomass are addressed below.

Fluxes of meroplanktonic larvae may be modelled along with those of the other zooplankton but it remains possible that a considerable fraction of the successful recruitment results from those few larvae which chance not to drift, being caught in local features of the water flows that are too small to be modelled. There will be an on-going need for research into the effective extents of larval drifts, research which would usefully inform not only management of all MPAs but other aspects of oceans management also.

While this Indicator 5 concerns monitoring of the fluxes across the MPA's boundaries, interpreting the relevance of the results will require additional supporting baseline research. An MPA off Scatarie would be a novel development, in that it would emphasize protection of general ecosystems (rather than just that of a specific benthic feature) in a "flow through" system. Both to understand the functioning of such an MPA and to ensure that its goals are not undermined by changes outside its boundaries, it will be necessary to explore the connections that are maintained by the fluxes. That may, for example, involve mapping the sea pen fields, upstream of the one in the AOI, which supply larvae to that protected field, as well as those downstream which are supported by the spawning of the protected animals.

Indicator 6: Bentho-pelagic exchanges: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

Current knowledge of the ecosystems in the AOI, as in the oceans generally, tends to focus on either the pelagic or the benthic systems in isolation, yet the linkages between the two are important. How they operate in the AOI is, at the time of writing, essentially unknown but should be investigated through baseline research as resources permit. Indicator 6 is, for the present, intended as a placeholder for the monitoring which could be designed once that research has been completed.

Indicator 7: Primary Production: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

The primary source of energy for the ecosystems within the AOI is phytoplankton production, although most will be production outside the AOI's boundaries. While the data products to be developed under Indicators 1 and 2 could include estimates of primary production, it is recommended that this separate Indicator be included to place a focus on the key ecological variable, as distinct from the measured concentrations of chlorophyll.

On its own, a simple index of production, in terms of grams of carbon fixed per unit area per year, would be insufficient to provide an understanding of trends in the ecosystem. One valuable supplement would be the timing of the spring phytoplankton bloom, which can readily be determined from satellite observations of ocean colour. A more demanding, but very valuable, variable would be the composition of the phytoplankton community, particularly the ratio of diatoms to dinoflagellates, which is expected to be sensitive to climate change. Measurements of phytoplankton pigments allow such ratios to be determined during AZMP cruises but their sampling is necessarily limited in space and time. Development of new products from ocean-colour measurements in the coming years may allow similar determinations from satellite data.

It is not recommended that phytoplankton species compositions be routinely derived from net sampling, since the costs would be unreasonably high.

Indicator 8: Mesozooplankton: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 1d, 2, 2a, 2b and 3.

Calanoid copepods and euphausiids are thought to play key roles in the transfer of energy from phytoplankton, in the surface layers, to the wall of the Laurentian Channel, where that energy sustains elevated summer groundfish diversity, redfish concentrations and, perhaps, overwintering fish populations from the GSL. Those parts of the zooplankton community could best be monitored using existing AZMP protocols at a new line of stations within the AOI, while also ensuring that the plankton sampling continues on the Cabot Strait line. Monitoring of zooplankton is inherently expensive, since it requires net sampling from research vessels. However, the addition of a few stations to existing AZMP missions in waters already routinely traversed between other established lines would require only a few hours of vessel time. There would also be a requirement for between $500 and $1,000 per survey for sample sorting and analysis.

Indicator 9: Harmful algae: Nova Scotian coastal waters experience natural blooms of harmful algae at intervals, with potentially serious consequences for the ecosystems affected. Those blooms are already monitored, because of their effects on human health, and the Department should copy all reports of blooms in the vicinity of northeastern Cape Breton into the MPA monitoring archive.

Effectiveness Indicators: Benthic Environments

Effectiveness monitoring, meaning monitoring focused on the attainment of management goals and objectives (*cf.* Kenchington 2010), must be a major part of any MPA monitoring program. Meanwhile, the principal ecological effects of a relatively small MPA set in a current are likely to concern those ecosystem components which do not move: the benthos, abiotic aspects of seabed habitats and sedentary demersal fish. It is recommended that monitoring those components be seen as the core of this program.

Indicator 10: Representative Benthic Environments in the MPA: Monitors some aspects of progress towards Objectives 1, 1a, 1c, 2, 2a and 3.

It is anticipated that one primary goal of a future MPA off Scatarie would be protection of a suite of benthic environments as representative examples of some of the types found on the eastern Scotian Shelf. Monitoring the condition of those examples should be a central function of the MPA's monitoring program, with all of community-wide, species-specific and abiotic variables being considered.

While this Indicator is primarily addressed to the monitoring of benthic environments *per se*, another goal of the MPA may be supporting recovery of depleted populations of relatively-sedentary demersal fish, such as Atlantic wolffish. The support will not come from a reduction in fishing mortality alone but also from the protection of prime habitats for the species in question. It is intended that those habitats be monitored under this Indicator.

Trends in selected benthic species, perhaps particularly those of the mega-epifauna, will be of particular concern but it is also necessary to monitor the state of the community as a whole, lest some species be more sensitive to temporal change than those thought to be of greater concern. Diversity measures provide a useful summary of community-wide events but there is always a risk of species replacement without detectable change in diversity. Hence, community composition remains an important consideration. Both diversity and composition are rather expensive to track since they need identification of many, relatively rare species.

This Indicator includes monitoring of surficial sediments, not only during an initial baseline phase but also through on-going trend monitoring. Most of the sediments in the AOI will not change measurably over time and hence the observed “trends” are likely to be zero. Changes can occur offshore nonetheless, particularly if a sand lens moves across coarser seabeds. To avoid confusion when interpreting benthic monitoring data, it is therefore important to record the surficial sediment present at the monitoring site and at the time of data collection.

Indicator 11: Comparable Benthic Environments outside the MPA: Contributes to understanding of progress towards Objectives 1, 1a, 2, and 3.

Unlike an MPA which was selected primarily to protect unique features, the AOI’s selection stressed the representativeness of the environments within the boundary. That invites a long-term experiment into the effectiveness of an MPA in the area, through a comparison of stations inside and outside the boundary, with the monitoring program providing the data. The stations should be selected to provide a valid experimental design supporting future statistical analysis.

Indicator 12: Distinctive Benthic Features in the MPA: Monitors some aspects of progress towards Objectives 1, 1b, 1d, 2, 2b and 3.

While the original selection of the AOI emphasized representativeness, the area does include some exceptional seabed features which are likely to be named amongst the objectives of any future MPA, such as sponge and seapen patches. Their condition should be monitored alongside those of the representative portions, though it will first be necessary to complete an initial mapping and analysis of the AOI’s seabeds to determine what distinctive features are present and where they are located.

Indicator 13: Spatial extent of distinctive benthic features: Monitors some aspects of progress towards Objectives 1, 1b, 1d, 2, 2b and 3.

Repeated mapping of all of the seabed environments in the AOI would be too costly to consider as part of a monitoring program, but sampling only at selected stations carries a risk that the extent of some features might contract, without measurable change at the monitoring stations within them. The few distinctive features yet identified in the AOI, or suggested to occur there, are marked by macro-epibenthic organisms (if herring egg masses can be considered as macrobenthos) and hence can be readily mapped using towed camera systems. It is therefore recommended that those most-highly valued components of the AOI’s ecosystems be monitored for changes in their extent, as well as their content.

Kenchington *et al.* (2012) have recently proposed a suite of indicators for monitoring corals and sponges in the Eastern Arctic. Their suggestions are not directly applicable to the AOI, since they were designed for a very large area containing multiple patches of the species of interest, whereas the AOI is a small area which may only contain one significant sponge patch and one seapen field. Kenchington *et al.* (2012) also focused on data from trawl bycatches, whereas zoning within an MPA off Scatarie seems likely to forbid the use of mobile, bottom-contact fishing gears in the few special patches within the Protected Area. Nevertheless, those of their recommended indicators that are applicable to single patches were biomass and patch area, which correspond to Indicators 10 and 11 of this framework.

Effectiveness Indicators: Fish and Fishery Resources

No relatively-small MPA, such as one within the St. Anns Bank AOI, should be expected to have much effect on populations of mobile species. While area-based restrictions on anthropogenic pressures within an MPA serve to move human activities elsewhere, they do not, in general, reduce the extent of those activities. In particular, Canada's fisheries are mostly managed by catch quotas and restricting a fishery in one small place (such as an MPA) merely means that the allowed catch will be caught elsewhere. Target species which move across spatial scales substantially larger than the MPA will thus typically experience the same fishing mortality, regardless of the area-specific restrictions – though that mortality might be differently distributed across ages, sizes or other subgroups of the fish. Non-target species may be subject to higher fishing pressure as a consequence of MPA regulations, since displacing a fishery away from the fishermen's chosen grounds will typically increase the effort needed to catch the quota, resulting in more fishing and hence more bycatch.

There are sedentary benthic resource species in the AOI (*e.g.* whelks) that would be expected to benefit from local restrictions on fishing but those would be monitored under Indicators 9, 10 and 11. There may be some low-mobility finfish in the area (*e.g.* sculpins or liparid seasnails) which would benefit from local restrictions on human activities but, with the possible exception of Atlantic wolffish, those have yet to draw any attention in MPA planning. None are resource species. Otherwise, any non-negligible effects of an MPA in the AOI on finfish or on fishery resources would only be expected to arise indirectly. For example, protection of seabed environments might improve habitat quality for juvenile cod sufficiently to enhance recovery of the Sydney Bight resident population, if that population utilizes nursery areas off Scatarie, which has yet to be demonstrated.

Such limited prospects for detectable effects of an MPA on fish and fishery resources suggests that little effort should be expended on effectiveness monitoring of those components of the ecosystems in the AOI. There are, however, existing and on-going programs within the Department which could provide monitoring data to MPA management at negligible additional cost, thus providing trend monitoring of such unanticipated effects as the MPA may have. Those programs would also serve to monitor the fish in the AOI as important components of the ecosystems there, much as the background oceanographic variables should be monitored, even if the fish, as much as the water flows, cannot be influenced by MPA management.

