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Environmental Monitoring of the Gully Marine Protected Area: A Recommendation

Surveillance environnementale de la zone de protection marine du Gully : Recommandation

Trevor J. Kenchington

Ecosystems Research Division
Department of Fisheries and Oceans
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth, Nova Scotia
B2Y 4A2 Canada

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TABLE OF CONTENTS

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ABSTRACT

Department of Fisheries and Oceans Science Sector's recommendations for the environmental monitoring of the Gully Marine Protected Area are presented, with particular reference to the remainder of the current funding cycle (fiscal 2010 and 2011) and for the 5 years beyond (fiscal 2012 to 2016). The Gully, a Marine Protected Area since 2004, is a giant submarine canyon at the edge of the Scotian Shelf, which supports a unique ecosystem. Its offshore location and great depth severely constrain the options for effective, affordable monitoring. Most of the work will require large research vessels operated by the Department, though the recommendations presented here also anticipate roles for various partners.

The monitoring recommendations focus on effects monitoring and threat monitoring. Forty-seven monitoring indicators are presented, along with rationales for their selection. It is further recommended that those indicators be monitored through 18 discrete "component programs" – most of which rely on data from a single form of research-platform deployment (e.g. a cetacean survey aboard a sailing vessel). Where possible, each component program is based around an extension of an existing monitoring program. The proposed approach for each component program is described, while workplans for the coming years are offered. Because of current weaknesses in knowledge of the Gully ecosystem, the initial work must strongly emphasize baseline monitoring, including both analysis of existing data and further research-oriented characterization studies, but the recommendations also provide for on-going trend monitoring.

It is recommended that delivery and development of the monitoring program be overseen by a committee comprising the project leaders of the component programs, which committee should hold an annual Gully Monitoring Workshop to examine the data collected and the results of preliminary analyses. Monitoring results should be reported through existing Science Advisory Process procedures, while all data should be made available through a web-based data-management system.

NOTICE

The monitoring plan presented in this document is a recommendation of how the Gully MPA should be monitored. It is not a commitment of staff, budget, ship time or other resources to that monitoring. The recommendation proposes monitoring roles for parties external to the Department of Fisheries and Oceans. No firm commitments to support the monitoring have yet been made by those parties.

RÉSUMÉ

Les recommandations présentées par le Secteur des sciences du ministère des Pêches et des Océans pour la surveillance environnementale de la zone de protection marine du Gully portent particulièrement sur le reste de la période financière en cours (2010 et 2011) et plus généralement sur les 5 années suivantes (exercices 2012 à 2016). Le Gully, qui est devenu une zone de protection marine en 2004, est un immense canyon sous marin situé au bord du plateau néo écossais, qui abrite un écosystème unique. En raison de sa situation géographique (en pleine mer) et de sa grande profondeur, il est difficile d'y effectuer une surveillance efficace à des coûts abordables. La plupart des travaux de surveillance devront faire appel à de grands navires de recherche exploités par le Ministère, même si les recommandations présentées ici prévoient des rôles pour des partenaires divers.

Les recommandations portent surtout sur la surveillance des effets des activités et sur la surveillance des menaces. On y présente quarante sept indicateurs ainsi que la justification du choix de ces indicateurs. On recommande également que ces indicateurs soient mesurés grâce à 18 « sous programmes » distincts, dont la plupart s'appuieront sur des données recueillies à partir d'une seule plateforme de recherche (p. ex. étude des cétacés réalisée à bord d'un voilier). Dans la mesure du possible, chaque sous programme s'inscrira dans le prolongement d'un programme de surveillance existant. L'approche proposée pour chaque sous programme est décrite et les plans de travail pour les années à venir sont proposés. En raison des lacunes actuelles dans les connaissances sur l'écosystème du Gully, il faudra insister, dans la phase de travail initiale, sur l'évaluation de base, tant par l'analyse des données existantes que par d'autres études de caractérisation axées sur la recherche. Toutefois, les recommandations prévoient également une surveillance continue des tendances.

On recommande que l'exécution et l'élaboration du plan de surveillance soit dirigée par un comité composé des responsables des sous programmes, qui organiserait chaque année un atelier sur la surveillance environnementale du Gully pour examiner les données recueillies et les résultats des analyses préliminaires. Les résultats du programme de surveillance devraient être publiés selon les procédures en vigueur dans le processus de consultation scientifique (PCS), et toutes les données devraient être mises à la disposition des intéressés grâce à un système de gestion des données accessible sur le Web.

AVIS

Le plan de surveillance décrit dans le présent document est une recommandation concernant la façon dont doit s'effectuer la surveillance de la ZPM du Gully. Il ne s'agit pas d'un engagement en ce qui a trait à l'affectation de personnel, de budgets, de navires ou d'autres ressources à la surveillance. La recommandation propose des rôles de surveillance pour des parties externes au ministère des Pêches et des Océans qui ne se sont pas encore fermement engagées à appuyer la surveillance de la ZPM du Gully.

INTRODUCTION

The Gully is a giant submarine canyon – the largest in the northwest Atlantic – which cuts the edge of the Scotian Shelf east of Sable Island (Figures 1, 2). It supports a unique ecosystem, with a high diversity of whales (including an endangered population of northern bottlenose whales) and equally of benthic habitats, the latter including some of the richest coral growths known in Canadian waters. This remarkable area has been a focus of conservation interest since the early 1990s and in May 2004 was designated as a Marine Protected Area ("MPA") under the *Oceans Act*. Management of the MPA is conducted in accordance with the *Gully Marine Protected Area Regulations* and *The Gully Marine Protected Area Management Plan* of 2008, which calls for monitoring to provide managers with accurate and timely information necessary for the conservation and management of the MPA.

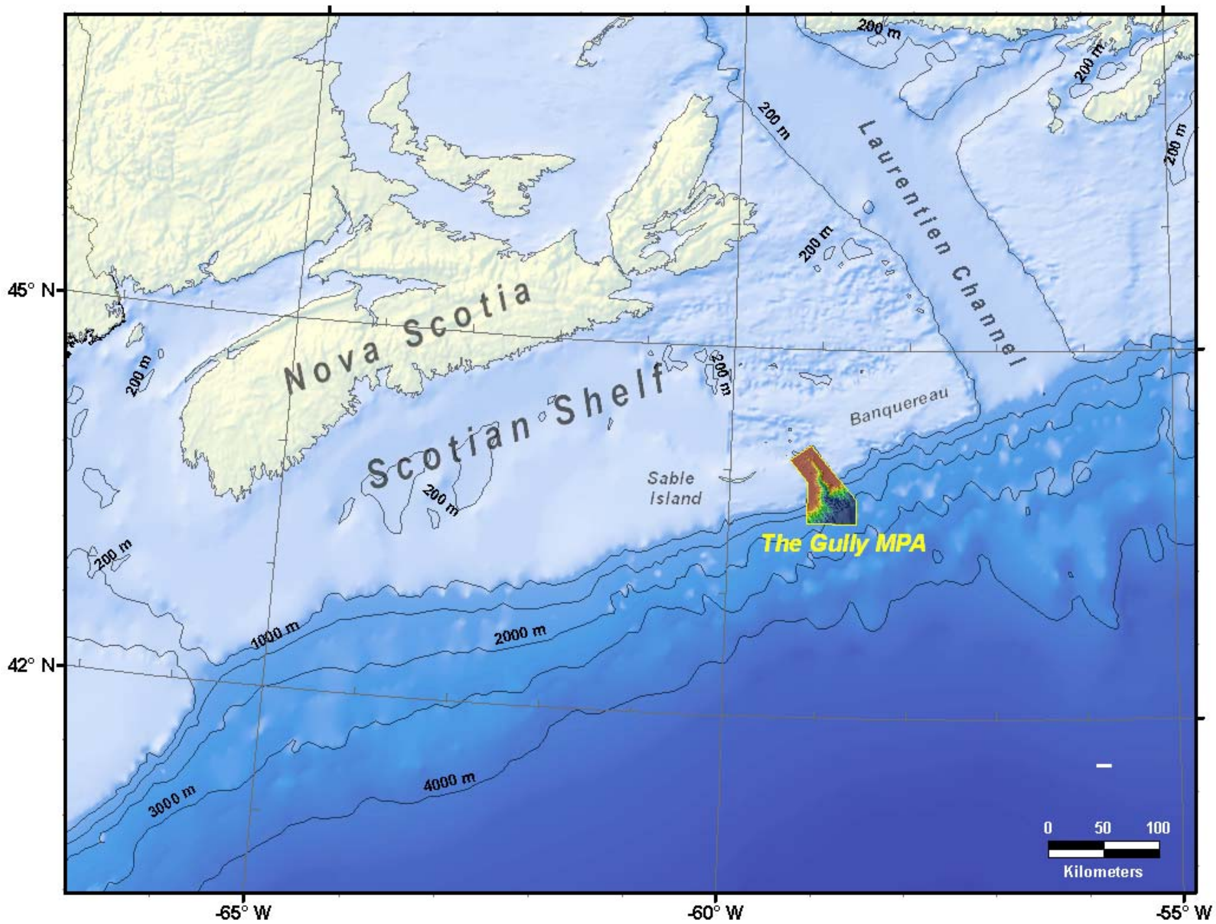

Figure 1: Location of the Gully MPA.

Under the *Health of the Oceans* program ("HOTO"), the Science Sector of the Department of Fisheries and Oceans ("DFO") committed to providing the Department's MPA managers with a recommended environmental monitoring plan for each of Canada's *Oceans Act* MPAs. The present document presents the recommendations for the Gully MPA. Its development began with an initial proposal, drafted in close collaboration with the MPA's managers and after consideration of the recommendations of Pomeroy *et al*. (2004), IOC (2006), Worcester (2006) and Wilson and Tsang (2007), plus examination of examples of other MPA monitoring plans. That proposal was then discussed with the scientists who would be charged with undertaking the monitoring, along with other specialists with relevant expertise, through both collective and individual meetings. Building on their recommendations, a substantially-revised proposal was developed and presented to a SAP review. Incorporation of the further comments offered through that review led to the final recommendations presented here.

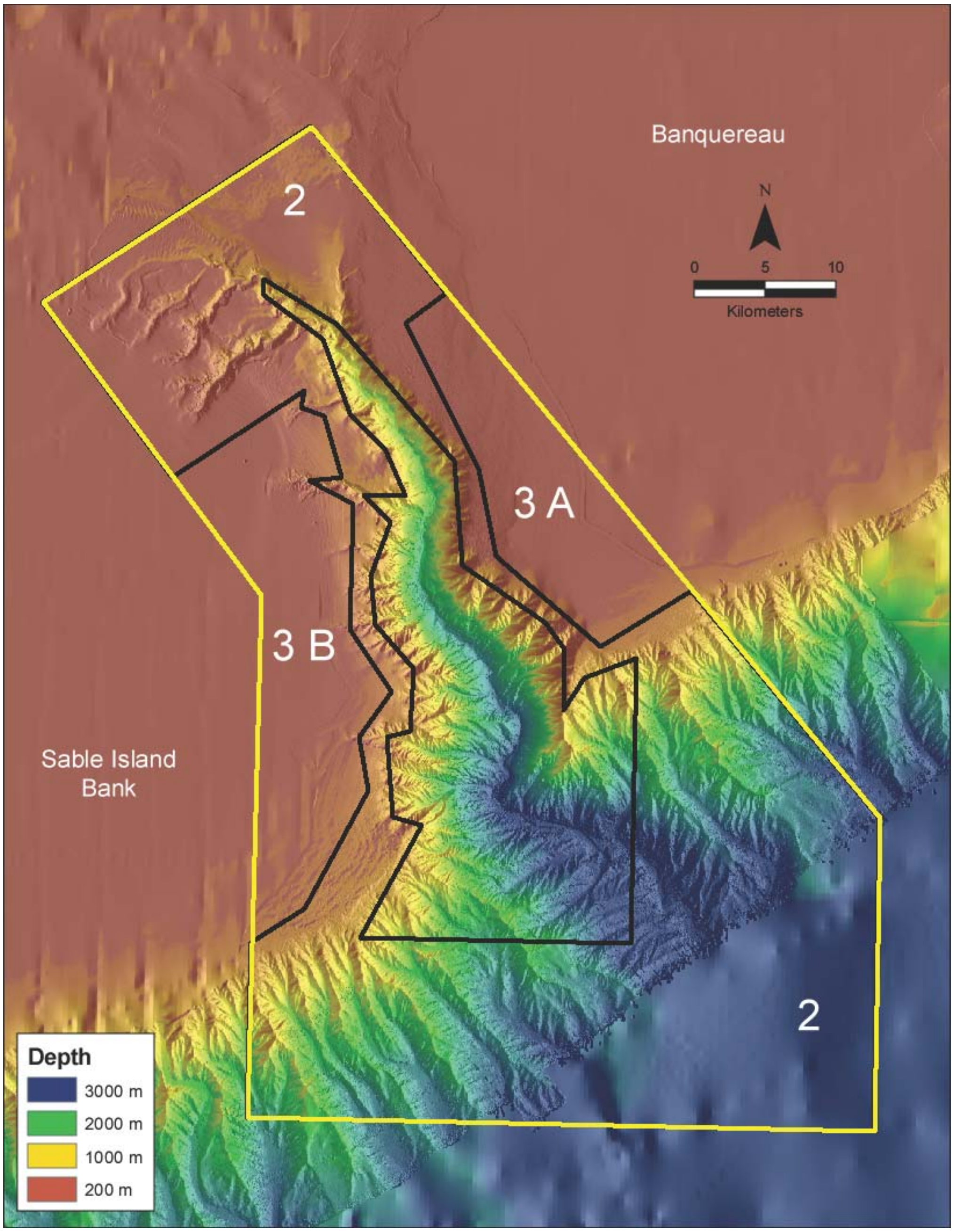

Figure 2: The Gully, showing the boundaries of the Marine Protected Area and its management zones, overlain on the detailed bathymetric information from multibeam surveys. (Note that the bathymetry of the deeper waters to southeast has not been surveyed to the same accuracy.)