Indicator 14: Population-wide resource status: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 2, 2b and 3.

The Department already expends considerable resources on monitoring population-wide trends in fishery-resources and the results of such assessments (of those populations that pass through the AOI) could be passed to MPA managers at zero cost. There is no justification to duplicate that effort and no reason to think that it could be improved upon by scientists working in MPA monitoring, though an additional focus on the information needs of ocean conservation might draw attention to additional key aspects of each resource. Long-term temporal trends in older and larger individuals, for example, might be of as much concern to MPA managers as sustainable yields in the immediate future are to fisheries managers.

Indicator 15: Trawl-vulnerable groundfish: Contributes to understanding of, and monitors some aspects of, progress towards Objectives 1, 1a, 1b, 1c, 2, 2a, 2b and 3.

The Department's existing bottom-trawl surveys, variously focused on groundfish and snow crab, have provided the foundation information on the fish of the AOI, used both in selecting it and in baseline characterization of its ecosystems. Those surveys promise an on-going, well-standardized data stream that can provide trend monitoring of an MPA at negligible additional cost. The area of enhanced groundfish species richness along the wall of the Laurentian Channel was detected by the trawl surveys and it is specifically an area of (somewhat) higher richness in the fish vulnerable to those surveys. It can only be monitored by continuing the same survey protocols.

This recommendation to use the existing trawl surveys is made in full understanding of their limitations. The groundfish survey, in particular, was designed for biomass estimation of, primarily, cod and haddock, with an emphasis on offshore sub-populations. Over the past 40 years, it has performed its intended function well but it has been less successful in some other roles. Some species are poorly represented in survey catches: biomass estimates of redfish, for example, vary wildly, most skates are run over by the bobbin gear used on the nets and hence are only caught in small numbers, while adult halibut are so rarely taken that the survey data are not used in assessments of those fish. Even when the biomass of a species is well estimated, juvenile abundances may not be. Young-of-the-year cod, for example, are typically found in shallow water and often on rough seabeds – both being environments deliberately avoided by the survey design. Moreover, the stratified-random survey design was intended for efficient estimation of biomass across management units often comprising multiple NAFO Divisions. It cannot be relied upon for local details, unless as an average over multiple years. That design ends at the 100 m depth contour along the coast and does not extend to the floor of the Laurentian Channel.

Moreover, the principal groundfish trawl survey that encompasses the AOI is a summer survey, conducted in June and July. That will remain central to trend monitoring of an MPA but it gives a seasonally-limited view of the fish in an area that spans a major migration route and which hence experiences a strong cycle in fish presence. While additional surveys for MPA monitoring alone cannot be recommended (due to the excessive cost for limited returns), the data from any other groundfish surveys that the Department may operate in the vicinity of the AOI should be given as much attention, for MPA trend monitoring, as are the summer surveys.

While the surveys are on-going and will continue to generate monitoring data irrespective of MPA management, the stratified-random design of the groundfish survey, while appropriate for that program's intended purpose, confounds spatial variation with temporal change when used for trend monitoring of small areas, such as the AOI. Consideration should therefore be given to adding to the survey design one or more fixed stations within any future MPA off Scatarie Island, the data from which would have to be excluded from population biomass estimation but would be the prime foundation for local monitoring.

Additionally, the focus of the MPA program on whole-ecosystem conservation draws attention to the lack of routine trawl sampling on the floor of the Laurentian Channel within DFO's Maritimes Region – in marked contrast to the surveys of the northern Gulf, which do extend throughout the Channel, west of Cabot Strait. Whether the summer groundfish surveys should incorporate a channel-floor stratum is a question beyond the scope of this monitoring framework, but fixed stations within a future MPA's portion of that environment would be needed.

Adding such stations to an existing survey would be very much cheaper than mobilizing a research trawler specifically for an MPA-monitoring cruise and likely much cheaper even than sending a scientific party to sea on a chartered commercial trawler. It would not, however, be free. As a minimum, it would require some re-direction of survey effort away from present purposes and into MPA monitoring, if not the addition of more ship time to each annual survey.

As MPA design progresses, there may be parts of the area that are deemed unsuitable for fishing with mobile bottom-tending gear. If so, decisions must be made about whether to allow a small amount of survey fishing in those areas or else to forgo the data from them.

Indicator 16: Longline-vulnerable groundfish: Contributes to understanding of, and monitors some aspects of, progress towards Objectives 1, 1a, 1b, 1c, 2, 2a, 2b and 3.

While the trawl surveys have provided the basic information on fish present in the AOI, they can only monitor the trawl-vulnerable portion of the ichthyofauna. Longline gear offers an alternative perspective on the fish, which has already proven useful in MPA planning, not least because the gear can be used in some areas where bottom trawling may be deemed inappropriate. Longlining, however, is less suited than trawling to standardization and really needs both local knowledge and adaptation to the changing behaviour of the fish. Hence the data currently available have come from industry fishing, rather than research-vessel survey. That approach is recommended for the future because of its practicality and the opportunity to involve local fishermen, even though the data will be more “noisy” than those that a scientist-directed survey might provide.

Two data streams are currently available and it is recommended that both continue and be incorporated into the MPA monitoring program. The principal one comes from a small-hook sentinel survey, which operates across the shallower portion of the AOI, inshore of the rim of the Laurentian Channel. That data source will be key to understanding the fish on harder bottoms. The second data stream comes from the halibut resource surveys conducted as a collaborative venture between DFO and the halibut fishery. There are relatively few halibut or other large groundfish, vulnerable to capture on halibut hooks, in the AOI but the fishery may be permitted to continue in a future MPA, in which event the on-going survey would offer some information on the effects on halibut in the area, while also serving to involve the fishermen with management of the Area, at negligible cost.

Indicator 17: Mesopelagic nekton: Monitors some aspects of progress towards Objectives 1, 1a, 2 and 3.

Essentially nothing is yet known about the midwater ecosystem in the Laurentian Channel portion of the AOI, below the epipelagic layer. There is a pressing need for baseline work to fill that knowledge gap, after which some on-going trend monitoring would be appropriate, though it would require the deployment of a survey program that does not currently exist. Unlike the epipelagic resource species, for which stock assessments will be available under Indicator 13, there is no substitute for new fieldwork if the mesopelagics are to be monitored.

Indicators 18 and 19: Comparable groundfish: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 2, 2a, 2b and 3.

While it is not expected that a small MPA off Scatarie will have much effect on mobile resource species, and some part of any effect it does have will be population-wide, there is a chance that there may be detectable, local effects. Meanwhile, public interest in the potential for enhancement of resource species within MPAs and their “spill-over” to fishable areas outside remain key issues for the designation and design of future MPA networks. Monitoring of an MPA within the present AOI should therefore include examination of whether such enhancement and “spill-over” occur and, if they do, should estimate their magnitude.

One aspect of that monitoring should be direct comparisons of fish abundances across the MPA’s boundaries. In turn, that task can be addressed at various scales of distance from the MPA. Differing temporal trends between the fish in an MPA and their overall populations would be one indication of an effect, as would a differing trend between areas immediately outside the boundary and those further away. Those do not, however, need any additional data collection. More localized comparisons across the boundary would need specific survey designs (likely using pairs of fixed stations) that would conform to a statistically-valid experimental design, allowing testing of the existence and magnitude of MPA effects on the fish.

Indicator 20: Wolffish in Sub-Tidal Zone: Monitors one aspect of progress towards Objective 2a.

The AOI does not extend to the shore but the ecosystems within it are not delimited by its boundaries. Of particular note, large individuals of Atlantic wolffish, which species appears to be relatively more abundant in the AOI than on most other portions of the eastern Scotian Shelf (at least in the size-classes that are vulnerable to survey trawls), make seasonal migrations that take some of the largest individuals into very shallow waters in summer. Wolffish are recorded in the AOI by the trawl surveys (mainly along the edge of the Laurentian Channel) and by the sentinel longline fishery (mainly at lesser depths, closer to shore), though the differences between the distributions recorded by those gears suggests that they take different fish (perhaps different size classes). A survey of the sub-tidal zone, along adjacent shores, would provide a third indicator of any trends in their abundance – and likely an indicator of a trend in a third component of the population.

Such a survey could readily be performed by SCUBA divers, following a swim-transect design, since large wolffish are easily visible underwater. It is suggested that local volunteers be encouraged to take up the task, the value of the data for monitoring being, perhaps, exceeded by the value of the resulting direct public engagement with the MPA.

Indicator 21: Fluxes of nekton across the boundaries of the MPA: Contributes to understanding of progress towards Objectives 1, 1a, 1b, 1c, 2, 2a and 3.

While the existence of an MPA off Scatarie would do little to protect the migrant populations which pass through that Area, they are thought to be one major factor shaping the local ecosystems and information on the amounts and kinds of migrants in the MPA would be important. Routine, direct monitoring of their fluxes would be prohibitively expensive at present but the potential of emerging technology has been demonstrated by Comeau *et al*. (2002b), while on-going development by the Ocean Tracking Network and others will likely reduce costs over time. Hence, this Indicator is recommended primarily as a placeholder for development as affordable monitoring techniques emerge.

In the meanwhile, the stock-assessment results compiled under Indicator 14 could be combined with existing knowledge of fish movements and with the results of further baseline studies to estimate the quantities of different kinds of migrants entering the AOI, along with the timing of those movements.

Effectiveness Indicators: Marine Mammals, Seabirds and Marine Reptiles

Indicator 22: Mammal, bird and reptile surveys: Monitors some aspects of progress towards Objectives 2, 2a and 3.