In keeping with their origins under HOTO, these recommendations are primarily directed towards the remainder of the current funding cycle (fiscal 2010 and 2011) and for the five years beyond (fiscal 2012 to 2016). In view of the timing of these recommendations, only limited advances in monitoring the Gully MPA can be expected during 2010–11 and hence implementation is not anticipated before fiscal 2011.

The recommendations presented here concern only environmental monitoring, including monitoring of anthropogenic impacts on the Gully ecosystem. Management of the MPA, however, requires a comprehensive monitoring program, including socio-economic monitoring of the effects of the MPA on human interests and governance monitoring to ensure that the MPA's management system is performing as intended. While those are essential aspects of the overall program, they are beyond the scope of the present recommendations and are not considered further here.

This document begins with a general account of MPA monitoring, though with a focus on the special requirements of offshore, deepwater areas such as The Gully. It also provides an introduction to The Gully, including both the ecosystem to be monitored and the management regime within which a monitoring program must be embedded. The greater part of this document, however, presents the recommended monitoring plan itself, explaining the proposed strategy, providing a rationale for each of the recommended monitoring indicators and then outlining the monitoring approaches for each of a series of "component programs", through which the indicators should be monitored. The final section presents rationales for the rejection of indicators which were considered for inclusion but which are not recommended for monitoring.

ECOSYSTEM-BASED MONITORING IN MPA MANAGEMENT

THE REQUIREMENT FOR A MONITORING PROGRAM

The establishment of an MPA is a necessary first step but is not itself sufficient to ensure protection for the biota and ecosystem within its boundaries. Even introducing protective regulations and a management plan with specified objectives, such as those for the Gully MPA, is not enough: regulations must be enforced, the application of exemptions must be administered, progress towards the objectives must be monitored to ensure that the combination of the established boundaries, the regulations and the management is having the intended effect, and the results of the monitoring must be fed back into the management process to support on-going revision of the management plan. The feedback provided by a monitoring program that is fully integrating into the management process is fundamental to adaptive management since it is the only way to measure effectiveness and to provide a foundation for improving management (cf. Pomeroy *et al*. 2004; Wilson and Tsang 2007). Monitoring of existing MPAs is also essential to provide a foundation for science-based answers to questions about which other areas should be given special protection. Monitoring, in short, is a critical component of management of an MPA, which in turn is essential if the Area is to generate its intended benefits. For the Gully MPA specifically, this requirement is explicitly recognized in the Management Plan, which calls for monitoring to provide managers with the accurate and timely information necessary for the conservation and management of the MPA, under a *Research and Monitoring Strategy for the Gully MPA*[1].

Monitoring can be defined as the systematic collection of data and information on a regular basis for an extended period of time to determine the degree of achievement of some goal or standard. In the context of an MPA, it includes gathering of data on the living and non-living components of the area, on the human users and on the management processes themselves (cf. Wilson and Tsang 2007). The systematic collection of the data is critical when monitoring marine systems. They are inevitably highly variable, particularly in an open, offshore area like

[1] To date, the *Research and Monitoring Strategy for the Gully MPA* only exists as a 2006 discussion draft (Worcester 2006).

The Gully, and detecting temporal change in the face of that variability will require rigorous, statistically-valid approaches. Meanwhile, the data gathered will depend as much on the measurement protocols as on the state of the ecosystem itself. Unless those protocols are carefully standardized and the standards maintained unchanged over long periods, it will be impossible to distinguish meaningful signals from the background “noise” in the data.

If it is to be effective, and even more if it is to be efficient, environmental monitoring must be designed around an understanding of the ecosystem, such that critical pathways and key species can be identified and appropriate monitoring indicators developed. Some of those indicators will be obvious, such as the abundance of bottlenose whales in The Gully, but others (the factors which control whale abundance, for example) are less easily selected. There are an unlimited number of variables that could be considered in even a small MPA, while the monitoring of many of them would be very expensive. Hence, it is imperative that efforts be focused where necessarily-scarce monitoring resources will provide the greatest amount of the most critical information for management. Efficiency and effectiveness further require a coordinated and comprehensive plan, ensuring that all appropriate indicators are monitored at the least cost and particularly, where offshore MPAs are concerned, with the minimum necessary expenditure of expensive ship time. The requirement is thus for a plan for science-based monitoring, using standardized protocols, of a suite of indicators that together capture the condition of an MPA’s ecosystem and which can be used to evaluate success in achieving conservation objectives.

MONITORING INDICATORS

The requirement for standardized monitoring protocols leads directly to a need for specified “indicators”, which are the variables actually monitored. It is trends in the indicators which are reported to an MPA’s managers. In practice, an indicator can be something directly measured (e.g. sea surface temperature at a defined station), something derived from measurements (e.g. the abundance of some species, based on survey data) or a higher-order summation of a variety of measured and derived values. Very often, a mixture of those three types will be required both to capture trends in an MPA’s ecosystem and to communicate those trends to managers and stakeholders. Regardless, it is essential that the indicators be capable of evaluation by rigorous, reproducible methods, else confusion and dispute would negate the point of monitoring in the first place. Each indicator must have its own standardized monitoring protocol, founded on the form of statistical analysis that will be applied to the data, which protocol must be applied consistently.

Since monitoring is, by definition, a long-term activity, once selected, the suite of indicators should be maintained. Short runs of monitoring data will not detect slow changes and are usually a waste of resources. However, it is important to retain the flexibility to discard uninformative indicators, to adopt new ones relating to emerging threats and to correct faulty methodology. Hence, it is essential to have a system for managing the monitoring program which can find an appropriate balance between stability and change.

It is also necessary to draw a distinction between data collection, for which long-term standardization is imperative in monitoring programs, and data analysis. The latter can and should be upgraded whenever opportunities arise, provided that the new approaches are applied to the archived data, thus generating temporally-consistent indicator values. While a detailed protocol for conducting annual trawl surveys, for example, must be carefully standardized and while a measure of diversity calculated from the survey catch data might be specified as a monitoring indicator, the particular formulation of the diversity index can be left for the evolving judgments of annual review meetings. The current document thus emphasizes recommendations on what to measure, rather than details of what to derive from the resulting data.

Ideally, the suite of indicators should encompass the issues that require monitoring in a particular MPA, while allowing for some in-built redundancy such that major changes in the ecosystem would be detected even if one indicator proved non-informative. For efficiency, and so far as is practical, the MPA monitoring should be fully integrated into regional, national and international monitoring programs, without compromising its fulfillment of the specific needs of MPA management. Equally ideally, each individual indicator should be:

- 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
- Should have a pre-existing baseline.

(cf. Kabuta and Laane 2003; Pomeroy *et al.* 2004; Wilson and Tsang 2007). The combination of the baseline and the linkages to management objectives should allow the development of reference points specific to each indicator, while the full suite, in combination, should both capture an adequate overview of the state of the ecosystem and describe the effects on it of human activities.

While those are ideals, in practice there will often be conflict between the need for a set of indicators encompassing the management issues and the desirable characteristics of individual indicators. In The Gully, for example, monitoring of shallow-water benthos would meet the needs of simple, low-cost tracking of a sensitive indicator but would not address the state of the deep, pelagic ecosystem which supports the bottlenose whales. Monitoring that system will require complex, expensive technology that is not far behind the cutting-edge of oceanographic instrumentation. Other conflicts can arise between various ideals. For example: Public outreach is important to the management of any MPA, and hence indicators that are comprehensible by stakeholders and the wider public are important, yet it is critical for effective management that the monitoring detect key changes in an MPA's ecosystem, even if that necessitates approaches that are only readily understood by specialists. Indeed, the ideals notwithstanding, monitoring of a deep-water, offshore MPA will be severely constrained by both cost considerations and technical capabilities. Those constraints will require that the ideals be treated more as a guideline than as firm requirements. They are so treated here.

Some authors have recommended compiling monitoring data into comparatively few indicators that have values derived from various mathematical models (e.g. Link *et al.* 2002, Rice 2003). Such indices have value in simplistic management systems that rely on triggering pre-determined responses when an indicator passes a defined reference point. However, knowledge of the Gully ecosystem is not, as yet, sufficient for setting either the reference points or the responses. Moreover, the objectives defined for the Gully MPA call for monitoring of specific variables, such as bottlenose whale abundance, rather than for generic indicators of ecosystem "status", while the Gully ecosystem appears sufficiently complex that its various facets could well be trending in different directions, confusing compiled indicators. Thus, this recommended monitoring plan emphasizes multiple indicators which should be considered, by managers and stakeholders, both individually and collectively.

A TAXONOMY OF MONITORING

Any MPA monitoring program must fulfill a diverse range of requirements. They are frequently intersecting and interacting, with one function addressed through multiple types of data collection and yet one survey contributing to many requirements. Conceptually, however, the tasks can be classified into:

Baseline Monitoring:
Establishing a temporal baseline from which future changes can be monitored. Baseline monitoring can include extensive work characterizing the ecosystem, as a foundation for development of a monitoring program, and the determination of levels of natural variability in potential monitoring indicators, as well as the straightforward quantification of initial values of the selected indicators.

Trend Monitoring:
On-going tracking of temporal change in selected monitoring indicators. Trend monitoring extends from an established baseline.

Effectiveness Monitoring:
Monitoring focused on attainment of management goals and objectives, i.e. on the "end effect" of the MPA. Effectiveness monitoring usually requires a combination of baseline and trend monitoring.

Activity Monitoring:
Monitoring of the effects of a specific human activity, e.g. monitoring levels of hydrocarbon contamination downstream from petroleum-production platforms.

Compliance Monitoring:
Monitoring of a specific activity to ensure that it is conducted in accordance with the terms of regulations and permits. Compliance monitoring is sometimes but not always a form of activity monitoring.

Regulatory Monitoring:
Monitoring capable of generating evidence for enforcement actions. Regulatory monitoring is usually a sub-type of compliance monitoring, with procedures rigorous enough to meet legal tests, but it can also be a sub-type of activity monitoring, independent of specific permit requirements. The latter is particularly relevant to the Gully MPA since the *Gully Marine Protected Area Regulations* broadly prohibit any activities (with specified exemptions) that "disturb, damage or destroy … or remove" any organisms, their habitats or the seabed within the MPA – whether the activity happens within its boundaries or outside. Contravention of such

an all-encompassing requirement can ultimately be determined only by demonstrating that harm has occurred and is attributable to a particular activity.

Threat Monitoring:
Monitoring of a suspected threat, as distinct from its effects. Threat monitoring could include both point-source threats (e.g. produced water from a petroleum-production platform) and non-point source (e.g. underwater sound from all sources combined).

The recommendations for monitoring the Gully MPA offered in this document emphasize effectiveness monitoring, combining both baseline monitoring and trend monitoring, though not to the exclusion of some threat monitoring, particularly where that is a lower-cost alternative to monitoring the expected effects of the activities in question. For example, it is very much simpler to record the weight of any deepwater coral removed from the MPA by human activities that it would be to monitor damage to coral "forests" through extensive seabed surveys with expensive deep-diving vehicles.

The Gully ecosystem remains poorly known, raising the spectre of serious threats that have not been foreseen, while its offshore location leaves it vulnerable to major oceanographic change driven by climatic forces beyond human control. The prime needs, therefore, are to determine whether the MPA is achieving its objectives and to monitor change in the ecosystem, rather than to focus on perceived threats that may or may not actually pose the greatest risks. Activity monitoring has only a limited role since few of the potentially-harmful activities in and around The Gully have known effects which could be monitored and ascribed, with confidence, to any one activity.

The Gully MPA *Regulations* are broadly encompassing and phrased in terms of avoiding disturbance and damage to the ecosystem, rather than as prohibitions on specified activities. Regulatory monitoring would therefore require environmental monitoring. It is not, however, possible to anticipate in advance what types of harm might arise from which specific activities. Thus, all that can be done through long-term monitoring is to determine the state of the ecosystem (the task of effectiveness monitoring), with identification of the causes of any observed changes to be addressed subsequently through targeted studies and data collection. Otherwise, compliance and regulatory monitoring would necessarily be confined to the monitoring of specific permitted activities within or around The Gully. Such activities currently comprise mostly research and commercial fishing. The latter is and will continue to be intensively monitored, including by carrying observers on some trips and being subject to aerial surveillance. No additional compliance monitoring of fishing vessels is considered necessary, aside from some enhancement of data collection as described below. Meanwhile, most of the research work will be conducted by staff of the Department while aboard ships operated by the Canadian Coast Guard (itself answerable to the Minister). Hence, compliance will be assured through line-management channels without posting additional monitors aboard the research vessels. The only frequent visits to the MPA by non-DFO research vessels are for cetacean surveys, which themselves form part of this monitoring plan. If permits are granted for other activities within the MPA, the Department might well assign a staff member or other on-board observer, who would be charged with reporting on compliance with the terms of the permit, perhaps in addition to gathering other data (e.g. as whalewatcher). Such cases are, however, expected to be too infrequent and too variable in their nature to fulfill any on-going monitoring function.

Activity monitoring could be conducted outside the MPA's boundaries but the only activities that might be monitored are commercial fishing and petroleum development. Both are already subject to intense monitoring for other purposes and the compilation of relevant portions of those data is here regarded as one aspect of threat monitoring. Additional activity monitoring of those industry sectors is not recommended. There might be more value in additional monitoring of the shipping (other than fishing or offshore-petroleum vessels) passing through or near The Gully. The costs and complexities of placing on-board observers aboard foreign-going merchant ships or Canadian naval vessels would, however, be prohibitive and hence only remote monitoring is recommended here, as an aspect of threat monitoring.

The emphasis on effectiveness monitoring in this document means that the recommendations are founded on the goals and objectives of the MPA, which are presented below. The emphasis carries with it an implication that the recommended monitoring would serve to identify trends in the Gully ecosystem but would not explain the causes of those trends. Indeed, even the absence of a detectable trend would not show that the MPA was effective, since factors extraneous to any management measures also affect populations and other ecosystem components – factors which might over-ride any effects of the MPA itself. It is therefore necessary that this recommended monitoring plan be accompanied by on-going research, including investigations of any specific trends as they are identified, which research alone can build the knowledge base needed to understand the routinely-collected data.

The baseline facet of effectiveness monitoring is particularly important in the case of the Gully MPA since the Gully *Regulations* place much stress on keeping impacts within the range of natural variability. Hence, it will be essential to quantify the short-term, natural inter-annual variability in many of the monitoring indicators. Furthermore, baseline monitoring is critical in the Gully MPA because the structure of the ecosystem there remains so poorly understood that the key pathways cannot yet be identified and hence no optimally-efficient set of indicators can be developed without further knowledge. Again, in The Gully, monitoring and research must progress together.

Besides the above classification of the types of monitoring, monitoring indicators are sometimes separated into:

Direct Indicators:
Those which capture the current state of some management objective (e.g. the abundance of an MPA's "signature" species).

Indirect Indicators:
Those which, while informative for MPA management, do not directly capture the state of any management objective. Examples of indirect indicators might include measures of known threats to the "signature" species or indices of the quality and quantity of its habitat within the MPA.

In practice, management objectives are rarely defined in terms which allow for direct measurement or even estimation based on survey indices. Indeed, in the case of the Gully MPA, the goals have been set in such broad terms as to blur any distinction between their direct and indirect representation. Thus, the indicators recommended below were selected for their efficiency and efficacy in providing necessary information to support management of the MPA, without regard to the conceptual distinction between direct and indirect approaches.

MPA MONITORING AS EXPERIMENTAL DATA COLLECTION

Besides effectiveness monitoring to determine whether management objectives are being met within an MPA's boundaries, it will sometimes be useful to monitor the same variables at "control" sites, thus creating an "experiment" in which the "treatment" being tested is the establishment and operation of the MPA. However, while such an approach has simplistic appeal, any “experiment” which lacks valid statistical design can only return results that are unreliable – and often dangerously misleading. Since valid designs require randomization in the location of “control” and “treatment” sites, across the universe of potential locations, along with replication of either or both kinds of sites, such designs can only be achieved with MPAs in very particular settings. Indeed, with many MPAs, the area chosen for enhanced protection is carefully selected after long consideration of many issues. Often, the choice falls on an area recognized as meriting MPA status precisely because of its uniqueness – the Gully MPA being a notable example. In such a case, any attempt to monitor a “control” area or areas so as to distinguish the effects of the establishment and management of the MPA from those of other causes would merely divert monitoring resources away from the area of interest, while gathering data that could only serve to mislead those stakeholders who lack an appreciation for the necessities of experimental design. Hence, no such external monitoring is recommended here, though some of the recommended component programs are already engaged in monitoring much larger areas than The Gully.

The long-term effects of MPAs on populations of motile species, and particularly on fishery-resource populations, nevertheless remain contentious and in some cases obscure. Use of “control” sites would rarely inform such questions as the resource populations which might be enhanced typically occupy extensive areas, encompassing all potential “controls”, while the use of neighbouring populations would move the monitoring into different oceanographic regions which experience different underlying trends. In many cases, however, there is value in studying the local effects of an MPA on motile species, such as the promotion of “spill over” of fish from an enhanced aggregation within a protected area to open fishing grounds outside. Such studies are often best characterized as research but there can be a role for routine monitoring also. As explained below, such monitoring has been considered for the Gully MPA, though it is not recommended here.

THE GULLY MPA

OBJECTIVES OF THE GULLY MPA

Monitoring of the Gully MPA is intended to aid management of the area, which in turn must strive towards defined goals and objectives. Thus, one primary focus of an efficient monitoring program must be on those goals.

***Oceans Act* Objectives for the Gully MPA**

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 fulfill the mandate of the Minister of Fisheries and Oceans.

At its designation, the Gully MPA was deemed to meet all five criteria. In this context, the *Management Plan* specifically mentions:

1) The importance of the area to commercial and non-commercial fish species, notably halibut and myctophid lanternfishes,
2) The high diversity of demersal fish species,
3) The endangered population of northern bottlenose whales,
4) Coldwater corals and seapens that are vulnerable to human impact,
5) The high diversity of benthic habitats and the high biodiversity that is expected to result, and
6) The canyon's unique size, depths, slopes and links to the middle and inner Scotian Shelf.

Objectives Defined in the Gully MPA Declaration

The *Regulatory Impact Analysis Statement* that accompanied the *Gully Marine Protected Area Regulations* declared the purpose of designating the MPA as:

> "to conserve and protect the natural biological diversity of "The Gully", and to ensure its long-term health."

The Statement also drew attention to the bottlenose and other whales, the high productivity and food supply in the area, the high diversity of benthic habitats and the highest known diversity of corals in Atlantic Canada.

Objectives and Priorities Defined in the Gully MPA Management Plan

The *Gully Marine Protected Area Management Plan*, which incorporates the lessons of extensive stakeholder consultation, declares the overarching vision for the Gully MPA to be:

> "To protect the marine ecosystem of the Gully MPA for future generations by providing effective programs for management, conservation, research, monitoring, and stewardship".

The *Management Plan* also declares a number of objectives for the MPA:

1) Protect the health and integrity of the Gully ecosystem;
    a. Protect the natural biodiversity of the Gully,
    b. Protect the physical structure of the Gully and its physical and chemical properties,
    c. Maintain the productivity of the Gully ecosystem,
2) Establish effective management of the Gully MPA,
    a. Promote collaboration among all users, regulators, and other interests,
    b. Involve stakeholders and the general public in the management of the MPA,
    c. Establish co-operative agreements with responsible regulatory authorities to meet objectives for the MPA,
    d. Ensure that human activities within the MPA are consistent with Regulations and the conservation objectives,
    e. Monitor and evaluate the design, management, and effectiveness of the MPA on a regular basis to ensure that it is meeting defined objectives,

3) Promote stewardship activities,
    a. Increase understanding of the Gully ecosystem among regulators, user groups and the public,
    b. Promote active participation and engagement in management and research,
4) Increase our understanding of the Gully and the potential for human impacts on this ecosystem,
5) Foster collaboration and communication among managers and natural and social scientists, and
6) Provide managers with accurate and timely information on the state of the Gully ecosystem and potential threats to conservation and management objectives.

When approaching those objectives, the *Management Plan* saw a number of priority conservation issues for the 2008–2012 period:

1) Protecting cetaceans from impacts caused by human activities,
2) Protecting seafloor habitat and associated benthic communities from alteration caused by human activities,
3) Maintaining or restoring the quality of the water and sediments of the Gully, and
4) Conserving other commercial and non-commercial living resources.

<u>Summary</u>

These many and varied goals provide direction to the design of any monitoring plan for the Gully MPA. Collectively, they suggest that the key components of the Gully ecosystem meriting management attention and hence monitoring are:

- Biological diversity, productivity, "health" and integrity of the Gully ecosystem – which together subsume concern over the abundances and production of many species,
- Canyon bathymetry,
- Physical and chemical properties of The Gully, both water column and sediments,
- Northern bottlenose whales,
- Other whales,
- Coldwater corals, including seapens, and their diversity,
- Diversity of benthic habitats and benthic communities,
- Diversity of demersal fish species,
- Halibut,
- Myctophid lanternfishes, and
- Other commercial and non-commercial living resources.

It must be noted that some of those defy cost-effective monitoring or indeed any monitoring at all. Such high-level objectives as "protecting natural biological diversity" or the integrity of an ecosystem pose daunting challenges for effectiveness monitoring.

THE GULLY ECOSYSTEM

There is much that remains unknown about the Gully ecosystem (or, more properly, ecosystems) but the then-available scientific knowledge was compiled by Harrison and Fenton (1998) and Gordon and Fenton (2002), while Rutherford and Breeze (2002) presented a first ecosystem framework for the area. The account offered in this section has been compiled from those sources and from more recent, often on-going, research. It is intended to provide a foundation for the monitoring of the MPA, not least by highlighting some knowledge gaps that require further characterization studies before an efficient and effective monitoring program can be fully implemented. It is not intended as a definitive statement of the structure and functioning of the ecosystems in The Gully.

Bathymetry

The Gully is an enormous submarine canyon, some 40 km long, up to 16 km wide, with water depths exceeding 3000 m where it cuts across the continental slope. It lies at the edge of a wide continental shelf, far from the mainland and its direct influences – though Sable Island is only 30 km away, while the outflow of the St. Lawrence has a pervasive effect, as it does across the entire eastern Scotian Shelf. The main canyon winds between Banquereau and Sable Island banks, with its floor as much as 1800 m below the shallow seabed on either side. The thalweg, an imaginary line joining the deepest points on sections across the channel, dips at a steady 2° towards the south (Fader and Strang 2002). At its outer end, the canyon extends beyond the shelf break as a channel cut 1000 m and more into the continental slope and rise, where the thalweg is bordered by levees formed by turbidity currents (Fader *et al*. 1998). Within the canyon proper and at depths of around 800 m, which was the limit of iceberg scour during glacial times, much of the canyon wall is steeper than 50°, suggesting intense erosion (Fader and Strang 2002). Indeed, in some places, vertical bedrock cliff faces have been seen in video imagery.

There are a number of substantial feeder canyons running into the main feature, mostly from the west and predominantly around the canyon head, while the walls of both the main and feeder canyons are furrowed by minor canyons and the ridges between them. Most notable of the ridges is a mighty spur, rising some 2000 m from the thalweg and projecting from the southernmost tip of Banquereau. Sometimes called the “Southwest Prong”, that ridge is formed by a curve in the thalweg where it intersects the continental slope. This “Prong” delimits and defines the canyon mouth. It is also a persistent centre of dense midwater acoustic scattering (Kenchington *et al*. 2009), suggesting that the shape of the ridge and the resulting water movements across it may have major effects on the structure of the Gully ecosystem.

What may make The Gully unique is that, unlike most submarine canyons, its head connects to a large, shallow basin in the central Scotian Shelf, sometimes called “The Trough”, which lies north of Sable Island and links the Gully to the inner Scotian Shelf. The edge of the western Scotian Shelf takes the form of several broad saddles between shallow banks. It is known that water moves between deep ocean and the mid-shelf basins, across those saddles, under meteorological forcing (Petrie 1983). In contrast, from Sable Island Bank eastwards to the Laurentian Channel, the edge of the Shelf is formed by an almost unbroken mountain wall, reaching from below 4000 m depth to within 100 m of the surface. The sole break in that wall is The Gully and its connection to The Trough. While only preliminary observations have yet been made (Kenchington *et al*. 2009; Dr. B. Greenan, BIO, *pers. comm*.), it appears that the meteorological forcing and the restricted passage combine to produce swift flows through the canyon at great depths.

Surficial Geology

The Gully seabed has a wide variety of sediments, with boulders and gravel in parts but sands and fine silts in others. There is exposed bedrock on the canyon walls in places, the rock being semi-consolidated mudstone, siltstone and sandstone of Tertiary age, though the shallower portions of the walls are covered with the types of sediment seen elsewhere on the Scotian Shelf: “Sable Island Sand” above the lowest sea level of the last glaciation, “Sambro Sand” below that and then an outcropping of the glacially-deposited “Scotian Shelf Drift”. Around the canyon head, there are areas of “Emerald Silt” which is typical of the flanks of the Scotian Shelf banks. The shallower seabed is marked by glacial scours and moraines, particularly on the Banquereau side.

Around the head of the main and feeder canyons, the seabed is sandy, with bedforms (including sandwaves up to 11 m high) indicating active transport of sand into and down the Gully thalweg. A large scoured depression or "megaflute" indicates high-velocity flows in the bottom water where The Trough meets the canyon (Fader and Strang 2002).

Water Masses and Water Movements

The ocean area off Nova Scotia has often been identified as one of the most highly variable on the planet. The Gully is especially exposed to those variations. Above 100 m depth, its overlying waters are usually continuous with those over the rest of the eastern Scotian Shelf and Slope, which are ultimately derived from that portion of the Labrador Current which flows over the Grand Banks. Some of the water from that Current passes into and back out of the Gulf of St. Lawrence – the outflow, which passes clockwise around Cape Breton and onto the Scotian Shelf, being markedly diluted by river water. The resulting low-salinity (about 32‰) and hence low-density mixture undergoes intense winter cooling, while only the uppermost layers are warmed in the summer, leading to the formation of a subsurface Cold Intermediate Layer ("CIL"), extending to about 100 m depth. The core of that layer can remain close to 0 C even in late summer, when the surface may reach almost 20 C, while the subsurface maximum (at 150 to 200 m) may approach 10 C – though the extent and core temperature of the CIL are variable over time and space.

Below the depths of the surrounding banks, the canyon is isolated by its rock walls but its mouth remains open to the deep waters of the North Atlantic. That portion of The Gully is usually flooded by cold water from the deeper parts of the Labrador Current, which curls around Grand Bank and flows far to the southwest following the edge of the continent. Temperatures at depth are around 4°C and salinities about 35‰.

Seaward of the shelf break, however, the waters are extremely dynamic. The Gulf Stream usually lies several tens of kilometres to the south, while the volume to the north of the Stream's Cold Wall is occupied by Slope Water – a mixture of Gulf Stream and continental-shelf waters that forms near Cape Hatteras and flows to the northeast beside the Stream. The northern edge of the Slope Water is marked by a shelf / slope front which approximately overlies the shelf break from Hatteras to the Nantucket Shoals. The Slope Water, however, breaks away from the continent in the vicinity of the southern flank of Georges Bank and the shelf / slope front usually lies some distance south of shelf break where it passes The Gully. The positions of that front and of the Gulf Stream are, however, highly variable. Besides regular seasonal changes in their latitudes, there are inter-annual variations associated with the North Atlantic Oscillation ("NAO": An index of atmospheric pressure differences across the North Atlantic) and short-period changes driven by the meandering of the Stream. The shelf / slope front has been observed lying at the shelf break, across the mouth of The Gully (author's personal observation in August 2009), and it is fully possible that parcels of Slope Water, and even sometimes Gulf Stream Water, enter the canyon at times. Alternatively, the volume of the CIL has been seen to expand, pushing the shelf / slope front away from the Scotian Shelf and leading to negative temperature anomalies of several degrees seaward of the shelf break (Petrie *et al*. 2008).