The AOI overlaps with a known “hotspot” for leatherback turtles. It is expected to be relatively important for seabirds, at least those which breed in nearby colonies, though field data are lacking. The area appears as a “hole” on maps of marine mammal sightings, though apparently more because of a lack of survey effort than any absence of whales. There is every reason to think that much of the summer cetacean population in the GSL passes through or near the AOI in spring and fall. As MPA design proceeds, there is a need for baseline characterization of the use of the Area by all three groups of air-breathing marine animals. That could likely best be achieved following a transect survey design, using chartered local boats and suitably-trained observers (perhaps three individuals, though cross-trained observers able to record whales, birds and turtles may be available). Cape Breton University has deployed cetacean observers on the North Sydney to Argentia ferries which could provide a more frequent, but more spatially restricted, supplement. As the baseline emerges, on-going trend monitoring could be designed, likely continuing with the same at-sea approach. Aerial surveys would provide an alternative for mammals and reptiles but would be expensive to mount for MPA monitoring alone, while the existing regional surveys spend too little time in any one area to be useful for MPA purposes.

Since such surveys use visual observations at the surface, they usually record not simply the numbers of each species present but also their current activities (*e.g.* flight directions of birds, diving of cetaceans). Besides their value for ecological research, the records of activity can add value to the raw counts of abundances and so have been included in the wording of this Indicator.

Indicator 23: Cetacean activity: Monitors some aspects of progress towards Objectives 2, 2a and 3.

Until initial surveys under Indicator 22 produce evidence of cetacean presence in the AOI, it would be premature to suggest expending further resources on them. The importance of ship traffic in the Area will, however, necessitate the monitoring of anthropogenic sound in a future MPA off Scatarie. Since the same data records can be searched for whale vocalizations at relatively low incremental cost, this Indicator is recommended as a means to monitor the cetaceans at night and during seasons when small-boat surveys are impractical.

Indicator 24: Seal breeding: Monitors some aspects of progress towards Objectives 1, 2 and 3.

There has not been any suggestion that an MPA off Scatarie would serve to protect seals but they may be important to the ecosystems in the AOI and, much as with the background oceanography, an understanding of temporal change in the seal populations may prove to be important in comprehending the meaning of changes in other monitoring indicators. While seals range widely across the Scotian Shelf and would be recorded when in a future MPA under Indicator 21, the AOI is likely to be particularly impacted by the grey seal colony which breeds nearby on Hay Island (lying close to the Scatarie Island) and perhaps also by harp seals in those years when ice conditions carry the Gulf breeding population out through the Cabot Strait. It is not suggested that any new monitoring of seals be undertaken as part of an MPA program, but available information on the two breeding groups should be gathered from other units within the Department.

Indicator 25: Seabird nesting: Monitors some aspects of progress towards Objectives 2, 2a and 3.

An MPA off Scatarie may yet have, amidst its objectives, an aim to protect the breeding-season foraging grounds of some of the seabird colonies on adjacent coasts. Even if not, the birds may play a significant, if local, role in the ecosystems of the AOI. While it is not suggested that any new monitoring of nests be undertaken by DFO, nor as part of an MPA program, available information on the colonies should be gathered for inclusion in the MPA's monitoring archive.

Indicator 26: Trophic relationships: Monitors some aspects of progress towards Objectives 1, 1a, 1b, 1c, 2, 2a, 2b and 3.

While the first step in monitoring temporal trends in ecosystems properly centres on the abundances of taxa (here captured for a future MPA by Indicators 10, 12, 13, 15, 16, 17, 21, 22, 23 and 24), a full understanding also requires attention to the trophic relationships among those species. A variety of indices, such as Mean Trophic Level, have been suggested as ways to summarize those complex linkages in one or more scalar values and, if nothing else, this Indicator should be used to report the results of the groundfish surveys (captured by Indicators 15 and 16) in terms relevant to trophic relationships. Past studies of diets could be used to assign trophic levels to each size class of each of the principal species. It would, however, be much preferable, though considerably more expensive, to track changes in diets, while also extending the coverage beyond the summer groundfish community. There is a particular need for at least short-term baseline studies of the feeding of overwintering migrants while they are in the AOI. Whether the latter work needs to be continued through trend monitoring remains to be determined once baseline knowledge has been gathered.

Indicator 27: Ecosystem function: Monitors some aspects of progress towards Objectives 1, 1a, 1b, 1c, 2, 2a, 2b and 3.

In any MPA, protection of ecosystem function is as important as the conservation of particular ecosystem components. That is particularly true for an MPA selected more for being "representative" than for any specific features that could be the subject of directed monitoring. Ecosystem function cannot be reduced to a few measurable variables but various indices have been suggested and should be explored for application to an MPA off Scatarie.

Indicator 28: MARXAN variables:

The selection of the St. Anns Bank AOI was originally based on an analysis using the MARXAN approach, which combines information from many disparate datasets. Since the same or similar analyses may be used in future spatial-planning tasks, it would be desirable to look closely at the AOI to see whether the information in the analyzed datasets is corroborated by more intensive surveying. That would be a short-term study that might best be approached by exploring the MARXAN analysis to discover which variables drove the selection of the AOI and then comparing results from baseline studies of the Area to the values used in the original analysis, wherever comparable data are available. Whether it would be worth gathering other data exclusively for the purpose of testing the MARXAN inputs must be doubtful.

If an MPA is established off Scatarie, trend monitoring of the principal driving variables would show whether long-term temporal change is sufficient to invalidate the foundations of the selection of the AOI – which might not be grounds to eliminate an MPA designation but should give pause when choosing future areas to protect. Since any changes would be expected to be slow, this Indicator might only need re-evaluation at decadal or longer terms.

Pressure and Impact Indicators

While effectiveness monitoring should be the central concern of an MPA monitoring program, a full understanding of events within the protected ecosystems, particularly an understanding of why the ecosystems change, also requires monitoring of the anthropogenic pressures on those ecosystems.

Indicators 29 and 30: Vessel activity: Monitor some aspects of pressures 4 and 5, as well as the potential for pressures 2e, 6 and 7.

Almost all of the human activities which impinge on any MPA, excluding those areas which reach to the shoreline, involve some form of watercraft. In some cases, it is the moving vessel and the noise which it radiates that are the potentially harmful intervention. In others, the vessel is merely a platform from which other kinds of pressures may be exerted. Either way, an accounting of vessel presence is needed.

Most vessels passing Scatarie will simply be on passage through the area. They can most readily be recorded as the number of transits through the AOI, though to make the statistics more meaningful it would be well to subdivide the totals among a few major types of vessels. Since vessel speed affects the potential for whale strikes and relevant data can be extracted from the same records as show the transits, it may prove useful to also compile the distribution of speeds within an MPA. That would be of more use than an average speed, since it is likely to be a few high-speed transits that are of concern, rather than the larger number of average ones. Unless recreational use of the area grows very large, it is recommended that pleasure craft be excluded from this monitoring since the complexities of gathering such data would outweigh the minor per-transit impacts that yachts could cause.

The Cabot Strait / Sydney Bight region sees some of the heaviest marine traffic in any Canadian waters, with almost all of the seaborne trade into and out of the Seaway, the ports of Montreal and Québec, plus the other Gulf ports, passing through the Strait, while the ferries from North

Sydney to and from Newfoundland traverse the same waters. The large ships which follow those routes radiate a great deal of noise into the ocean. With the exception of behavioural impacts on whales, there has been very little study of the environmental consequences of persistent ship noise but it is an issue of growing concern. It is therefore suggested that the recording of ship transits not be confined to those which pass through a future MPA but also those which pass close enough to insonify the waters within the MPA with sufficient intensity to potentially influence marine life. The appropriate limiting intensity and a corresponding distance have yet to be determined.

While most vessels passing Scatarie would merely transit through the area, a few would enter an MPA to work. Since the latter would all require permits for their activities, gathering more detailed data on them should not pose great burdens, while simple counts of the number of vessel passages across the MPA's boundaries would not reflect the degree of pressure that vessels remaining in the Area for some time would impose on the ecosystems. Hence, it is recommended that the presence of non-transiting vessels other than commercial fishing vessels (and still excluding pleasure craft) be monitored in units of hours of operation within the MPA. The nature of each operation should be recorded along with the permit issued but it is not recommended that that extra detail be reported in an indicator, since there are too many different kinds of operation for any classification to be both meaningful and comprehensible.

Indicator 31: Authorized fishing effort in the MPA: Monitors some aspects of pressures 4 and 5, as well as the potential for pressures 1, 2, 3 and 6.

The remaining form of non-recreational vessel activity not monitored under Indicators 29 and 30 is commercial fishing, which is best recorded in units of fishing effort, since that is anyway needed as a measure of an important and direct pressure on the ecosystems in the MPA.

Indicator 32: Fishing effort outside the MPA:

While the monitoring program's primary interest in fishing effort should concern the amount expended within the MPA, an understanding of potential "spill-over" effects requires knowledge of effort immediately outside the boundaries. Evidence that fishermen are (or are not) "fishing the line", with effort concentrated close to the boundary, would be important to understanding the effects of the MPA.

Indicator 33: Unauthorized fishing effort:

Indicators 31 and 32 can only be used to quantify duly licensed and reported fishing effort. The extents of illegal, unreported or under-reported (IUU) effort, by their nature, cannot be fully evaluated. It would, however, be a mistake to assume that they do not occur. This Indicator is intended to capture such (often qualitative) signs as are available to the Department of the extent of IUU fishing in and around the MPA.

Indicators 34, 35, 36 and 37: Areas swept by fishing gears: Monitors some aspects of pressures 2 and 3.

For an MPA which primarily protects the seabed and the benthos, hours of operation of research vessels and conventional measures of commercial fishing effort do not provide a sufficient index of direct, physical, anthropogenic impacts on the seabed. The fixed gears also involve lengths of vertical and horizontal lines which carry risks of entangling the endangered leatherback turtles which use the Area, as well as marine mammals which pass through. These four Indicators are thus intended to provide more precise measures of the anthropogenic pressures, subdivided by the coarsest of gear-type distinctions and by the kind of seabed impacted.