Besides the potential for replacement of the usual water masses within and over the canyon, which must have profound consequences for benthic organisms exposed to sharp temperature changes, the pronounced oceanographic variations south of the Scotian Shelf can have dramatic effects on plankton production. The spring bloom in 2007, for example, was markedly enhanced, apparently because of upwelling along the shelf break, driven by a northward movement of the shelf / slope front (Harrison *et al*. 2008; Petrie *et al*. 2008).

While the Gulf Stream and the Slope Water move generally northeastwards, north of the shelf / slope front, the flow is typically towards the southwest, with a prominent current in that direction along the shelf break. That broad regional pattern is interrupted by sometimes-weak clockwise gyres which form around the shallow banks, The Gully being particularly influenced by the gyres circling Banquereau and Sable Island Bank. In the surface layers, the former gyre draws water from seaward of the shelf break into the canyon and so onto the Scotian Shelf. Meanwhile, the circulation around Sable Island Bank moves water in the reverse direction. In the spring, the former is much the stronger flow, producing a net movement through The Gully onto the Shelf, but that transport is less marked at other seasons (Han *et al*. 2002). With an inflow on the eastern side of The Gully and an outflow to the west, there is some recirculation of water, forming an anticlockwise gyre over the deep water of the canyon, particularly in fall and winter. That serves to retain plankton over the canyon, enhancing opportunities for local spawning to lead to local recruitment, though the gyre could also serve to retain pollutants. Its effects should not be exaggerated; however, most water in the surface layers over The Gully will not remain there for long.

In addition to those seasonal, mean flows, there are shorter-period water movements, principally tidal or meteorologically-driven. Of particular note, the tidal streams interact with the bathymetry of the upper continental slope, creating internal waves on the strong pycnoclines bordering the CIL. Most of the wave energy propagates shoreward and becomes concentrated into solitons, which can break, producing mixing and turbulence. That is seen mostly above 200 m depth on the Banquereau side of The Gully (Sandstrom and Elliott 2002). In summer, when nutrients in surface water are depleted and, in consequence, phytoplankton production becomes restricted, such mixing should allow on-going production locally (Harrison and Fenton 1998; Mann 2002). The magnitude of the enrichment is not known, however, nor is its fate: the area concerned is so placed within the gyre around the bank that the additional plankton may be carried away from the canyon.

Circulation patterns within the canyon below the CIL are only now being investigated. While strong along-canyon flows have been observed (Dr. B. Greenan, BIO, *pers. comm*.), their details remain unclear. As already noted, there are indications that meteorological forcing may be an important driver, meaning that the flows are likely to be irregular.

Biota

The wide range of depths, the complex bathymetry and the varied geology of The Gully mean that the area contains a high diversity of habitats, and thus supports a diverse array of species, within a relatively small space. Where the seabed is shallower than about 200 m, however, the ecosystem does not differ greatly from what is seen elsewhere on the eastern Scotian Shelf. If there is enhanced productivity or biomass, that has yet to be detected. In contrast to those shallow areas, The Gully appears to sustain exceptional biomass densities at great depth – the principal indication being a concentration of northern bottlenose whales (*Hyperoodon ampullatus*), which feed at depth but are readily seen when they surface to breathe.

The phytoplankton in the surface waters within the MPA show no notable differences from those over the rest of the eastern Scotian Shelf and its adjacent continental slope. Amongst the zooplankton, there does not appear to be any special concentration of copepods in or over The Gully (Head and Harrison 1996; Head and Pepin 2008), but there can be high densities of krill, including *Meganyctiphanes norvegica* (Sameoto *et al.* 2002), spending their days within the canyon but migrating up to the surface waters above it to feed at night. There are also many pelagic decapods but little indication that they are more abundant within The Gully than outside. The epipelagic fish are primarily the same neritic species as are seen on and over the adjacent banks, but there are also meso- and bathypelagic species which live at depth within the canyon, at least during daylight, though some migrate to the surface for the night. As elsewhere in the world ocean, that deep-living fauna is dominated by the myctophid lanternfishes, which in The Gully (as in much of the rest of the northwest Atlantic north of the shelf / slope front) are predominantly represented by *Benthosema glaciale*. They are abundant in the outer portion of the canyon though, as yet, there is little sign that they are markedly more dense there than outside. There is also a variety of pelagic cephalopods in The Gully but, to date, midwater trawling has failed to take them in large amounts.

The deep-living benthos in the canyon is particularly noted for rich growths of a diverse community of cold-water corals, though on-going research is finding many other forms, from a bivalve previously unknown to science to Xenophyophores – giant protozoans, found in The Gully for the first time only in 2007 (Dr. E. Kenchington, BIO, *pers. comm.*). Current research into this fauna has emphasized video observations, and hence relatively immobile species, but earlier work documented mobile predators, perhaps most notably the stone crab, *Lithodes maia*, which was found to be particularly abundant in The Gully (Perry 1969).

Between the benthos and the pelagic fauna lie the demersal or bentho-pelagic species. In the shallow areas of the MPA, they include the same assortment of groundfish as is seen elsewhere on the Scotian Shelf. There is also a deep-living demersal fauna within the canyon, which includes particularly halibut (*Hippoglossus hippoglossus*) and redfish (*Sebastes fasciatus* and *S. mentella*) but also a variety of other species with depth ranges which span the shelf break. The exclusively deep-dwelling bentho-pelagic fauna within The Gully has been little studied, since the canyon walls cannot readily be fished for active species, aside from those which will take a longline hook. Observations have largely been confined to incidental video records made during studies of the benthos and to the presence of bottom-associated scattering layers seen in acoustic records.

Although The Gully shows a high diversity of habitats and species, it has not been especially remarkable as a productive fishing ground and few of the resource species are concentrated there. None appear to use it as a major spawning ground. Over the years, various fisheries have been active within what is now the Gully MPA but it has only been a noted area for the halibut longline, redfish trawl, swordfish (*Xiphius gladius*) longline and, at one time, pollock (*Pollachius virens*) trawl fisheries (Breeze 2002). Zones 2 and 3 of the MPA remain open to bottom longlining for halibut and pelagic longlining for swordfish, with the former actively exploiting the area.

Those many smaller species notwithstanding, The Gully is most notable for the concentration of cetaceans in the area, which include a wide variety of toothed and baleen species. Most importantly, the near-200 members of the endangered Scotian Shelf population of northern bottlenose whales each spend, on average, around a third their time within the MPA (Gowans *et al.* 2000) – apparently using the area for foraging. Much of their remaining time is divided between Haldeman and Shortland canyons, which cut the slope of Banquereau to the eastward of The Gully, though individual whales may range more widely. Within the MPA, the distribution of the bottlenose whales varies seasonally and inter-annually but they are most often seen over water depths of 1000 to 1500 m, within the canyon but more towards its mouth than its head (Hooker *et al.* 2002a). They dive to depths of 500 to 1500 m to feed, both day and night year-round, and seem to often closely approach the seabed while hunting (Hooker and Baird 1999).

Bottlenose whales are primarily predators of squids and, elsewhere in the North Atlantic, as well as in the Arctic Ocean, they are known to feed largely (sometimes almost exclusively) on the armhook squid, *Gonatus fabricii*. There is evidence that the Scotian Shelf population has much the same specialized diet, though perhaps also including a more southerly armhook species, *G. steenstrupi* (Hooker *et al.* 2001). Hooker *et al.* (2002b) estimated a daily consumption of 12,000 adult *Gonatus* spp. by the bottlenose whales in The Gully and the presence of the actively-feeding cetaceans demonstrates the existence of a high cephalopod biomass at great depth within the canyon. Recent midwater-trawl surveys (e.g. Kenchington *et al.* 2009) have taken *Gonatus* spp. and other mesopelagic squids, though only *Brachioteuthis* spp. have been caught in large numbers and they are vertically migratory – meaning that they cannot be the nocturnal prey of a whale hunting at depth. It is not currently known whether the principal prey of the bottlenose whales is an active squid, capable of evading midwater trawls (which adult male *Gonatus* spp. likely could), or whether it has a bentho-pelagic habit in The Gully and hence lives too close to the canyon walls to be safely caught with trawls.

<u>Potential Energy Pathways Through the Ecosystems of The Gully</u>

While certain signature species of the MPA are of interest of themselves, there is a primary management concern over the integrity of the entire Gully ecosystem or, rather, the interlinked ecosystems on the canyon. That concern necessarily leads to major questions about the degree to which The Gully supports self-contained systems *versus* the extent to which it is dependent on adjacent sea areas and particularly to questions about the source of the energy that powers the ecosystems in the MPA. Large as it is for a canyon, The Gully is a very small piece of the northwest Atlantic, with a correspondingly-high ratio of boundary length to enclosed area, suggesting that fluxes across those boundaries may be more important to the ecosystems within the MPA than are the energy flows within those ecosystems.

Concern over the source of the energy is heightened because Hooker *et al.* (2002b) estimated that sustaining the bottlenose whales within The Gully through local primary productivity alone would require an order of magnitude enhancement in carbon fixation per unit area compared to average levels for the Scotian Slope. Mann (2002) reviewed the evidence for such enhanced primary production in The Gully and found little sign of it. Thus, it appears that the ecosystem supporting the whales, if also not the MPA's other ecosystems, is dependent on a concentration, within the canyon, of energy from allochthonous primary production. If so, the supply of prey to the MPA's signature species, a species which uses The Gully for feeding, is dependent on sea areas that do not enjoy the protections provided within the MPA's boundaries. What remains essentially unknown is the form, or more likely forms, in which the energy enters The Gully and what pathways it then follows to each of the charismatic species of particular management concern, It does, however, seem likely, from the limited observations available, that different components of the ecosystems are primarily supported by different sources through different pathways. The absence of greater understanding of this aspect of The Gully's ecosystems poses a major challenge to monitoring the MPA and, indeed, to its management.

The particular forms in which energy might enter The Gully are little better than matters for speculation, except that there is no reasonable doubt that the ultimate source lies in carbon fixation by phytoplankton. The Gully is too far from the mainland to see the supplementary organic input from terrestrial sources or from shallow-water kelps which have been noted in other canyons. Otherwise, all that can be offered here is an indication of the scope and scale of the current uncertainty.

Mann (2002) suggested that phytoplankton produced across the adjacent banks might tend to settle out over The Gully, where there is less tidal mixing, though the absence of any apparent enhancement of herbivorous zooplankton suggests that the mechanism may not be a major one. Alternatively, there may be a substantial flux of detrital organic matter off the Scotian Shelf and through the canyon, probably as a near-bottom downslope movement (Harding 1998). That could provide food for many filter- and deposit-feeding benthic species, including the cold-water corals, which in turn would support demersal fish and cephalopods, as well as benthic predators – but perhaps not the normally-oceanic *Gonatus fabricii*.

Secondary production on the eastern Scotian Shelf is dominated by large copepods, particularly *Calanus finmarchicus*. After feeding in the euphotic zone in spring and summer, *Calanus* copepodites migrate downwards to overwinter at depth. In fall and early winter, they can be found in the deep basins of the shelf but also along the Scotian Slope, typically with their maximum concentrations at 400–600 m (Head and Pepin 2008). The location and large size of The Gully, and particularly the extent of The Trough, suggest that it should collect the downward-migrating copepods from much of the eastern Scotian Shelf, which would constitute an enormous seasonal supply of organic material to the Gully ecosystem. Densities of *Calanus* spp. within the canyon and immediately outside its mouth in the fall are, however, unexceptional (Head and Harrison 1996; Head and Pepin 2008), which casts doubt on the importance of the mechanism – unless the migrating copepodites are swiftly consumed by predators taking advantage of some local enhancement of ecological efficiency. The principal consumer of *Calanus* spp. in The Gully is presumably *Meganyctiphanes norvegic*a, which is sometimes very abundant. *M. norvegic*a also undertakes seasonal migrations and it is possible that a movement of krill into The Gully, rather than or in addition to a movement of their prey, provides a major net energy flux into the canyon.

An apparently-persistent feature of the Gully ecosystem is a concentration of the myctophid lanternfish *Benthosema glaciale* near the mouth of the canyon and perhaps particularly around the “Southwest Prong” of Banquereau (Sameoto *et al.* 2002; Kenchington *et al.* 2009). If the lanternfish are able to utilize the complex flows at the mouth of the canyon to maintain their position relative to the seabed with little expenditure of energy, they may be able to crop much of the zooplankton production of the continental slope off Banquereau, as it is carried into the canyon by the shelf-break current – potentially a very substantial concentration of allochthonous energy. Alternatively, the diel migrations of *B. glaciale* and *Meganyctiphanes norvegica* within the canyon may allow them to exploit neritic production at night, as zooplankton drift off both Banquereau and Sable Island Bank, with the predators carrying the energy down to depth at dawn. It is certain that both *B. glaciale* and *M. norvegica* are able to maintain their position above the canyon while swimming in surface waters, which their plankton prey presumably cannot do.

Each of these mechanisms may be supplemented by local enhancements of ecological efficiency. *Meganyctiphanes norvegica*, for example, is known to swarm when in swift and variable water flows, such as those which appear to be shaped by the bathymetry of the canyon. The resulting behaviour likely makes the krill much more readily available to baleen whales and maybe other predators, thus enhancing the predator biomass that can be supported by a given amount of production at lower trophic levels.

However, none of those mechanisms seems able to explain the feeding of the bottlenose whales. While their squid prey may escape midwater trawls, it is unlikely that the food of the cephalopods does so. Meanwhile, the continued diel and nocturnal feeding of the whales at great depth implies that the squid on which they feed do not undertake vertical feeding migrations of their own. Yet, the recent midwater trawl surveys in The Gully have caught little biomass below 750 m depth and certainly insufficient to support the bottlenose whales. Hooker *et al.* (2002b) suggested a possible solution to that conundrum, hypothesizing that that female *Gonatus fabricii* may migrate into the canyon to brood their eggs. Since they do not feed while brooding (Arkhipkin and Bjørke 1999), that would imply that the entire prey source of the bottlenose whales is external to The Gully and that the energy enters the canyon in the form of migrating squid. One very recent survey has taken spent female *G. fabricii* within the MPA, confirming that brooding and larval release does occur there, though the numbers caught were small. Since brooding females are almost non-motile (Arkhipkin and Bjørke 1999) and yet to date none have been caught in The Gully despite the extensive trawl surveys conducted in recent years, if Hooker *et al.*'s (2002b) hypothesis is correct, the females must live in close proximity to the canyon walls, where they would be invulnerable to trawling.