Mobile and fixed gears should be accounted separately because only the length of the latter can be quantified, not the width of seabed across which the nets or lines may move, whereas the amount of bottom impacted by mobile gears can be measured in units of area. Trap fisheries (for lobster, rock crab, snow crab and whelk in the AOI) involve elements of both area and length impacted, the area by the traps themselves and the length by any groundlines between one trap and the next. They are thus best separated from the other fixed gears, which include groundfish longlines but perhaps also bottom-set gillnets.

Indicator 38: Quantity of bait:

Fisheries are commonly perceived as extracting biomass from the ocean but most hook and trap fisheries also introduce large quantities in the form of bait. The consequences of that energy supplement are not well understood, though it may serve to encourage those scavengers large enough to cope with pieces of high-protein food of substantial size. The quantities and types of bait used in an MPA should be monitored unless and until those can be shown to have negligible ecological effects.

Indicator 39: Catches and discards: Monitors some aspects of pressure 1.

Previous indicators would serve to measure fishing effort. This one measures the direct consequences of that effort on resource populations.

Indicator 40: Engineering works: Monitors some aspects of pressures 2d and 2f, as well as potential for pressures 9 and 10.

Marine ecosystems in coastal waters, such as those off Scatarie, are potentially subject to modification by any of a wide range of human developments, either in nearby waters or in upland catchment basins which drain to the coastal area. Offshore petroleum projects may be the most visible but the AOI could equally be affected by exploratory drilling for sub-seabed coal, by the development of a container terminal in Sydney Harbour and the resulting shipping traffic, or by the development of an offshore windfarm, to name but three examples. The laying of new communication cables through the Area may be restricted by future MPA regulations but there are multiple old cables already present. While the MPA regulations would likely not control such developments outside the boundaries of the Area and no significant monitoring budget should be expended on discovering plans for such projects, none of them should proceed without DFO being at least notified and copies of such notices for development projects within the surrounding region should be gathered as part of the input information for MPA management.

In the case of a parallel indicator recommended for use in monitoring the Gully MPA, stakeholder concerns have been raised over inconsistencies in the distances around the MPA within which engineering works are monitored. Some projects can be expected to impose pressures on the ecosystems within an MPA at greater range than do others and hence, for the purposes of this Indicator 40, the width of the “general vicinity” of the MPA may appropriately vary but any variations should be justified.

Indicator 41: Vessels anchoring: Monitors pressure 2e.

Anthropogenic seabed disturbance in offshore waters is mostly caused by fishing gears, simply because the total area that they contact, summed across all fishing operations, is larger than those impacted by other activities. The severity of disturbance by the anchors of big ships is, however, far greater per unit area than that caused by trawling. The AOI straddles major shipping routes and portions of it are shallow enough for anchoring. The extent of the practice should be monitored. Depending on how that is done, it may be appropriate to exclude anchoring by smaller vessels, on the grounds that the disturbance caused by their light anchors is insufficient to justify the costs of monitoring.

Indicators 42, 43 and 44: Discharges: Monitor pressures 6, 7 and 10.

Discharges of all kinds are likely to be one of the more important classes of anthropogenic impacts on the ecosystems within the AOI. It is not suggested that the MPA monitoring budget be expended on measuring those discharges, but data already available to public agencies should be gathered and compiled to provide a record of the extent of and, more especially, temporal change in discharges. For an MPA off Scatarie, Indicator 44 may be the most important of the three indicators. Besides the expected issues with run-off from an urbanized, industrialized area like Sydney, there is a particular problem with contaminated water from abandoned and flooded coalmines which is currently being treated and then discharged into Sydney Bight.

The data available from Transport Canada on ballast-water exchange do not allow for meaningful estimates of quantities of water exchanged within any particular distance of an MPA and hence Indicator 42 may prove rather uninformative. However, the harm which may result from ballast water, through the introduction of invasive species, is fundamentally regional (rather than local) in nature. Hence, additional monitoring to improve the information content of the Indicator is unlikely to be viable for MPA purposes. Any invasive would most likely appear outside an MPA before moving in and thus would be subject to monitoring under Indicator 50. It is therefore recommended that Indicator 42 capture the available data stream but that nothing more be attempted.

Indicator 45: Contaminants: Monitors some aspects of pressures 6, 10 and 11.

Portions of the AOI have among the highest levels of contamination of anywhere on the Scotian Shelf (excluding its adjacent harbours), mostly due to their location in the St. Lawrence outflow. While those levels are low in absolute terms, their continued monitoring is essential if there is to be an MPA in the area.

There is a particular local issue with unexploded ordinance. Considerable quantities of “UXO” (some containing chemical-warfare agents) were dumped at sea off Nova Scotia at the end of the 1939–45 War, with the locations of the dumping often being poorly recorded. There are two known dumps near the AOI and may be others inside it. Breakdown of the material, releasing toxic contaminants, is on-going and the dump sites may constitute the most serious local point sources of pollutants in, or immediately upstream of, the Area. Maintaining management awareness of them through monitoring is vital.

Indicators 46 and 47: Debris: Floating debris is a general concern in the ocean but particularly so in an area utilized by leatherback turtles, which feed on jellyfish and too often can ingest plastic bags, mistaking them for edible food. Floating material of various sizes can be monitored comparatively cheaply from vessels deployed in an MPA for monitoring other indicators. Seabed debris is only a rather general concern in the AOI but it too can be monitored, as an adjunct to monitoring of the benthos, at a low incremental cost.

Indicators 48 and 49: Entanglement, ship-strike and strandings incidents: Monitor pressures 3 and 4.

There are unlikely to be any reports of cetacean or leatherback-turtle ship strikes or gear entanglements in the AOI because the events themselves are highly improbable, and because ship strikes are unlikely to be recognized if they do occur. Should any reports of such incidents reach the Department, they should be entered into the MPA monitoring archive.

Strandings of cetaceans and turtles on the shores of easternmost Cape Breton are rare but they do occur. Much as for incidents within an MPA, available reports should be compiled for consideration in connection with the MPA.

Indicator 50: Invasive species: Monitors pressure 13.

Some of the most dramatic changes in Nova Scotian coastal ecosystems have been caused by invasive species. They cannot readily be monitored before they become established since a very wide variety of organisms, each demanding a different monitoring approach, could potentially invade. However, incidental observations in the MPA of species known elsewhere as invasives should be brought to the attention of MPA managers, as should any advance towards the MPA of species already established on the Nova Scotian coast.

The Department's current monitoring of invasives is conducted inshore. If offshore monitoring is desired, the AOI would provide a convenient site, though that work would go beyond the immediate needs of MPA monitoring.

Indicator 51: Noise in the MPA: Monitors some aspects of pressures 5, 8 and 9.

Anthropogenic sound may prove to be one of the principal pressures acting directly on the ecosystems in the AOI. Its sources, such as ship transits, should be monitored under other indicators but direct monitoring of the sound itself is essential to provide confirmation of the intensities experienced. That monitoring will, however, require the purchase and deployment of appropriate hardware and thus will be expensive.

Socio-Economic Indicators

DFO Science Branch's commitment to the development of MPA monitoring plans does not extend to socio-economic indicators but their monitoring is an essential part of responsive MPA management and they should be part of an integrated monitoring program. The socio-economic indicators should capture information on the effects, both positive and negative, of an MPA on people, to ensure that the Area meets its goals and that it does so with the least disruption to negatively affected individuals or communities. Detailed monitoring is required to provide managers with information on how an MPA is being used, as a foundation for management planning.

Indicators 52, 53, 54 and 55: Economic role of marine activities in and around the MPA: The foundation for an understanding of the socio-economic effects of an MPA is knowledge of the economic uses being made of regional seas (with the extent of the "region" for this purpose remaining to be determined). To ensure coverage of the issue, it is suggested that value (including both gross and net), investment and employment (including both numbers employed and total payroll value) each be considered as a separate indicator. It is intended that each of those will be evaluated by industry sector (*e.g.* fishing, shipping, tourism) as well as overall but, given the importance of the interactions between seafood harvesting and MPA management, it is suggested that the values of the catch be considered as a fourth indicator. The full extent of the marine activities that should be considered remains to be decided but, besides on-water operations, it would presumably include port operations, boat building and the like.

The magnitude and nature of these human activities will be influenced by many factors extending far beyond MPA management. Fishing, for example, will be affected by resource abundance, fishery regulations and market conditions. Ocean shipping through the Cabot Strait will be influenced by the state of the global economy, by the regional economy around the Laurentian Great Lakes and by developments in container-ship size (encouraging cargo to move through Atlantic ports and rail connections *versus* the Port of Montreal). Where ecological issues are concerned, it is suggested above that the background oceanographic factors be monitored under their own indicators – or rather that data from on-going monitoring of those factors be incorporated into the MPA monitoring program. Information on the natural forces shaping the ecosystems will then be available to aid interpretation of data on the indicators of more immediate interest to MPA managers. The same approach cannot be taken with socio-economic factors since the range of external issues affecting human marine activities is far too wide. Instead, future analysts who examine the data on an MPA off Scatarie must be charged with considering available information on all external factors that might explain any observed trends.

Indicators 56, 57, 58 and 59: Economic role of marine activities in the MPA: MPA regulations cannot directly affect any of the biota living within the Area, but subject to some degree of non-compliance, they do control human activities. However, human responses to regulatory control are apt to be far more complex than those of ecosystems, not simply because *Homo sapiens* has a wider behavioural repertoire than any other marine species, but more because people will respond to an MPA within the contexts of regional, national and global societies and economies. To capture the complexities, it is suggested that marine activities be considered regionally under Indicators 52 to 55, while the activities specifically in or related to the MPA be considered under Indicators 56 to 59. Since a particular fishery may proceed within the AOI until excluded by regulation, while a particular boat may fish inside the MPA in one fishery and outside when pursuing some other, excluded, fishery, this regional and MPA-specific arrangement appears more intuitive than an outside / inside division, though the activities outside the MPA are simply the regional total less those inside.