These various mechanisms remain, at best, mere hypotheses. They serve to illustrate, however, how fundamentally and massively unknown the Gully ecosystems remain – as the physical oceanography of the area illustrates how temporally variable those systems are. The Gully MPA must be monitored despite that variability and uncertainty and hence the monitoring program must be designed to cope with both.

PERCEIVED THREATS TO THE GULLY ECOSYSTEM

The threats to the Gully ecosystem, both actual and potential, that are currently perceived include, not necessarily in priority sequence:

1) Extractive use of fish and invertebrate populations by:
    a) Commercial fisheries, and
    b) Research and monitoring,
2) Disturbance of corals and of seabed habitats by:
    a) Commercial bottom fisheries,
    b) Research and monitoring sampling on the seabed,
    c) Deployment on the seabed of other research and monitoring equipment,
    d) Laying of telecommunications cables, and
    e) Natural turbidity currents flowing down the canyon,
3) Entanglement of whales and other animals by:
    a) Commercial fishing gear, particularly longlines, and
    b) Research and monitoring gear,
4) Development of the petroleum reserves at the Primrose significant discovery, resulting in:
    a) Seabed disturbance,
    b) Release of contaminants, including but not limited to drill muds, cuttings and produced water,
    c) Local seismic surveys, and
    d) Increased vessel and aircraft traffic,
5) Vessel traffic both in and near the MPA by:
    a) Research and monitoring vessels,
    b) Surface naval vessels,
    c) Submarines,
    d) Other government vessels,
    e) Commercial fishing vessels,
    f) Ecotourism vessels, and
    g) Other mercantile vessels, particularly large cargo ships,

    The traffic resulting in:
    a) Whale strikes,

   b) Emitted sound (primarily engine noise and sonar emissions), with effects on whales and other animals,
   c) Release of contaminants, and
   d) Release of invasive species during ballast-water exchange,

   though not all vessel types pose all forms of risk,
6) Aircraft noise,
7) Retention and concentration of contaminants from outside the MPA boundary, including:
   a) Non-point source contaminants, and
   b) Point source contaminants, particularly from petroleum exploration and development,
8) Sound emitted by seismic surveys outside the MPA boundary, if any enters the area at biologically-significant intensities, and
9) Changes in the oceanographic climate of the northwest Atlantic, whether driven by anthropogenic global climate change or otherwise.

SPECIAL CHALLENGES CONFRONTING MONITORING OF THE GULLY MPA

Monitoring of The Gully faces four particular challenges not seen with most other MPAs. The first, the very broad and generalized goals and regulations set for The Gully, have already been noted. They greatly complicate effectiveness and regulatory monitoring respectively.

Secondly, The Gully's offshore location means that almost all monitoring requires specialized and expensive platforms – usually large research ships, which primarily means DFO vessels. Given the scarcity of such ships, once existing routine monitoring requirements have been addressed, and the high costs of deploying a vessel for a single, specialized mission, it will be necessary to mount Gully monitoring tasks on cruises designed for other purposes whenever possible and, indeed, to utilize existing monitoring programs whenever their data streams can provide information relevant to management of the Gully MPA. There are specialized exceptions to this requirement for research ships, such as photography-based whale surveys (which require a lower height of the observer's eye than is practical on a ship and thus need either an ocean-capable yacht or a large inshore fishing boat) but the operation of smaller vessels far from shore poses substantial safety concerns. Only a few aspects of monitoring in the Gully MPA can avoid these requirements for watercraft, notably those which can be provided through satellite systems (e.g. sea surface temperatures) or using instruments located on Sable Island (e.g. meteorological variables). Very little of the required monitoring can be conducted by local stakeholder interests, in contrast to what may be expected with inshore MPAs, the sole exceptions being industry-based surveys for some fishery resources, notably longline surveys.

The third special challenge is the great depth of water, generally coupled to very steep seabed slopes, in those parts of the MPA that are of the greatest conservation concern. The shallow bank areas of the MPA's Zone 3 are amenable to sampling with well-proven, affordable, conventional gears. However, the most highly valued components of the Gully ecosystem (including the bottlenose whales, the deepwater corals, the halibut and the lanternfish) live in Zones 1 and 2, where sampling on or near the seabed is a more daunting prospect. Some of the tasks facing a monitoring program are merely expensive, such as laying deepwater oceanographic moorings, but others require cutting-edge technology, such as remote and autonomous underwater vehicles with depth capabilities to 2,000 m or more – technology that is, as yet, barely suited to routine deployments.

Finally, the current lack of understanding of the structure and function of the Gully ecosystem, which has been stressed above, prevents the identification of key pathways or components that could be selected as efficient monitoring indicators. Hence, for the next number of years, truly effective monitoring this MPA would require an impractically-expensive broad-brush approach. It is not recommended that the available research-vessel and scientific resources be squandered on a hopeless attempt at such monitoring. Rather, those resources would be better utilized on characterization studies that promise to yield the knowledge needed to later identify the key pathways, while confining routine monitoring in the short and medium terms to only the most cost-effective extensions of existing programs.

A different form of challenge will arise within the MPA's management system: while some aspects of The Gully can be monitored by non-invasive or minimally-invasive methods, much requires approaches which raise the spectre of harming the ecosystem or the charismatic species that are being monitored and that the MPA itself is designed to protect. All of the monitoring, save those parts that can be done by remote sensing or from remote sites, will require Ministerial approval and hence formal review through the MPA's management system – a system that is necessarily oriented towards protection rather than understanding. It would not, of course, be wise to expose the Gully ecosystems to unlimited sampling, in the name of intense monitoring, but neither would it be sensible to frustrate necessary monitoring activities through an on-going paperwork burden by requiring annual approvals for routine tasks. Such a challenge would pit the scientists doing the monitoring against their client group, the MPA managers, for whom the service is provided and thus would swiftly lead to withdrawal of scientific support and the end of effective monitoring. Rather, the monitoring plan as a whole (including its baseline characterization studies) should be assessed for its impacts on The Gully and, following any required amendments, long-term permitting of routine tasks should be provided, subject to on-going review.

DESIGNING AN MPA MONITORING PROGRAM FOR THE GULLY

In conclusion, while theoretical concepts and suggested approaches for the ideal monitoring of marine protected areas can provide valuable guidance in the design of particular monitoring programs, as they have done in the present case, all that can reasonably be attempted in the Gully MPA in the immediate future is monitoring of the principal objectives and threats. The constraints imposed by limited monitoring resources, particularly the availability of research-ship time, demand a pragmatic approach, focused on key indicators, using the simplest available methodology and utilizing existing deployments of ships wherever possible.

While the monitoring program should be built around such knowledge of the Gully ecosystem as exists, current ignorance of even the basic structure of that system will limit monitoring (out to the present planning horizons) to rather basic indicators. There should, however, be a strong emphasis during the remainder of the current funding cycle (fiscal 2010 and 2011) and indeed for the five years beyond (fiscal 2012 to 2016) on baseline monitoring to develop the foundations of understanding on which more effective, and more efficient, monitoring can be built in the future. That should include research to better characterize the system, analysis of existing data (where available) to establish quantitative baselines, and intensive monitoring to gather such required baseline data as do not currently exist. Aspects of the recommended monitoring plan thus resemble a list of research priorities, as a direct consequence of the current limited understanding of the ecosystem in the MPA.

The recommendations presented below were developed in light of these conclusions. The indicators were selected to ensure that the goals, objectives and priorities of the *Oceans Act* and those of the *Management Plan* were fully addressed. The selection process began with multiple lists of points of focus: MPA goals and objectives, valued components of the Gully ecosystems, identified conservation issues, threats and forcing variables, existing monitoring baselines, and monitoring programs that could be extended to cover the needs of MPA management with relatively low incremental costs. Review of those lists led to an initial set of indicators, which was then refined. Throughout, three guiding principles were followed. They were that, in so far as is practical, the monitoring should be:

- Non-invasive, not causing harm or disruption to the Gully ecosystem,
- Cost-efficient, maximizing the information gained while minimizing costs to Canadian taxpayers, and
- Fully integrated into regional, national and international monitoring programs, while also meeting the specific needs of Gully MPA management.

THE RECOMMENDED MONITORING PLAN

INTRODUCTION

The aim of this recommended monitoring plan is to provide the information necessary for effective and adaptive management of the Gully MPA, through a monitoring program integral to that management. This plan should also serve to coordinate monitoring of the Gully MPA with the Department's regional, zonal and national monitoring programs, such that the MPA monitoring both utilizes the on-going work and contributes to the wider programs.

In any such program, continuity of the monitoring, including the details of the methodology employed, is essential so that trends over time can be detected without confusion caused by artifacts in the data. Scrupulous attention to standardization of protocols is essential so that the results are comparable over time, despite staff turnover, changing research interests and evolving Departmental priorities. However, while some elements of the monitoring program are already well established and will continue into the indefinite future, others require at least methodological refinement and some cannot be fully implemented without extensive baseline characterization of the Gully ecosystem. Hence, the monitoring plan must evolve over time. The present document addresses primarily the next steps in that process, through the remainder of the current HOTO funding cycle, which is to say fiscal 2010 and 2011.

This recommended plan includes an annual Gully Monitoring Workshop to receive and review the monitoring results. The 2011 meeting should be expanded to include an update of the monitoring plan to cover the 2012 to 2016 period.

MONITORING STRATEGY

To achieve acceptable cost-effectiveness, this recommended program is composed of a set of "component programs", most of them based around a single platform and several utilizing existing routine deployments – such as Atlantic Zonal Monitoring Program ("AZMP") monitoring cruises or summer groundfish surveys. Where new deployments are unavoidable, whenever possible they have been chosen as extensions of existing programs, the better to utilize expertise within the Department and to facilitate the combination of Gully data with wider datasets from the eastern Scotian Shelf.

ECOSYSTEM MONITORING INDICATORS

List of Indicators

The recommended monitoring indicators could be listed following many alternative sequences, such as the mode of their monitoring or the MPA *Management Plan* objectives that they primarily relate to. For convenience and clarity, they are here arranged as effects and threat indicators, with the former subdivided by the ecosystem components being monitored.

Tables are provided at the end of this document which illustrate the concordance between these indicators and each of: the objectives of the MPA, the perceived threats to the MPA and the various types of monitoring discussed above.

Effects Indicators

Cetaceans

1. Abundance of the Scotian Shelf population of northern bottlenose whales (including all members of the population, whether in The Gully or not),
2. Use of the Gully MPA by bottlenose whales, measured as the percentage of the Scotian Shelf population within the Gully MPA,
3. Size, age and sex structure of the Scotian Shelf bottlenose population,
4. Percentage of individuals in the Scotian Shelf bottlenose population showing fresh scars,
5. Genetic diversity within the Scotian Shelf bottlenose population,
6. Levels of contaminants in the blubber of individuals in the Scotian Shelf bottlenose population,
7. Relative abundances of cetaceans (other than northern bottlenose whales) in the Gully MPA,
8. Cetacean presence and activity in the MPA, year-round,
9. Number of reported strandings of Scotian Shelf bottlenose whales,
10. Number of reported ship strikes on cetaceans in or near the Gully and of strikes on Scotian Shelf bottlenose whales elsewhere,
11. Number of reported gear entanglements of cetaceans in or near the Gully and of entanglements of Scotian Shelf bottlenose whales elsewhere,
12. Number of reports of other interactions between human activities and cetaceans in or near the Gully and of interactions with Scotian Shelf bottlenose whales elsewhere,

Corals[2] and Benthic Habitats: (See also Indicator 35)

13. Coral distribution, density and size structure by species at selected monitoring sites within the MPA,
14. Coral diversity at selected monitoring sites within the MPA,
15. Proportions of live and dead corals, by species, at selected monitoring sites within the MPA,
16. Proportion of live corals at selected monitoring sites within the MPA that show zooanthid over-growths and the extent of over-growth in any affected colonies,

Fish and Fishery Resources

17. Relative abundances, size distributions and diversity of selected groundfish and trawl-vulnerable invertebrates in Zone 3 of the MPA,
18. Relative abundances, size distributions and diversity of selected longline-vulnerable species in Zones 2 and 3 of the MPA,
19. Relative abundances, size distributions and diversity of selected trap-vulnerable species in Zones 1 and 2 of the MPA,

[2] For the purpose of interpreting these indicators "coral" should be taken as including all of gorgonians, scleractinians (both solitary and colonial) and sea pens. Alcyonacean soft corals are not included and neither are the antipatharians.