These indicators should consider activities relating to an MPA itself (*e.g.* tourist trips motivated by MPA status) but should also be area-focused. Hence, baseline monitoring should document the activities in the area which will become the MPA before it is established, not simply begin with the designation of the MPA.

Indicators 60 and 61: Social and economic dependence on marine activities: Coastal communities, including many in Cape Breton, tend to be isolated, often offering few economic opportunities other than those which draw on the sea. In consequence, the marine economy can be far more important locally than its dollar value alone would suggest. The sea and access to its resources are often woven into the social structure of such communities. These indicators are recommended to ensure that those factors are not lost to sight amongst the purely-economic considerations. Because the use of marine resources by coastal communities (save those that host larger vessels) tends to be very local, it will be important to consider both dependence in general and specifically that on the area of an MPA (including before the establishment of the MPA).

Indicators 62 and 63: Recreational and tourism activities within or related to the MPA: MPA-related recreation and tourism are parts of the marine activities considered under the above indicators but they are also the principal kinds of human activity which should be actively encouraged by management of the Area. Thus, the nature of that activity and its value should be drawn out by being given their own indicators. While some of the value is easily comprehended (*e.g.* amounts paid for whale-watching trips), other aspects will be more subtle. It might, for example, be found that some proportion of visitors to easternmost Cape Breton remain there for an extra over-night because of opportunities offered by an MPA. Indicator 63 should also seek to capture non-monetary values of MPA-related recreation and tourism.

There is an understandable tendency for monitoring to focus on quantitative measurements, risking a confusion between what is measurable and what is important. Recreational activities, however, come in many and varied forms, which may also be temporally variable. These two indicators provide opportunities for MPA management to understand, qualitatively, the nature of the recreational uses being made of the area, in addition to quantifying them.

Indicator 64: Public awareness and knowledge of the MPA's ecosystems: Along with recreation and tourism, one of the primary benefits of an MPA to human society is the opportunity for public engagement with the protected ecosystems, leading to enhanced understanding and support for future conservation efforts. Monitoring of that educational function is essential.

Indicator 65: Public involvement in monitoring and managing the MPA: Most members of the public who interact with an MPA will do so as users but the greatest value will flow to those who opt for more intensive involvement. They will also serve as an essential conduit between local communities and MPA managers. The extent and nature of that participation must be tracked.

Indicator 66: Influence of the MPA on public attitudes towards marine conservation: The effect of MPAs on conservation of marine ecosystems lies not only in the limited protections afforded within their boundaries by regulatory restrictions but also in the focus that they provide for public engagement, leading over the long term to political and budgetary support for much broader conservation efforts. While it will be hard to measure the impact of any one MPA on public attitudes with useful certainty, the effect is too important to be ignored by a monitoring program.

Indicator 67: Spatial and temporal distribution of marine-resource use in and around the MPA: Fishing effort in and around an MPA should be monitored under Indicators 31 to 36, with catch in the Area under Indicator 39, ship movements under Indicators 29 and 30, development projects under Indicator 40 and the economic values of those activities under indicators 52 to 59. Each of those Indicators, however, emphasizes magnitude, rather than spatial or within-year temporal distributions. Since MPAs are, by definition, place-based measures, an understanding of the locations of human activities, both before and after MPA establishment, is essential for the design of boundaries, the development of a management plan and its later review. Seasonal distributions can also be critical to some stakeholders: opportunities to fish for cod, in summer weather but outside a regulated lobster season, may be vital to the viability of a fisherman’s annual cycle and may depend on the fish being available for harvest, outside any protected area, during that one portion of the year. Similar spatio-temporal considerations may be critical to the success of conservation efforts, if certain human activities overlap in time with the passage of migrants through the MPA. This Indicator is therefore intended to capture the detailed distributional information which may be missed by the more numerical ones.

Particularly for locally-based, small-boat fisheries, in which the operating range from home ports can be very limited, it will not be sufficient to map where people work at sea but also which on-shore communities are linked to which sea areas. The AOI may be regionally unimportant as a ground for some particular fishery and yet critically important to fishermen who pursue that fishery out of, say, Port Morien and Main-à-Dieu.

Into the late 20th Century, it was normal for access to inshore fishery resources by Nova Scotian small-boat fishermen to be controlled not only by governmental regulations but also by traditional, local rules – sometimes termed “Territorial User Rights in Fisheries” (TURFs) by anthropologists. Whether any local, spatial management remains within the AOI is currently unknown but, should it be active, it must be considered during MPA development, lest a sub-optimal design provoke local opposition. The collection of baseline data for this Indicator should therefore include a focus on TURFs, their use and nature in the AOI.

Indicator 68: Costs and benefits of exclusion of fishing and other economic activities from the MPA: While the primary purpose of an MPA is conservation of marine ecosystems and their components (both living and non-living), the restrictions on human activities that are necessary to provide that protection will inevitably produce costs to some stakeholders. The resulting conservation will provide benefits to the same, or different, interest groups. The magnitude of the costs and benefits, along with their natures and their distributions across individuals and communities cannot be monitored as such. They can only be estimated based on analysis of data gathered under other indicators. The overall effect of the MPA on human interests will, however, be of such great public concern that this Indicator is recommended as way to focus attention and ensure that the estimates are prepared. Developing those estimates will be demanding and the nature of what is included and excluded may evolve over time.

Indicator 69: MPA costs: Operating an MPA is not cheap and the budgets for the overall program must be weighed against its benefits. This indicator is recommended as means to integrate those amounts with the rest of the monitoring data.

Indicator 70: Social and cultural significance of the MPA: Other socio-economic indicators largely address uses of the area and especially economic values. It is also necessary for MPA managers to be aware of other types of relationships between people and places. Scatarie Island, now an uninhabited protected area, still holds special significance for those residents of nearby communities who were raised on the island. That relationship is likely to change as the individuals concerned pass away, though family memories will persist. This indicator is recommended as a reminder, firstly that baseline studies should determine whether there is similar significance of Scatarie Bank and the other portions of the AOI to local people and, secondly, that (should such relationships be found) they need to be tracked over time if MPA management is to enjoy the success which requires support from local communities.

Indicators 71, 72, 73, 74 to 75: Perceptions of the MPA: While some of the effects of an MPA on humans can be reduced to dollar equivalents or otherwise quantified, much of the point lies in how the MPA is perceived. To ensure coverage of the various issues, it is recommended that perceptions be monitored under five indicators covering, respectively, the operation and management of the area, its success in its prime role of conservation, its implications for activities formerly conducted in the area, satisfaction with opportunities for public access to the area, and implications for human health and safety. For an MPA entirely within the present boundaries of the St. Anns Bank AOI, the only access issue may be that the area is inaccessible to the general public. Should the MPA be extended shoreward, however, direct public use would become more important and many concerns, from boat ramps to hiking trails along the coast, might come to the fore. Some coastal MPAs have considerable health and safety implications, such as reduced shellfish contamination. For an MPA in the AOI, the concerns may be narrowed to simply an increased risk to those small-boat fishermen who are compelled to move their operations further from shore when excluded from the protected area. That issue is, however, so important to those immediately involved as to justify monitoring.

Indicator 64 will likely record overall satisfaction (or dissatisfaction) with the management of the MPA. International experience suggests that a major concern for local stakeholders is whether their knowledge of the area has been given due weight. That could be given its own indicator but is here subsumed within the broader satisfaction issue.

Monitoring of these indicators should consider separately the perceptions of members of immediately-adjacent coastal communities, those amongst tourists and other visitors to the MPA and the adjacent coastal area, those among Cape Breton residents generally and those among Canadians generally. It is to be expected that those groups will perceive an MPA very differently from one another.

Indicator 76: Socio-economic characteristics of MPA users and other stakeholders: Understanding the effects of an MPA on people requires understanding the people affected. Interpreting monitoring data gathered from people requires an understanding of those who provide the information, which demands that they be asked questions about themselves. Since those answers are likely to be a primary source of data for understanding the affected individuals, the two requirements are here brought together under this one Indicator.

The published international advice to those who manage MPAs in tropical nations urges particular attention to gender issues in monitoring and management. Modern Canadian society displays less distinction between the genders, but an understanding of gender-based patterns in marine activities, in the use of an MPA, and in perceptions about MPAs remains important. That should be drawn out in the socio-economic monitoring.

OUTLINE METHODOLOGIES

Indicator 1: Ship-Board Oceanographic Monitoring:
Indicator 2: Satellite-Based Oceanographic Monitoring:
Indicator 3: Meteorological Monitoring:

These indicators form a coordinated trio, separated by their modes of gathering data but united in their topics and, to a considerable degree, in the analysts and analyses that will be required for their assessment. Data collection is on-going and, with minor exceptions concerning the AZMP, will continue without requiring any specific action by MPA managers. These three indicators also form a distinct group in that, in contrast to the remainder of this recommended monitoring plan, very large data sets already exist and can support development of detailed, quantitative baselines.

While it would be important to management of a possible future MPA off Scatarie for data collection to continue, the more demanding tasks are four. Firstly, arrangements should be made for access to the various data streams and for copies to be routinely archived with other MPA-monitoring data. That is a task of data coordination and perhaps software development.

Secondly, consideration should be given to the addition of a new, short AZMP line across the AOI. A trial transect that included five stations, extending from St. Anns Bank to the Laurentian Channel, was run during the fall 2011 AZMP cruise. It required about nine hours of ship time for the fieldwork. It has also been suggested that routine deployment of acoustic doppler current profilers aboard the ferries between North Sydney and Port Aux Basques would provide valuable additional data on the flow through Cabot Strait, during the prolonged periods between AZMP cruises, at relatively little cost.

The third, and much greater, required task is one of baseline research into the oceanography of the AOI, as a foundation for later interpretation of the data streams from on-going trend monitoring. That research effort, which requires a field element (*e.g.* deployment of current meter moorings) as well as analysis of archived data, has commenced at the time of writing and should continue.

Finally, the existing oceanographic and meteorological data have not been worked up to provide information products optimized for MPA monitoring purposes. Interpretable and understandable means of presenting the data streams need to be developed, along with the software that would allow for routine updating in the future, while quantitative baselines (including indications of variability around mean values and any discernable long-term trends) should be prepared, so that future monitoring results can be presented in both the form of anomalies around those baselines and as multi-year trends.

While none of those tasks are especially challenging, they do require resources, particularly the time and labour of scientists for the third and fourth items. Besides the short-term requirements for baseline work, the members of the AZMP team already have heavy commitments to annual reporting of their zonal results. Adding an extra round of analysis, reporting and attendance at the recommended Monitoring Workshop for even one MPA (let alone meetings for each MPA in the whole proposed network) would be a major additional burden. In short, despite the abundant existing data and the relatively low incremental cost of adding AOI-related fieldwork to the AZMP, monitoring these three Indicators would require significant extra staff and budget.

Indicator 4: Ice cover: It is not intended that any new data on ice cover be collected as part of an MPA monitoring program. Those data are already available and indeed are already routinely reported within DFO, in *State of the Ocean* summaries. The only tasks required for an MPA monitoring program would be arranging for regular access to the data stream and development of a data product that would best support MPA management.

Indicator 5: Fluxes across the MPA boundaries, excluding nekton: It is intended that the fluxes across the boundaries of an MPA be derived from an oceanographic model of water movement, which should be driven by the data gathered under Indicators 1, 2, 3 (providing for meteorological drivers) and, if an ice term is needed in the model, 4. If they are available from other sources, it may be appropriate to also include among the model inputs three other data streams which (to avoid escalating complexity) are not suggested to be part of the MPA monitoring. Those are the rate of winter inflow into the GSL through the Strait of Belle Isle, the flow rates of the St. Lawrence and other major rivers that discharge into the Gulf, and the characteristics of the deep waters entering the mouth of the Laurentian Channel. In combination those three flows shape the characteristics of the Gulf outflow through the Cabot Strait, which is also the inflow to the AOI. That model-based approach would require a very significant effort in constructing and verifying the model itself, which task would have to include analysis of the existing baseline data and very probably additional short-duration studies. It is not, however, suggested that there be on-going, long-term deployments of current meters, which would be very expensive to maintain beyond the model-verification period. On-going costs of operating the model to generate flux estimates for each year should be much lower but not inconsequential for the staff assigned to that duty.

Once model outputs describing water movements are available, most other fluxes (*e.g.* of nutrients or chlorophyll) could be readily determined by combining the movements with the concentration of each factor of interest, as revealed by other indicators. Zooplankton fluxes would require more complex modelling, because of their vertical migrations, which might need to be supported by additional fieldwork for baseline studies into the movements of the principal species.

Indicator 6: Bentho-pelagic exchanges: The nature of the monitoring under this indicator has yet to be developed. It has been suggested that it should include consideration of benthic-pelagic coupling, sedimented organic material, settled larvae, and the capture of settled organic matter into benthic food webs. Baseline research in the AOI should relate the processes operating there to what is known more generally of temperate continental shelves, from which the requirements for on-going trend monitoring may emerge.

Indicator 7: Primary Production: The data required to support estimates of primary production should be collected under Indicators 1 and 2. Interpretation of those data to derive the estimates may be technically demanding but should not pose any challenges which are not routinely confronted, except that the proposed calculations of production and community composition (based on ratios of pigments) from satellite data remain under development.

Indicator 8: Mesozooplankton: The methodology for zooplankton sampling at AZMP stations is well established and primarily relies on vertical hauls with ringnets, which are adequate for surveying copepods but are avoided by euphausiid krill. The BIONESS multi-net system, which does take representative samples of krill, is also deployed at some stations. Where water depth permits the safe deployment of BIONESS, it should be used at the stations of the Cabot Strait Line, the proposed new line in the AOI and the inshore stations of the Louisbourg Line, thus providing for euphausiid monitoring both upstream and down from the AOI.

The requirement for zooplankton monitoring does, however, raise a need for resources to support sample processing ashore. Currently, AZMP zooplankton samples are only processed if there is specific funding available.

Indicator 9: Harmful algae: This indicator only needs the gathering into the MPA monitoring archive of such relevant information as the Department obtains.

Indicator 10: Representative Benthic Environments in the MPA:
Indicator 11: Comparable Benthic Environments outside the MPA:
Indicator 12: Distinctive Benthic Features in the MPA:

As the existing AOI moves towards establishment of an MPA, one of the major tasks to be undertaken is a baseline mapping of the seabed environments in the area. That will be required for effective development of MPA objectives, boundaries, zoning, and regulations. It will also provide a foundation for future trend monitoring of those environments.

A field survey for high-precision bathymetric mapping, using multibeam sonar, has been completed for part of the AOI and those data are being processed. A geological interpretation of the rest of the area is being prepared at the time of writing. Various observations of the benthos have been made, though more will be required. That work will face some challenges. The AOI extends from depths within the operating range of divers using air SCUBA down to the floor of the Laurentian Channel, which can only be reached by either heavy sampling gear or an expensive ROV, either one of which requires deployment from a large research ship. In between, there are depths at which monitoring using light gear, potentially worked off an inshore fishing boat, would be an option. The environments of interest include soft sediments, where the primary focus is on the infauna and invasive sampling with dredges or grabs may be unavoidable, but also hard bottoms, where the macro-epibenthos is best monitored visually, either by divers or remote cameras. As the baseline mapping proceeds and the kinds of seabed environments in the AOI are better understood, it will become possible to determine which gears are appropriate for which areas. That knowledge should shape future trend monitoring.

Where water depths and seabed environments permit, as much of the monitoring as possible should be carried out using local boats and local personnel, subject to required technical standards being maintained. That would be more cost-effective than relying on government staff based in Halifax but it would also assist in linking an MPA off Scatarie to the local community. Providing for such monitoring would, however, require more than merely chartering inshore fishing boats as work platforms. It would also demand an effort in relationship-building between the Department's scientists and MPA managers, on the one hand, and both the local fishing communities and marine scientists based in Cape Breton, especially those at the university and at the Unama'ki Institute of Natural Resources.

While the baseline work should be spatially extensive, for any given budget, trend monitoring will have a higher ability to detect temporal change if spatial variability is eliminated from the data through the use of fixed-station surveys. That approach carries a risk that the monitored stations will experience trends that are atypical for the MPA as a whole, although the risk can be minimized by judicious station selection (following extensive baseline mapping) and by including multiple stations.

Indicator 13: Spatial extent of distinctive benthic features: As part of the baseline mapping of the AOI, the extent of each identified distinctive seabed feature (*e.g.* macroalagal bed, seapen field) should be determined, likely using a towed camera system. That mapping should be repeated at intervals, perhaps every five years, or following any exceptional events that may have affected the feature.

Indicator 14: *Population-wide Resource Status*:
Indicator 15: *Trawl-vulnerable groundfish*:
Indicator 16: *Longline-vulnerable groundfish*:

These indicators require little more than continuation of on-going surveys and analyses. Some new fixed stations may need to be added, which would require that significant new budgetary resources be found, but otherwise all that is needed are means to generate suitable data products and arrangements for routine capture of existing data streams.

Indicator 17: Mesopelagic nekton: An understanding of the ecosystems in that broad swath of the AOI beyond the rim of the Laurentian Channel requires at least a baseline survey of the midwater nekton below the epipelagic layer. That could well follow the approach applied in The Gully by Kenchington *et al.* (2009). If it then proves appropriate to continue with trend monitoring, adaptations of that approach similar to those recommended for monitoring the Gully MPA (Kenchington 2010) could be followed.

Indicators 18 and 19: *Comparable groundfish*: As for the groundfish within the AOI, these indicators require little more than continuation of on-going surveys and analyses, perhaps with some new fixed stations added.

Indicator 20: *Wolffish in Sub-Tidal Zone*: Diver surveys of large wolffish in the shallow sub-tidal zone would need some development of a survey design but would not pose any particular technical difficulties. The primary tasks in their initiation and continuation would be ones surrounding the organization of volunteer labour and on-going leadership of that effort.

Indicator 21: Fluxes of nekton across the boundaries of the MPA: Viable methods for monitoring this indicator over the long term do not yet exist, beyond combining short-term studies of fish migrations with stock-assessment estimates of the abundances of various populations. More direct, technologically-based methods, such as combining transponder tags with on-bottom receiver units (*cf.* Comeau *et al.* 2002b), or perhaps upward-looking, bottom-mounted echo sounders, do exist and should be employed if and when their costs become viable for routine monitoring.

Indicator 22: Mammal, bird and reptile surveys: Mobilizing small-vessel visual surveys of the AOI would be something of an organizational challenge but does not pose any particular technical burdens.

Indicator 23: Cetacean activity: Deployment of acoustic recorders in the AOI is required for the monitoring of Indicator 51. Once the data from those has been recovered, it can be analyzed for evidence of cetacean vocalizations. The work would require development of software for detecting the sounds made by various species of whales but that is an existing task required by other monitoring programs within the Department, such that incremental costs for applying the techniques to data from off Scatarie should not be excessive, though they will not be negligible either.

Indicator 24: Seal breeding:
Indicator 25: Seabird nesting:

These indicators require only arrangements for accessing existing data and the development of suitable information products for reporting to MPA managers.