20. Relative abundances, size distributions and diversity of selected mesopelagic nektonic species in Zones 1 and 2 of the MPA,

Physical, Chemical and Biological Environment

21. Temperature, salinity, oxygen concentration, alkalinity, pH, light levels, chlorophyll, pigments and nutrients in the watercolumn within the MPA, including in close proximity to the seabed,
22. Temperature, salinity, oxygen concentration, light levels, chlorophyll, pigments and nutrients in waters flowing into and past the MPA, as measured on the Louisbourg Line, the Halifax Line and the Extended Halifax Line,
23. Physical (temperature, salinity, wind, sea-surface height) and biological (ocean colour) sea surface properties in the MPA and the surrounding region,
24. Weather conditions at the Sable Island weather station and at the Banquereau and Laurentian Fan weather-buoy sites, including wind direction and speed, air pressure and sea-level air temperatures, plus for the buoy sites sea surface temperatures, wave height and dominant wave period,
25. Three-dimensional distribution and movements of watermasses within and around the MPA,
26. Phytoplankton production, community composition and the timing of the spring bloom in the MPA and the surrounding region,
27. Zooplankton biomass, community composition and the biomass of selected species within the MPA,
28. Acoustic scattering in the watercolumn within the MPA,
29. Distribution and abundance of seabird species within the MPA,

Threat Indicators

30. Number of transits of the MPA by vessels other than pleasure craft, broken down into mercantile vessels, surface naval vessels and fishing vessels not fishing in the area,
31. 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, and ecotourism vessels,
32. Commercial fishing effort within the MPA,
33. Commercial fishing effort in close proximity to the MPA boundary,
34. Suspected and confirmed unauthorized fishing activity within or in close proximity to the MPA,
35. Quantities of corals removed from or discarded within the MPA by commercial fishing activities and by research activities,
36. Quantities of target organisms removed from or discarded within the MPA and of bycatch organisms (other than corals) removed from the MPA by commercial fishing,
37. Quantities of organisms (other than corals) removed from or discarded within the MPA by research activities,
38. Seabed area swept by bottom-tending mobile research and monitoring gear within the MPA, both as a total and subdivided by seabed habitat type,
39. Length of lines of, and seabed area occupied by, bottom-set fixed commercial fishing and research and monitoring gears set within the MPA, both as totals and subdivided by seabed habitat type,
40. Number and types of offshore-petroleum exploration and development activities on the eastern Scotian Shelf,
41. Number, quantities and type of discharges from offshore-petroleum installations and activities on the eastern Scotian Shelf,

42. Number of ships' ballast-water exchanges in the proximity of the MPA and the quantities of ballast exchanged,
43. Number, quantities and type of other discharges from shipping within or in proximity to the MPA,
44. Quantity of floating debris (i.e. large objects) in the Gully MPA,
45. Quantity of anthropogenic debris on the seabed at selected monitoring sites in the Gully MPA,
46. Reports of known invasive species in the Gully MPA, and
47. Quantitative characteristics of anthropogenic sound within the MPA.

Rationales for Indicators

Indicators 1, 2, 3: Northern bottlenose whales are the prime signature species of the MPA and their population was specifically mentioned at the MPA's declaration. Confirming that their numbers are maintained and that the population retains a sustainable mix of sexes and ages is central to this monitoring program – though monitoring alone cannot demonstrate the contribution of the MPA to the maintenance of the population. (It is the purpose of monitoring to show that the whale population has been successfully protected, not to show that declaration and management of the MPA has provided that protection.) Fortunately, there is an established, effective and affordable protocol for determining the required information. It can provide direct and cost-effective information on the status of the Scotian Shelf population. The alternative of monitoring the condition of the whales' habitat within The Gully would be considerably more expensive (not least because of a requirement for larger research vessels) and highly uncertain, not to say problematic, given current ignorance of what features of the canyon are important to the whales.

The Scotian Shelf population is not confined to The Gully, however. Limiting the surveys to those individuals present within the MPA at any one time would introduce "noise" into the data stream, with various proportions of the animals being elsewhere. Hence, the surveys should be extended beyond The Gully, to incorporate at least Shortland and Haldeman canyons, in order to better characterize trends in the population. Monitoring of Indicator 1 across the entire population is also required by the *Recovery Strategy for the Northern Bottlenose Whale*. The same survey program should be used to fulfil both monitoring requirements and hence a population-wide indicator is recommended here.

Indicator 4: Once a cetacean survey is deployed to The Gully, there is negligible additional cost in recording observations of injuries to individual bottlenose whales, while the indicator provides useful information for understanding trends in the threats to the whales. Gathering those data is already a part of the existing survey protocol.

Indicators 5, 6: While much of the required monitoring information on bottlenose whales can be obtained by visual observations alone, understanding of the conservation status of the population will be greatly enhanced by monitoring of intra-population genetic diversity – even though it requires non-lethal invasive sampling of individual animals. Meanwhile, former studies (Yeats *et al.* 2008) have indicated a worrying increase in concentrations of organic contaminants in the blubber of the whales. The continuing trend should be monitored. The same physical samples can be used for monitoring the two indicators.

Monitoring of Indicator 6 is also required by the *Recovery Strategy for the Northern Bottlenose Whale*. The same biopsy-sampling program should be used to fulfil both monitoring requirements.

Indicator 7: Besides the northern bottlenose whale, other cetacean species in the MPA are of concern to management and are identified as such in the *Management Plan*. They are not partially-resident in the canyon, as the bottlenose is, and population-wide estimates of abundance cannot be determined from surveys conducted there, but relative abundances can be effectively tracked by observations made aboard cetacean surveys deployed for monitoring the bottlenose whales.

Indicator 8: While much can be learnt about cetaceans in The Gully from surveys, those are necessarily limited in temporal extent, are confined to the summer by the need to use small vessels that allow for observers with low height of eye, and can do little at night, in fog or in heavy weather. They are also largely limited to observing the whales while at the surface. In contrast, long-term and potentially year-round monitoring of some aspects of cetacean distributions and behaviours, particularly the hunting activities of the toothed whales, can be provided by deploying passive acoustic recorders on the seabed – albeit at significant cost. Such monitoring would provide a very valuable complement to the cetacean surveys and both are recommended.

Indicators 9, 10, 11, 12: Reports of cetacean strandings, ship strikes, gear entanglements or other interactions with humans in The Gully or, for Scotian shelf bottlenose whales only, elsewhere are unlikely to be made, either because the events themselves are highly improbable (strandings of bottlenose whales excepted), because they are unlikely to be recognized if they occur and/or because it is not in the interests of potential observers to report what is seen. However, should reports reach the Department but not the MPA managers, the consequences could prove embarrassing, while opportunities for enhanced management would be lost. Since arrangements for data sharing can be developed at negligible cost, they should be and any reports received should enter the MPA monitoring archive.

Indicators 13, 14: Following the bottlenose whales, deepwater corals are signature species of the MPA and are specifically mentioned in the MPA's *Monitoring Plan*. Such corals were also recognized as prime examples of "Vulnerable Marine Ecosystems" by the U.N. General Assembly in 2006 and are regarded as "structural habitat features" under Canada's 2009 *Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas*. Ensuring that they are effectively conserved is a key responsibility for this monitoring program. However, the very high cost of deploying near-seabed sensors within the canyon to the depths where the corals occur severely constrains options for their monitoring. Hence, they can only be effectively and directly monitored at specific, selected sites. Once a suitable vehicle is deployed, video observations can efficiently provide information on distributions, densities and diversity.

Unlike the bottlenose whales, individuals of which species move between The Gully and other canyons, the corals are sedentary after their larval stages. Thus, while monitoring of deepwater corals elsewhere in Canadian waters may be necessary for other management purposes, it need not be incorporated into this MPA monitoring plan. That exclusion may have to be modified if recruitment of new coral colonies within The Gully should, in future, be shown to be dependent on spawning elsewhere.

Various MPA management documents distinguish seapens from "corals". Biologically, seapens are one form of corals and these indicators (as also Indicators 15 and 16) are intended to be inclusive of all coldwater corals (including all gorgonians, scleractinians and sea pens) in The Gully, except for the alcyonacean soft corals and the antipatharian precious corals. The Alcyonacea cannot be identified to species in video records, while they are abundant and their colonies are shorter-lived than those of members of the other groups – and hence not vulnerable to the same range of threats. In contrast, the Antipatharia are too scarce in the Gully for effective quantitative monitoring.

Indicator 15: Most threats to the corals cannot be efficiently monitored by direct observations. However, the cumulative consequences of all threats can be monitored, from the video records of the coral surveys, at a gross level by observing the proportions of live and dead material – the difference being readily perceived and yet the skeletal material being persistent over long periods. This indicator can only represent a relative index, not a quantitative measure of mortality rates. As such, it does not require knowledge of the various breakdown rates of dead coral of different species.

Indicator 16: The only biotic threat to the corals yet observed is their over-growth by zooanthids, which have been seen to be killing corals in the Northeast Channel (between Georges and Browns banks). That too can be readily monitored using video records.

Indicators 17, 18: The goals and objectives for the MPA make mention of the diversity of demersal fish species and particularly name halibut. Monitoring of such fish is highly influenced by the selective characteristics of the survey gear, with the least-selective instruments, otter trawls, giving the best representation of diversity. The use of bottom trawls within Zones 1 and 2 of the MPA would, however, be problematic for technical reasons resulting from the rugged bathymetry. It would also pose unacceptable risks to the benthos and benthic habitats that the MPA is intended to protect. Longlines offer an alternative gear particularly well suited to surveys of halibut (which are poorly monitored by otter trawls). Longlines are, however, highly selective for certain species, while they still pose substantial risks to coral colonies if deployed in certain portions of The Gully.

Individual halibut are highly mobile and their partial protection within the area of the (relatively small) Gully MPA, much of which is open to commercial fishing for the species, is not expected to affect either the overall size of the resource or even their abundance within The Gully, either materially or measurably. That abundance nevertheless remains important to the ecosystem within the MPA, even though it is not influenced by the MPA, and it should be monitored for that reason. A longline survey would also serve to track other species taken on such gear, notably hake, cusk and skates – including a number of species which are or may be at risk.

Hence, it is recommended that groundfish within the MPA be monitored using extensions of two existing survey programs: The summer research-vessel trawl survey for a mix of species, even though that gear must be restricted to selected portions of Zone 3, and the industry-based collaborative longline survey, primarily for halibut, which can be extended into Zone 2. The risks to the MPA's conservation goals that would be inherent in routine surveys of demersal fish in Zone 1 are considered unacceptable.

While these surveys are primarily designed, respectively, for a mix of groundfish and for halibut, it is now standard practice to record the entire catch and that should be continued in the MPA, thus providing some monitoring of other fish species and of the epibenthos. If the indicators were to include all species taken, however, managers would be overwhelmed by a welter of information, much of which would confound random variations in the survey data with real trends in abundance. Hence, it is recommended that these indicators, along with Indicators 19 and 20, be focused on selected species – the selection to be made after analysis of baseline data. It would be desirable to monitor species that would be sensitive to change in the MPA, though it is likely that the selection will fall primarily on species showing relatively low variances in the survey data.

Although the formal indicators thus focus on selected species, it is intended that data on the full suite of species taken in the surveys should be examined and that any emerging trends in non-selected species should be brought to the attention of MPA managers.

These two indicators, along with Indicators 19 and 20, require monitoring of abundances and calculation of diversity indices from those abundance data. However, they also call for monitoring of size distributions of the selected species, which can often prove to be more sensitive to environmental change than are either abundance or diversity. While the field collection of survey data must follow standardized protocols, both the diversity indices and the indices of individual sizes can evolve over time, with improved methods being applied to the archived data. Thus, no attempt is made here to suggest which indices should be used.

Indicator 19: The trawl and longline surveys, even in combination and despite the addition of information from the video surveys of corals, would leave an absence of information on mobile epibenthos, notably deepwater crabs, in Zones 1 and 2 of the MPA. Relevant data could be gathered at reasonable cost and without unacceptable impacts on the seabed through a trap survey, organized on the lines of past industry-based collaborative surveys of the continental slope that have been conducted primarily for snow crab.

Traps, and indeed longlines, have greater limitations as survey gears than do trawls. All three are selective sampling devices, as are all other fishing gears, with the selectivities varying not only among species and sizes of animals but also with environmental conditions and the details of gear design and deployment. Hence, each instrument gives a biased picture of the biota in the surveyed area – at best, indices of relative abundance, not estimates of absolute abundances. Even then, the picture generated by any one gear can only be trusted to be consistent over time if the sampling is rigorously standardized. Catches by fixed gears are, however, relatively more dependent on the behaviour of the animals, whereas trawl catches are depend more on the ways that the gears are used. Hence, the standardization of trawl-survey protocols is somewhat more within human control. Since traps are particularly dependent on the willingness of animals to trap themselves, the resulting data are especially vulnerable to inconsistencies driven by, for example, changes in water temperatures or the availability of natural foods. Moreover, trap catches appear even more vulnerable to the problems of "hyperstability" (a tendency for the catch per unit effort to remain steady as the abundance of the animals around the gear changes) than are those of other fishing gears, due to the effects of crowding within traps on the willingness of additional animals to enter.

Notwithstanding all of these deficiencies, a trap survey is recommended as the only way to monitor certain of the species in The Gully which live in areas where bottom trawling would be unacceptable and which are either invulnerable to longlines or else live in areas where even longlining would pose an unacceptable threat to the benthos – the deepwater crabs being the prime species of concern. It is expected that those crabs are important top predators in the benthic ecosystem and the opportunity to monitor them, even with imperfect gear, is considered valuable to understanding broader trends in the MPA.

Indicator 20: The MPA's *Management Plan* makes specific reference to the myctophid lanternfishes, which comprise most of the biomass of pelagic nekton within and over the canyon – and may, in consequence, be a key intermediary in passing energy down to the squids on which the bottlenose whales feed. Monitoring the myctophids will require a dedicated program as it cannot be effectively added to any existing survey series, nor by expansion of any such series, but the same sampling can provide for monitoring of the micronekton, notably the abundant krill. Hence, this one indicator will provide for extensive monitoring of the pelagic ecosystem in the MPA, including what are supposed to be key energy pathways.

Indicators 21, 22: As an offshore MPA, environmental conditions within The Gully are very largely determined by the characteristics of the water that floods the area and those must be monitored. Current AZMP protocols emphasize standard oceanographic variables (temperature, salinity, oxygen concentration) and biological ones (light levels, chlorophyll, plus plant pigments to identify the composition of the community and plant nutrients). While the AZMP monitors broadly and the knowledge so gained should be used to inform MPA management, existing data from the Louisbourg Line of stations provides a solid baseline of information on the waters up-current of The Gully, as the Halifax Line and the Extended Halifax Line do down-current. Future data from those lines can serve in monitoring the characteristics of water masses and flow along the Shelf edge, though it would be advantageous to also extend the Louisbourg Line to the 3,000 m isobath, beyond the shelf break which it now reaches, in order to better characterize the waters up-current from the mouth of The Gully.

The AZMP has long worked one station in the head of The Gully and has recently added four at its mouth. Expanded coverage of the MPA will provide details of trends inside the canyon. Moreover, given the expectation of ocean acidification associated with global warming and the possible consequences for the corals in the MPA, it is desirable that The Gully become a prime point for monitoring acidity in subsurface waters of the northwest Atlantic. That is best monitored by measuring both alkalinity and pH.