Indicator 26: Trophic relationships: Three phases of work appear necessary for the trophic relationships within the AOI to be monitored. The first would be extensive baseline studies of diets and consumption rates. Considerable amounts of data have been collected for the groundfish on the Scotian Shelf (Cook and Bundy 2010) but they are not specific to the waters off Scatarie. More seriously, little is known of winter feeding by those fish that migrate out through the Cabot Strait: for a small Area astride a major migration route, site-specific diet data must necessarily be season-specific also. If the intent is to monitor the trophic relationships of more than groundfish (and their prey), then extensive baseline work on the diets of the zoobenthos would be needed. Feeding by zooplankton and small pelagic nekton may already be sufficiently known from regional studies but additional field and laboratory effort may be required there also. Indeed, one aspect of this baseline work should be an examination of the degree of spatial variability in diets and consumption rates within the eastern Scotian Shelf. If regional results prove adequate as descriptions of local predation, it will not be necessary to gather as much site-specific data as it would if there is a high degree of spatial variability. For all portions of the trophic structure that are studied, some tedious and expensive analyses of stomach contents will be necessary, though some relationships may be charted with greater certainty and at less cost through the use of stable-isotope methods (a technique that cannot provide site-specific information on migrant animals).

It may be possible to refine conclusions from raw diet and consumption data using mass-balance models, such as ECOPATH (*cf.* Bundy 2005), though the balance will only be found in an area as small as the AOI if fluxes across its boundaries are properly accounted for. Those may remain too uncertain for a modelling approach to be informative.

Once the typical diets and consumption rates have been described by predator species and size class, and perhaps by season and other factors also, it will be possible to monitor trophic relationships within a future MPA using catch data from survey fishing, particularly the groundfish data gathered under Indicators 15 and 16, supplemented by information on nekton fluxes through the Area (*cf.* Indicator 21). A number of indices have been proposed for tracking change in trophic structure based on trends in abundances and sizes of the species present. Not all are applicable to small, unfished areas such as MPAs but the Mean Trophic Level or Mean Trophic Index (Pauly *et al.* 1998; Pauly and Watson 2005) could be applied or else a simple ratio such as that between piscivores and planktivores. Any such index can only yield comparable values over time if it is evaluated using data from a consistent series of surveys. Hence, in the AOI it may be limited in its application to the trawl-vulnerable groundfish community in summer.

The final phase of the work would be on-going, though not necessarily annual, trend monitoring of the site-specific diets for each size class of each principal species. That would only be necessary if the diets prove to be temporally unstable, which cannot be known until the baseline work has been completed.

Indicator 27: Ecosystem function: As with trophic indices, a number of metrics have been suggested for tracking ecosystem function and their relative merits are under active discussion for application to other marine areas. Off Scatarie, they could likely only be applied to the summer community of trawl-caught groundfish, using the data gathered under Indicator 15. A review of the available indices with respect to that particular purpose should be prepared. Once one or more indices have been selected for routine use, this Indicator would become a means of reporting parts of the data gathered under Indicator 15 and any other data streams to which the indices could be applied.

Indicator 28: Data input to the MARXAN analysis: Aside from some examination of the analysis which led to selection of the AOI and which was, or should have been, conducted as part of that process, this Indicator requires nothing more than periodic comparisons between the data streams required for other indicators and those MARXAN input variables that were gathered using equivalent methodologies. At very long intervals (decadal at least), extra data collection targeted on change in those variables should be considered.

Indicator 29: Vessel activity: Transits: Monitoring of vessel traffic through the waters off Scatarie poses significant challenges and likely will continue to do so unless it was considered appropriate to introduce regulations requiring all transiting vessels to hail in and out of an MPA by radio, which seems an inappropriate burden. Large merchant ships in Canadian waters are already required to hail in at six-hour intervals through the Long Range Identification and Tracking System (LRIT) but that would give rather poor data so close to the coast, with significant numbers of ships making a major alteration of course as they pass Scatarie and thus confusing the record of their tracks between one hail and the next. LRIT does provide for more frequent hailing in specified places and perhaps the frequency could be increased for those passing between Cape Breton and Newfoundland. The Automatic Identification System (AIS) sees larger vessels transmitting their locations every few seconds but it uses VHF radio for data transmission and the range is insufficient for a receiver on a land base to track reliably vessels passing through the northern part of the AOI, let alone those bypassing the Area. Satellite reception of AIS signals may become possible in the near future, which would remove that limitation.

Monitoring of other types of vessels is even more challenging. Naval ships are not recorded through LRIT, though the Royal Canadian Navy might be prevailed upon to provide annual summaries of their movements of surface vessels through an MPA. It seems unlikely that submarine movement data would be released but those should be far too few to be of ecological consequence. Most working craft that are small enough to escape LRIT and AIS requirements are fishing boats. The larger ones are monitored through Vessel Monitoring Systems (VMS), the data from which are held by DFO. Monitoring of smaller fishing boats and of recreational craft may have to rely on visual and radar methods for tracking a small temporal subsample each year – or else simply be ignored.

Indicator 30:*Vessel activity: Work in the MPA*: Vessels working in an MPA would likely be required to report their activity as a permit condition. Hence, the data are readily available.

Indicator 31: Authorized fishing effort in the MPA: Besides normal reporting to the Department for fisheries-management purposes, additional data on fishing within an MPA could be required by licence condition. It is, however, important that the reporting burden does not become so great that it amounts to a *de facto* closure of the Area.

Indicator 32: Fishing effort outside the MPA: Fishing effort is already reported to the Department. Not all reports are precisely georeferenced, but those that are should be used to determine the spatial distribution of fishing around the AOI and subsequently analyzed for evidence of “fishing the line” to harvest “spill-over” fish after an MPA is established.

The analysis cannot be simple, however. When an MPA’s boundary is established across a fishing ground, and if fishermen continue their practices unchanged save for remaining outside of the MPA, maps of effort may show a concentration near the boundary simply because that line cuts through the waters where the fleet would have fished regardless of the new regulations. To avoid confusing such MPA-independent distributions with MPA-driven “fishing the line”, it will usually be necessary to examine comparative pre-closure data, while also considering MPA-independent temporal changes in resource distributions. Hence, like many others, this Indicator will need careful interpretation before conclusions can be drawn about the effects of an MPA.

Indicator 33: Unauthorized fishing effort: This Indicator needs only the gathering of such relevant information as the Department obtains by whatever means, incomplete though that may be.

Indicators 34 to 37: Areas swept by fishing gears:
Indicator 38: Quantity of bait:
Indicator 39: Catches and discards:

It is recommended that licence and permit conditions covering fishing for commercial, research or monitoring purposes in an MPA require reporting in sufficient detail that these Indicators can be evaluated. It is, however, important that reporting requirements do not become so burdensome that they act as *de facto* bans on commercial activity. Reconciling those requirements will likely mean using interview surveys and samples instead of demanding that every commercial fishing operation is comprehensively logged.

Documenting bycatches probably requires observer data collected from a sample of the fleet. Enhanced observer coverage required for MPA-monitoring purposes will likely need funding support from the monitoring budget.

Indicator 40: Engineering works: This Indicator primarily needs the compilation of such relevant information as the Department receives in connection with fish-habitat management. That should be supplemented through interactions with other relevant management agencies, such as the Canada-Nova Scotia Offshore Petroleum Board.

Indicator 41: Vessels anchoring: Monitoring of anchoring may require radar coverage of the shallower portions of the AOI, perhaps following a temporal sampling design, rather than a continuous watch. Alternatively, AIS might be sufficient to show that a vessel does not move for a substantial period and hence is likely anchored.

Indicators 42, 43 and 44: Discharges: These indicators need only the gathering of such relevant information as the Department receives.

Indicator 45: Contaminants: One requirement for the process of designing a new MPA off Scatarie is a comprehensive baseline survey of all forms of contaminants in the AOI and upstream. If that survey identifies particular concerns, trend monitoring should be developed. Otherwise, suitable species and collection protocols should be selected for routine sampling and analysis. Besides any routine monitoring, the comprehensive contaminants survey should be repeated at intervals, may be each decade.

Indicator 46: Floating debris: Research and monitoring vessels working in the MPA should be required to report floating debris seen at the surface. Given the use of the area by leatherback turtles and their vulnerability to ingestion of plastic bags, specific sampling for drifting plastic should be considered, to establish a baseline description of the problem. Decisions could then be made over whether to continue with trend monitoring.

Indicator 47: Seabed debris: Epibenthic monitoring (whether using divers, cameras or dredges) should include provision for recording and reporting anthropogenic debris on the bottom.

Indicators 48 and 49: Entanglement, ship-strike and strandings incidents: These indicators need only the gathering of such relevant information as the Department obtains.

Indicator 50: Invasive species: This Indicator needs two sources of information. One would consist of reports from anyone (but most likely scientists working in the MPA) who sees species that are suspected of being invasives within the Area. The other would be warnings from the Department’s aquatic invasive species program if known, established invasives are seen to be expanding their ranges and approaching the Area.

Indicator 51: Anthropogenic sound: Monitoring anthropogenic sound will require the deployment of on-bottom recorders, followed by their retrieval and analysis of the data. Those tasks would involve significant burdens but at least the deployment and retrieval of the recorders could be done using inshore fishing boats, perhaps those chartered for other monitoring activities, and hence at substantially lower cost than if research ships were used.

Socio-Economic Indicators: Methodologies for monitoring the socio-economic indicators remain to be developed by suitably-qualified social scientists. They will likely depend on a variety of survey instruments (such as interviews and questionnaires) delivered to samples of the target populations. The frequency of surveys will have to be decided but need not be annual for all indicators. Collecting the baseline data will be onerous and expensive but, since most of that information is needed for MPA design, it is not an incremental cost imposed by monitoring demands.

While specification of the approaches to be used is beyond the scope of the present recommendations, it should not be long delayed. Baseline research into the ecosystems off Scatarie is needed ahead of the development of an MPA there but gathering data for the quantitative baseline against which future trends will be assessed can be delayed, if necessary. Whatever anthropogenic impacts may be removed by MPA regulations, it will take some time for the local ecosystems to respond, opening an opportunity for the monitoring baseline to be established after the MPA is in place. In contrast, some human responses to the regulations can be expected to be immediate, since it is human activities that will be regulated. Hence, the baseline data for socio-economic monitoring must be gathered before the advent of an MPA changes behaviour patterns.

It will also be important to understand that, where socio-economic indicators are concerned, the same individuals will be at once the sources of the data, the subjects of the monitoring and the stakeholders in the management issues. Natural scientists will see the resulting risk of data distortions, although those will not pose any challenges unfamiliar to social scientists. What may be harder for non-specialists to comprehend is the need for openness: if useful data are to be gathered, it is necessary that those who are asked for information have confidence in those who will receive the data and in what they will do with it. Analyses must be performed swiftly and the results fed back to the stakeholders. Suspicion will remain, along with opposition, when private interests run counter to MPA objectives, but the former can and must be minimized by treating MPA monitoring and management as a partnership with stakeholders and local communities, rather than something imposed from outside.

MONITORING PROGRAM RESOURCE REQUIREMENTS

Gathering data already held by DFO or other Departments, maintaining those data in an archive, holding regular review meetings, refining data products and reporting to MPA managers would all involve considerable amounts of staff time but nothing more than should be expected for the on-going management of an MPA. This recommended monitoring program would, however, also demand more particular expenditures. Much would be for short-term assessments of baseline conditions or for analysis of existing data sets, neither of which pose any on-going demands, but there would also be some substantial long-term incremental costs.

Additions to existing surveys which are recommended for consideration include a few extra AZMP stations in the AOI, routine deployment of a BIONESS zooplankton sampler at AZMP stations in or near the AOI, and extra fixed stations added to the groundfish surveys. Implementation of those recommendations would require executive decisions to either accept the additional costs or else to re-deploy existing Departmental assets.

The major new field component recommended here is the set of benthic surveys (also to be charged with monitoring seabed debris), which might comprise the deployment of everything from SCUBA divers in the shallows to heavy grabs from an offshore research ship operating in the Laurentian Channel, as well as towed camera systems to determine the spatial extents of some seabed features. While expensive, that effort is unavoidable if the benthos is to be monitored and it is the one component of the AOI's ecosystems that should be markedly changed by the protections afforded by an MPA. It is also envisioned that there should be on-going visual surveys for marine mammals, birds and reptiles, additional field monitoring of contaminants, possibly a shallow-water diver survey for wolffish, deployment of acoustic recorders, possible deployment of an AIS receiver and / or radar to monitor vessel movements, plus various enhancements of existing reporting requirements. Socio-economic monitoring of the MPA would be an entirely new departure, likely needing interview surveys. In addition, Indicators 6, 17, 21 and 27 are here offered as placeholders for the later development of monitoring. Each may require significant budgetary support. The combined costs of all of those would be substantial and might amount to the major part of the overall cost of establishing and managing an MPA off Scatarie.

The costs of the recommended monitoring program could be greatly reduced by the use of local boats, local scientists, students and volunteers for as much of the work as possible, which alternative would have the added value of forging connections between the MPA and its adjacent human communities. Setting up and operating those linkages would, however, involve a considerable workload and, to some extent, a distinct skill set for the Department's MPA managers. There are considerations not only in terms of costs and contractual arrangements but also of health, safety and liability aspects, particularly if students or volunteers are deployed as divers or aboard small fishing boats for some aspects of the monitoring. All of those issues remain to be explored if the designation of an MPA off Scatarie Island proceeds.

INDICATORS CONSIDERED BUT REJECTED

A number of additional monitoring indicators and surveys were considered during the development of this recommended framework but set aside for the foreseeable future. The reasons for their rejection were as follows:

Phytoplankton production within the MPA: The recommended indicators include some that would provide for monitoring of chlorophyll in waters flowing into the AOI (and potentially within the AOI itself), as well as regionally, with the latter leading to calculated values for primary production. Direct field measurements of primary production, using standard isotope methods, would be far too expensive to carry out on a regional scale, since they would require deployment of multiple vessels for synoptic estimation during the brief spring bloom. Such measurements might be carried out within the AOI alone at potentially affordable costs, although even such limited fieldwork might still require deployment of a research ship when it would not otherwise be in the vicinity, in order to match the timing of the short and temporally-variable bloom. However, the resulting data would be of limited value, since most of the energy at higher trophic levels in the AOI is thought to be derived from primary production upstream. Hence, an understanding of the ecosystems in the one, local area requires information on primary production across a wider region and that is only available via satellite imagery of ocean colour.

Meroplanktonic egg and larval surveys: It is expected that establishment of an MPA would lead to a build up of spawning biomass of those species which enjoy the benefits of the protection. Some of the larvae from that enhanced spawning should be exported, seeding other areas outside the MPA's boundaries. It would be desirable to trace the eggs and larvae to wherever they settle. In practice, the challenges and costs would be great, even for ichthyoplankton. Yet most of the fish species in the area are migratory and hence not expected to gain effective protection from a relatively small MPA. Such spawning as may be enhanced is more likely to be that of benthic invertebrates, the very small eggs and larvae of which would be considerably harder to survey effectively. The cost of such work seems sure to be unacceptably high.

Seasonal trawl surveys: It has been noted that the existing groundfish trawl surveys give a biased impression of the fish in the AOI because of their emphasis on summer-time data, while the local ichthyofauna is expected to show strong seasonal cycles driven by migrations. It would be highly desirable to mount additional surveys at other times of year to provide a more complete picture of fish use of the Area. Although that can be recommended as a short-term research project, it is not suggested as an aspect of long-term monitoring simply because the cost would be impractically high, even if the surveys utilized local fishing vessels. Winter and spring surveys, which would be the most interesting, since the Gulf migrants would be present in the AOI, have in the past been problematic because of ice, though that may change in the future.

Acoustic surveys for redfish and other groundfish species: The redfishes are an important component of the ecosystem in the Laurentian Channel. Because of their schooling behaviour and their semi-pelagic habit, they are poorly monitored by the existing bottom-trawl groundfish surveys. One alternative would be to supplement the latter with an acoustic survey. That, however, would require development for a whole new survey program, with routine ship-time requirements which cannot be met with existing DFO vessels. Since the fish are members of mobile populations, whose distributions extend beyond the limits of the AOI, they can only be well surveyed across their entire ranges. Thus, the value of the extra, locally-collected data does not seem commensurate with the cost of collecting it.

Surveys for large and small pelagic fish: The recommended indicators provide for local monitoring of demersal fish but not for pelagics, some of which are important as tertiary producers (*e.g.* herring, mackerel) and others as top predators (*e.g.* large sharks). It would be most desirable to monitor those species within any future MPA off Scatarie but no cost-effective methods are available. There are no effective means of monitoring (with useful precision) the density of large sharks in a small area, save for intensive longline fishing which would not only be unduly expensive but would impose unacceptable mortality rates on the animals being monitored. Small pelagics could be monitored much more easily, most likely using an acoustic approach, with midwater trawls for groundtruthing. Even that, however, would require deployment of a new survey program, at a cost that would be hard to justify for fish that are expected to pass swiftly through the AOI, meaning that an MPA would afford them little protection.

Benthos on navigation buoys: The monitoring framework for the Manicouagan AOI includes a proposal to monitor the diversity of benthos growing on five navigation buoys in or near the proposed MPA, with the sampling conducted when the buoys are hauled for routine servicing (DFO 2010d). There are no navigation buoys in the St. Anns Bank AOI, the lights for that area being limited to those on Scatarie Island and Flint Rock. Should an eventual MPA have boundaries which extend closer to the coast, buoys in Main-à-Dieu Passage might be considered for monitoring, though inter-tidal and shallow sub-littoral surveys might prove more convenient there.

Distributions of species: Maps of the distributions, within the AOI, of selected species might offer a more sensitive indicator of ecosystem change than their abundances do. Indicator 13 provides for monitoring the extent of the distinctive benthic features of the AOI but not for mapping of either the more widespread types of benthic environments or the species they contain. Such mapping is not recommended here simply because of its high cost if undertaken on a routine basis.

Intra-specific genetic diversity: Monitoring of diversity at species levels and above is provided by the recommended indicators. Conservation of intra-specific genetic diversity is also important and some of the species of interest in the AOI, such as some sea pens, sponges or whelks, likely show measurable diversity even within that small area. The costs of routine DNA analyses needed to monitor genetic diversity nevertheless seem excessive for the information gained.

External connectedness: Protected-area approaches to the conservation of the ecosystems in the AOI are inevitably compromised by the Area’s location astride the Cape Breton Current. Most components of those ecosystems are, to some degree, dependent on the state of other ecosystems upstream (and so outside the area selected for special protection), whether for a supply of food, a source of larvae or otherwise. Management of an effective MPA off Scatarie will therefore need to address issues far outside the Area’s boundaries and will consequently need to be informed by regional-scale monitoring. Such an expansion of the MPA’s monitoring program cannot be recommended, however. Besides the unsupportable increase in overall costs, it would draw attention away from the Area, defeating much of the point of an MPA designation.

The AOI may, however, contain patches of some species of high conservation importance, perhaps especially amongst the sessile benthos, which are heavily dependent on larval supply from other patches of the same species in Sydney Bight or elsewhere. Should such linkages be identified by future research, monitoring of the populations in the upstream source area or areas would be critical to management decisions essential to the success of an MPA in what is now the AOI. Appropriate indicators would need to be developed and added to the framework presented here.

Vulnerable species: As knowledge of the ecosystems within the AOI increases, additional species with life-history traits which make them particularly vulnerable to anthropogenic impacts will emerge, beside those already recognized. Such species should be given attention through the on-going evolution of the monitoring plan but they cannot be anticipated in advance and hence cannot be accommodated within the present framework.

Anthropogenic marks on the seabed: Much of the seabed in the AOI is potentially subject to anthropogenic physical disturbance, most obviously by fishing gears but also by ship's anchors, scientific moorings and may be other equipment. It is recommended that the activities that could cause such disturbance should be monitored, rather than their effects. It would, however, be desirable to conduct a baseline survey of anthropogenic marks, using high-frequency (and hence high resolution) side-scan sonar to gather the data. That should be accompanied by a study of recovery rates, including variations in those rates across the AOI. At the present time, it is not thought that the data obtained from routine repeat surveys would justify their expense.

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