Understanding the benthic ecosystems in The Gully, including the charismatic corals, requires measurements within metres the seabed, particularly of oxygen concentrations but also of alkalinity, pH, nutrients and perhaps the other monitored variables. Those measurements would be in addition to ones taken at the same depths beneath the surface but further from the canyon walls or further down the thalweg, where seabed depths are greater. It may not, however, be possible to use conventional CTD casts in such close proximity to the bottom, when faced with the challenges of a drifting ship, variable currents at depth and steep bathymetry. Thus, this near-seabed monitoring may require deployment of moored, near-bottom sensors, in proximity to but outside concentrations of corals.

As recommended here, each of these indicators calls for data on a suite of directly-measurable variables. It is expected that, as existing baseline data are analyzed, there will be some refinement of these indicators (e.g. focusing on temperatures at certain stations), much development of optimal ways of presenting the data (e.g. anomaly plots for those variables which prove informative) and perhaps the generation of new indices of oceanographic conditions which draw on information from multiple variables. What requires standardization, however, and all that can be recommended pending analysis, is the data collection as defined by the indicators.

Indicator 23: The surface waters over The Gully are continuous with those outside the MPA's boundaries and are in continual motion. Understanding events in that layer of the water column requires frequent, synoptic, regional-scale monitoring which can only be provided by satellite. Fortunately, the data are freely available and are already routinely archived at the Bedford Institute of Oceanography ("BIO"). The range of data collected is changing over time and generally increasing. This indicator is therefore explicitly intended to allow development of new information products utilizing the data that may be available at any given time.

Indicator 24: While the physical oceanography of The Gully remains poorly understood, there are reasons to suspect that the deeper waters within the canyon undergo major movements, with meterological forcing being one primary driver. Extensive databases are required, first for baseline studies linking measured water movements to weather patterns and, potentially, to subsequently allow routine monitoring of the water displacements through observations of the meterological conditions which drive them. More immediately, weather conditions and sea state will affect the monitoring of many other variables. Access to meteorological data will therefore be needed during the analysis and interpretation phases of this monitoring plan.

A long and detailed series of observations are available from the Sable Island weather station, located fortuitously close to The Gully, while shorter supplementary datasets are available from nearby weather buoys – the latter adding information on sea state. All of those data are readily available and can be incorporated into the Gully monitoring archive at negligible cost.

Indicator 25: While Indicators 21, 22 and 23 focus on directly-measurable variables, there will be value in also providing MPA managers with interpreted summaries of the physical-oceanographic information, which summaries should be more biologically-meaningful and more readily comprehensible by non-specialists than either raw data or even anomaly plots would be. A variety of such summaries may be developed over time but, at present, it is only recommended that the temperature and salinity data be used to determine the distribution of watermasses within the canyon, while water movements should be inferred from steric heights (determined from temperature and salinity measurements) and data on meteorological forcing – though the latter will require prior baseline research.

Deployments of current meters in The Gully will likely be needed during baseline characterization studies but no requirement for on-going deployments during routine trend monitoring is foreseen at this time.

Indicator 26: Phytoplankton production is the sole source of energy for the Gully ecosystem, though production within the MPA's boundaries may be only a minor contributor to the energy flows through higher trophic levels in the canyon. It would be very valuable to monitor the magnitude of the production, even though it is not yet possible to determine the spatial extent of the phytoplankton that contribute energy to the MPA and further refinement of the indicator must await additional baseline research. To date, there is no affordable way to undertake that monitoring but means to calculate production from satellite data on ocean colour are being developed. Once they are ready, those data should be routinely interpreted in production terms.

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 form 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. Measurement 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.

Indicator 27: While the structure of the Gully ecosystem remains very poorly understood, the zooplankton are likely to form an important pathway for energy between primary producers and at least some species in the higher trophic levels. Zooplankton monitoring is thus important but it is also expensive, since for practical purposes it is confined to net sampling from research vessels, with much labour-intensive sorting of the catches.

Overall zooplankton biomass would only provide a very crude indication of trends in the ecosystems and information on the composition of the community is essential. Specific attention to some key species is recommended. For example, *Calanus finmarchicus*, and to a lesser extent *C. hyperborea*, are the principal herbivores on the eastern Scotian Shelf, may play a key role in The Gully and would merit monitoring. A different set of species can be expected to respond swiftly to increasing acidification, which is thought to be one of the larger threats to the Gully ecosystems, and thus also deserve close attention. Those would include terapod molluscs and foraminiferans.

As with the phytoplankton, it would be desirable to monitor the timing of the spring zooplankton bloom, which has major implications for year-class strengths in fishery resource species and likely in many non-resource species also. However, it is neither practical to station a research ship in The Gully for a long period each spring nor to monitor zooplankton remotely. Hence, routine monitoring of zooplankton blooms is not recommended at this time.

<u>Indicator 28</u>: Net sampling of zooplankton provides one image of animal life in the watercolumn, as trawl sampling of the nekton provides another. A complementary picture can be obtained at low incremental costs by running acoustic transects when appropriately-equipped research ships are in the area, though what would be monitored would be acoustic scattering rather than the animals themselves. Relevant data products would need to be developed, based on interpretations of the acoustic data and supporting baseline studies.

It is known from prior research that the pelagic community within The Gully is very highly spatially structured and hence meaningful monitoring would require that the acoustic data are collected on standard transects, rather than simply while ships are in transit from one sampling station to another.

At higher cost, ship-borne acoustic systems might usefully be supplemented by upward-looking, seabed-deployed systems, which could monitor fixed stations over long periods – potentially year-round.

<u>Indicator 29</u>: The Gully is an important area for marine birds throughout the year, being a summer feeding ground for breeding storm petrels and gulls, a staging ground for migrants and an over-wintering area for a variety of species – including the Southern Hemisphere shearwaters which “winter” there during the northern summer. The birds consume a variety of small fish, squid and larger plankton, including vertically-migrant myctophids and krill when they are near the surface at night. Hence, avian predation may be important to the trophic structure of the Gully ecosystems.

Zonal information on seabirds is currently gathered through the Canadian Wildlife Service’s Eastern Canada Seabird at Sea program, which uses observers deployed aboard ships of opportunity. Data are regularly gathered in The Gully, primarily by observers aboard AZMP cruises though also by those on other deployed research vessels. Thus, measures of seabird abundances in the MPA can be developed at low incremental cost.

<u>Indicators 30, 31</u>: Vessel strikes are a significant source of mortality in cetaceans. Also, in an offshore MPA, vessels of various kinds are almost the only means by which there can be a direct human presence in the area, with accompanying potential for assorted impacts on the ecosystem – not least the generation of anthropogenic noise. Large vessels transiting the area can be conveniently monitored using existing Automatic Identification System (“AIS”) signals. Apart from very small numbers of pleasure craft, the only vessels in the area which do not carry AIS are smaller fishing craft, which are subject to restrictions on passage through the MPA.

Comparatively few vessels operate within The Gully, aside from those passing through. Among those few, the commercial fishing vessels are subject to monitoring under other indicators. The remaining operators within the MPA require permits and their activities can readily be monitored through permit conditions requiring the filing of information.

For better understanding of any trends seen in the monitoring data, the records on both vessel transits and operations within the MPA should be broken down into convenient units, such as deepwater merchant ships, naval vessels, research vessels, other government vessels, ecotourism vessels, fishing vessels and other commercial vessels.

It is not recommended that there be any monitoring of either low-flying aircraft or pleasure surface vessels. Neither group is expected to be common enough nor to have a sufficient impact on the ecosystems to justify monitoring. Aircraft crossing the MPA at high altitude may not be uncommon but their ecosystem effects are expected to be entirely negligible. Further, it is not recommended that any attempt be made to monitor naval submarines in the area. They may be present and they might pose a significant threat to some whales but data on submarine operations will not be made publically available by the navies concerned and there are no means to monitor the presence of submerged submarines without naval assistance.

Indicators 32, 33: Geo-referenced fishing effort data are routinely gathered by the Department and indeed the data on areas near The Gully are already being packaged for and supplied to the MPA managers. Those data provide the basic information on one primary anthropogenic impact on the Gully ecosystem and, being available at zero additional cost, they should be included in this monitoring program.

The threats posed to the Gully ecosystems by fishing would be adequately monitored through data on effort expended within the MPA, even though effort outside would impact those ecosystems by intercepting both migrant fish approaching the canyon and resident animals which stray across the boundary. There is, however, a perennial question in MPA management concerning whether or not a protected area enhances fishing opportunities outside through the enhanced biomass densities within the area flowing out to where fishing continues. A concentration of effort along the boundaries of an MPA is not proof of significant overflow but it would be an indication that further research is needed and it is an indication available at negligible cost, since the geo-referenced data are already collected. Hence, a second indicator focused on effort outside the MPA's boundaries is recommended.

Indicator 34: Illegal and unreported fishing activities are, by their nature, inadequately recorded. However, when such activities are detected by the Department in the vicinity of The Gully, reports should be forwarded to the MPA managers and included in the monitoring archive.

Indicators 35, 36, 37: The direct effects of fishing activities (research as well as commercial) on marine ecosystems come through their removal of organisms as catch. Biologically, what matters is the deaths of animals “removed” from living populations but all that can practically be recorded are the amounts removed from the water, whether they are then removed from the MPA or are discarded back into the ecosystem. It is important that those amounts be monitored.

To facilitate interpretation by managers, removals by research activities should be separated from those caused by commercial fishing. For the commercial fleet, it will be useful to distinguish removals of target organisms from those of unintended bycatch, even though the distinction between those two is often unclear. It is rarely possible to define target species in research fishing. For the latter, there should be no difficulty in recording and reporting all organisms removed from the water, regardless of their subsequent fates. In commercial fishing, in contrast, experience shows that discarded bycatch rarely receives enough attention to be noticed, far less recorded. Thus, there is little point in seeking data on such discards.

For both research and commercial activities, there is a particular need to monitor removals of corals, because of their importance in the objectives of the MPA and because of the impracticability of monitoring their loss through observations of the seabed. In comparison, documenting the quantity taken through observations on the decks of fishing vessels is cheap, efficient and reliable. Data on coral catches by the commercial fleet will likely require observers, rather than relying on self-reporting by fishermen, but the importance of the data justify that extra expense.

Recreational fishing in The Gully is negligible, if it happens at all, and is disregarded here.

Indicators 38, 39: Bottom fishing activities, both research and commercial, pose one of the larger anthropogenic threats to the benthos and to seabed habitats in The Gully. Understanding the extent of the threat will require monitoring of the activity, using enhanced but otherwise conventional approaches. While the effects of commercial and research fishing using the same gears are not expected to differ, it will be more informative for managers if the two activities are distinguished in the data. Conversely, it will not be practical to maintain separate data on each gear-type variant and hence using one indicator for the aggregate of all activity with bottom trawls and a second for all those with fixed gear is the greatest extent of subdivision that can be recommended.

No commercial mobile bottom–tending fishing is authorized within the MPA and hence Indicator 38 only refers to research and monitoring activities.

Indicators 40, 41: Offshore-petroleum activities are on-going on the eastern Scotian Shelf and are closely monitored by the Canada-Nova Scotia Offshore Petroleum Board (“CNSOPB”). Basic data on the magnitude of the activity and on all forms of discharges which might be of concern to MPA managers should be available to DFO from CNSOPB at negligible additional cost.

Indicator 42: Most cargo ships entering Canadian waters are required to exchange their ballast water while in open ocean in order to minimize the risk of invasive species being introduced when the ballast is discharged in port. There is an authorized area for ballast exchange west of Sable Island and in water depths exceeding 1,000 m. Discharging ballast water there or elsewhere in the vicinity of The Gully carries a very small risk of introducing invasives into the MPA. That risk would be too small to justify a specific monitoring program, particularly since any water would be discharged into the surface layers which are disassociated from the deep waters of the canyon by the thermocline under the Cold Intermediate Layer. However, Transport Canada already gathers detailed data on ballast exchanges. Regular review of those may reveal patterns suggesting increased risks that merit management action.

Indicator 43: As with illegal fishing, shipping discharges (other than the mandated discharge of ballast water) in or near The Gully will rarely be reported but when any is detected by DFO, Environment Canada or Department of National Defence patrols, the information should be gathered into the monitoring archive.

Indicator 44: Once a cetacean survey is deployed to The Gully, there is negligible additional cost in recording observations of floating debris that threatens whales (and some other organisms). Gathering those data is already a part of the existing survey protocol.

Indicator 45: Similarly, once a video survey of corals is deployed to The Gully, there is negligible additional cost in recording observations of anthropogenic material seen on the seabed in the imagery of the monitoring sites. Such material can damage the corals.

Indicator 46: Invasives (often but not always introduced in ballast water) are unlikely to be a problem in an offshore MPA like The Gully: any species already living in the North Atlantic that could prosper in the canyon would probably have found its way there through natural transport, while the number of propagules that might be introduced by a ship exchanging ballast water in the area would be tiny, when compared to the vast volume of seawater, and hence the establishment of a viable population is improbable. There may be greater risks of invasive species becoming established along the coastline and then moving out to sea, though the canyon ecosystem is so different from that along the coast that such a pathway is unlikely. Improbable is not, however, impossible and an ecologically-damaging colonial tunicate has successfully established itself on Georges Bank in recent years, showing that the potential risk is real.

Unfortunately, recognizing invasive species in The Gully will be very difficult. Lists of naturally-occurring species are still incomplete, while the potential list of meso- and bathypelagic species that reach The Gully intermittently but naturally is as long as the list of species in those depth ranges in the entire North Atlantic – indeed, the entire World Ocean where the bathypelagics are concerned. In consequence, no specific monitoring of invasives is recommended. However, scientists working in the area should be encouraged to report any observations of potential invasives not known to be native to The Gully. Should any such reports be received, they should be added to the MPA's monitoring archive.

Indicator 47: Perhaps the most pervasive human impact on the Gully ecosystem (any consequences of anthropogenic global climate change aside) is noise radiated primarily by passing ships but also by distant seismic surveys and other sources. That sound can be efficiently monitored using the same acoustic recorders as are recommended for monitoring cetacean activity. The records will require analysis so that a variety of characteristics of the sound (frequencies, duration, intensities etc.) can be reported.

COMPONENT MONITORING PROGRAMS

It is recommended that the 47 indicators be monitored through fourteen separate "component programs". For efficiency, the indicators are distributed across the component programs in ways that minimize costs and maximise effectiveness, rather than in any ecological sequence. A further four component programs are recommended for the preparation of baselines, even though no corresponding indicators can yet be defined. Additional indicators may emerge once the baselines have been established.

The association between indicators and component programs can be summarized as:

Component Program	Indicator or Indicators
Cetacean Surveys	1, 2, 3, 4, 5, 6, 7, 44
Acoustic Recorders	8, 47
Coral Surveys	13, 14, 15, 16, 45
Habitat Mapping Baseline	
Trawl Surveys	17
Longline Surveys	18
Trap Surveys	19

Component Program	Indicator or Indicators
Mesopelagic Surveys	20
Pelagic Longline Baseline	
Seabird Surveys	29
Environmental Monitoring: Shipboard	21, 22, 25 in part, 27, 28
Environmental Monitoring: Satellite	23, 25 in part, 26
Environmental Monitoring: Meteorological	24, 25 in part
Sediment carbon Baseline	
Contaminants Baseline	
Monitoring of Vessel Traffic	30
Enhanced Logbook and Reporting	31, 35, 36, 37, 38, 39, 46
Compilation of Existing Records	9, 10, 11, 12, 32, 33, 34, 40, 41, 42, 43

Cetacean Surveys

Indicators 1, 2, 3, 4, 5, 6, 7, 44: The cetacean surveys should be conducted following the methodology established by the Whitehead Laboratory at Dalhousie University, which relies on photo-identification of individual animals, followed by mathematical modelling to estimate population abundance (Gowans *et al.* 2000; Whitehead and Wimmer 2005). Experience has shown that, for any given survey budget, that approach generates much more precise estimates of the abundance of a toothed-whale population and its temporal trend than do transect surveys, whether aerial or shipboard, and particularly so for a species that spends as much time underwater as northern bottlenose whales do. Furthermore, bottlenose whales are attracted to vessels, which severely biases data from shipboard transect surveys and the resulting population estimates. In accordance with the requirements of the *Recovery Strategy for the Northern Bottlenose Whale*, the surveys should have sufficient intensity to be able to track population trends with a precision of ±5%.

While some individuals in the population are largely resident within The Gully, most move routinely, at least as far as Shortland and Haldeman canyons. To reduce the inter-annual variability in population estimates could be caused by short-term shifts in the proportion of the whales within the MPA and to allow this survey series to meet the needs of the *Recovery Strategy*, the surveys should extend over those other canyons. Comparisons of trends in the use of the three areas by the bottlenose population (through Indicator 2) will then provide some indication of the effect of the MPA on this signature species.

Material for genetic and contaminant analyses, for assessment of Indicators 5 and 6, must be collected from live whales, through blubber biopsy using a sampler fired from a crossbow (Hooker *et al.* 2001). Such invasive sampling of an endangered population is inevitably problematic but the necessity has been recognized by the *Recovery Strategy*.

Cetaceans other than northern bottlenose whales will be recorded when seen in The Gully and elsewhere on the Scotian Shelf while the survey vessels are in transit to and from the MPA. The data obtained will not be suitable for estimation of absolute abundances but will support monitoring of trends over time in relative densities both inside and outside the MPA.

Indicators 1-4, 7 and 44 should be assessed every four years, each assessment requiring two summer seasons of fieldwork (i.e. a four-year cycle of two years on the water, followed by two off). Indicator 6 requires assessment at eight-year intervals – the last such biopsy-sampling having been undertaken in 2002-03, meaning that the next sampling should be conducted in 2010 or 2011. Indicator 5 does not need such frequent assessment but once blubber samples have been taken, with all that implies when working with an endangered species, it may be best to sequence their DNA so as to extract the maximum information from the material collected.

During fiscal 2010 and 2011, and with funding support from DFO, cetacean surveys should be conducted by the Whitehead Laboratory, using their sailing vessel *Balaena* as a survey platform, with both raw data and final indicator values for Indicators 1–4, 7 and 44 being passed to DFO. Sample material for genetic analysis and for contaminants analysis should be forwarded to DFO, the former for in-house processing, the latter for onward transmission to Environment Canada. Final indicator values for Indicators 5 and 6 should then be developed within DFO.

Three further tasks should be completed during 2010 and 2011: firstly, existing data from previous cetacean surveys in The Gully (primarily by the Whitehead Laboratory) should be compiled and analyzed to provide a formal baseline for on-going monitoring. Much of that analysis has already been completed and published but the intended use as a baseline involves a new perspective which will require a different format of presentation and likely supplementary analyses.

Secondly, the survey protocols should be upgraded as may be required by current understanding of the methodology, then standardized, and finally documented so as to facilitate a technology transfer to other operators – thus relieving the university research laboratory from on-going monitoring responsibilities, allowing it to focus on its primary functions, while placing long-term administration of routine, standardized monitoring with the Department, which is best suited to that task.

Finally, during the 2010 and 2011 fiscal years DFO should issue a call for expressions of interest, followed by a request for proposals, for third parties interested in operating these surveys through long-term agreements with both the Department and the Whitehead Laboratory, commencing in 2012. The critical requirement is for a survey platform that:

a. Is adequately seaworthy for safe operation offshore, being either able to ride out the inevitable periods of bad weather during a cruise of a few weeks' duration or else fast enough to be able to complete each survey on a series of brief runs out from the Nova Scotian mainland,
b. Provides an optimal height of eye for a cetacean observer – one metre being too low and ten metres too high,
c. Provides sufficient stability for telephoto photography in the sea states generated by winds of up to 15 knots, and
d. Is sufficiently manoeuvrable to close with pods of whales.

Quiet operation, such as can be provided by a sailing vessel, would be an asset but the surveys could be conducted under power.

It is anticipated that various potential operators would be interested in long-term contracts as providers of the "official" cetacean survey platform for the MPA, perhaps carrying "ecotourists" as a revenue-earning supplement to DFO funding, and maybe with regional-development funding in support of an MPA-oriented tourism venture out of a small harbour in eastern Nova Scotia. Potential platforms might include, for example, an ocean-capable sailing yacht out of Halifax, a converted 45 ft inshore fishing boat out of Canso or a large sailing charter vessel (such as operate on the coast of Maine in summer) that would make a cetacean survey in The Gully part of an annual schedule. The latter might have to be a foreign-flag vessel as there are few platforms of that type in Canada. It is possible, however, that no vessel suitable for photo-identification cetacean surveys would meet existing safety requirements for DFO staff working offshore.

It is recommended that the operation of these surveys from 2012 forwards should involve a three-way cooperative agreement between the Department (providing funding and receiving annual reports on the indicators, plus sample material for Indicators 5 and 6), the vessel operator (providing the survey platform and receiving both DFO funding and other receipts) and the Whitehead Laboratory, which would provide qualified cetacean observers and data-analysis services, receiving in exchange both funding and the use of the data in scientific studies.

Acoustic Recorders

Indicators 8, 47: The acoustic environment in The Gully remains poorly known. Understanding it sufficiently to design routine monitoring requires a workshop of acousticians, with specialist knowledge of the area, at which existing data collected by DFO (including the Institut Maurice-Lamontagne as well as BIO), Defence Research and Development Canada ("DRDC") and Dalhousie University should be examined, analyzed and interpreted. In conjunction with that workshop, it would also be appropriate to conduct an intensive baseline survey of the acoustic environment, using ship-borne, towed, floating, free-swimming and seabed sensors – a study under active consideration by DRDC. It is recommended that DFO host the workshop during winter 2010–11 and that the Department support DRDC in its baseline studies.

Longer-term trend monitoring should be designed by the workshop but would likely involve continuous deployment of passive, seabed acoustic recorders, such as the Cornell "pop-up" recorders which have been used in The Gully in the past. Recorders or, if necessary, suites of recorders should be selected to cover all frequencies from 10 Hz to 50 kHz, the low end being intended to monitor ship noise (a primary anthropogenic impact on the MPA) and the high end being for monitoring of the activity of bottlenose whales and other toothed whales, through recording of their hunting sonar. It is recommended that the recorders be released and recovered, on a "ship of opportunity" basis, by research vessels working in The Gully.

Coral Surveys

Indicators 13, 14, 15, 16, 45: Surveys should be conducted following the methodology of the 2007 coral study in The Gully, which used the ROPOS platform (a deep-diving Remotely Operated Vehicle or "ROV") to run transects across the seabed while gathering video records of the macro-epibenthos. Subsequent analysis of those records provides raw data for assessments of the five indicators.

In 2007, a transect was established in an area of gorgonian corals on the western side of the canyon, as was another in a seapen field on the flank of Banquereau during 2008. A planned cruise in July 2010 is scheduled to survey a further transect at depths suitable for gorgonian corals on the "Southwest Prong" of Banquereau. Thereafter, the surveys should be repeated at those three sites at ten-year intervals (i.e. with the next survey in 2017), the very slow development of the coral colonies and the limited extent of threats to them within the MPA making more-frequent surveys unnecessary, while cost considerations severely limit ROV monitoring in the deeper portions of the canyon.

Such infrequent surveys do carry a risk of substantial unrecognized losses of corals between one assessment and the next but sudden declines are not expected in extremely long-lived animals within a protected area. Ocean acidification and other major shifts in ocean climates are not expected to cause detectable change in the corals within a decade. There should, however, be provision to mount additional surveys swiftly following any event that is thought to have had a significant impact on the corals, including any turbidity flows in the canyon, tsunamis or reports of major, unintended bottom contact within coral-rich areas of The Gully – with follow-up surveys to monitor recovery as necessary. Moreover, in the unlikely event that planned bottom-contact activities using mobile gear are authorized within Zones 1 or 2 of the MPA, prior mapping of the corals in the areas likely to be affected should be undertaken in advance of the authorized activity, with a post-contact follow-up survey. Such monitoring should be incorporated into the coral surveys but the details cannot be anticipated here.

The entire transects should be filmed on each survey and the full record archived. However, following the establishment of baselines, only random subsamples of those videos need be examined and scored – the staff time currently needed to turn video imagery into data being expensive. (Automated processing of the imagery may become possible in the future, allowing full analysis of archived records.) The sampling fractions needed to achieve required levels of precision remain to be determined.

While the highly-capable ROPOS vehicle will remain expensive to operate, emerging technologies may allow substantial savings in coral-survey costs by 2017. Drop cameras capable of reaching the necessary depths are already available, though it may not be practical to follow defined transects within the confines of the canyon without the thrusters of an ROV. Autonomous Underwater Vehicles ("AUVs") may be a more promising alternative within a few years. Indeed, they may so greatly reduce costs as to allow not merely the currently-recommended fixed-station surveys but also wide-area mapping of seabed habitats and coral distributions throughout the canyon – something that would be prohibitively expensive with ROPOS.

In addition to routine monitoring of the corals, there is an urgent need for baseline research to identify the energy source supporting them (e.g. detrital supply from the Gully Trough). Once that can be completed, additional monitoring of the energy pathways leading to the corals may be appropriate.

Habitat Mapping Baseline

While the shallow areas in Zone 3 of the MPA could be mapped using methods previously applied elsewhere on the Scotian Shelf, currently-available technology does not allow affordable and yet comprehensive mapping of the habitats in the deeper parts of The Gully. Still less would it be practical to routinely monitor for changes in the distribution of those habitats. A knowledge of the spatial distribution of benthic habitats in the canyon nevertheless remains fundamental to understanding how the Gully ecosystems function and baseline studies contributing towards a comprehensive map are needed, even though the map itself remains beyond current capabilities.

It is recommended that steps be taken to assemble a baseline understanding of the benthic habitats in the MPA, including their spatial distribution.

Trawl Surveys

Indicator 17: Since 1970, what is now designated as the Gully MPA has been a small portion of the total area surveyed, at least annually, by bottom-trawl surveys for groundfish resources. In recent years, however, research-vessel trawling within the MPA has sometimes been blocked by concerns over its effects on seabed habitats, to the loss of both fishery-management data and MPA monitoring.

It is recommended that, during 2010, MPA management, working with scientific advice, should determine which portions of Zone 3 of the MPA are suitable for routine bottom trawling by DFO research-vessel surveys. (No such areas are to be expected in Zones 1 or 2.) The stratification of the routine groundfish surveys should then be modified to exclude areas in which trawl-sampling cannot continue, while routine sampling should resume, according to standard survey protocols, in those portions of Zone 3 where bottom trawling is appropriate – subject to the normal process of stratified-random station selection and with notification of those stations to MPA managers.

In the presence of the inevitable spatial variation, however, the small number of randomly-located stations that would be selected within the MPA for each annual survey (typically only one or two) would preclude useful tracking of temporal changes in the groundfish within Zone 3. Thus, it will be necessary to select additional, fixed trawling stations for MPA monitoring. Pending analysis of the data from the initial years of such monitoring, it is recommended that there should be two fixed stations, one each on Banquereau and Sable Island Bank. Sampling limited to two sets annually would not produce reliable estimates of abundance changes from year to year but may allow longer-term trends in the groundfish of Zone 3 to be monitored. The fixed stations would be additional to the stratified-random ones used for estimating resource-wide abundance and biomass. The data derived from sets made on those two stations would be exclusively for MPA monitoring as they cannot be combined with data from stratified-random sets in developing index values for resource monitoring.

The two fixed stations should be worked each year, as part of the routine summer groundfish surveys, using standard protocols (Hatt and Clark 2007; Clark and Emberley 2009) in all respects except for the station selection. The summer surveys are preferred since the long existing data series (currently 40 years) will provide the best available baseline, while the better weather in summer minimizes the complications resulting from lost ship time.

Besides station selection and an initial survey in 2011, the tasks for fiscal 2010 and 2011 include developing a statement of baseline conditions for the areas around the selected stations, using the existing years of summer-survey data. That baseline should include information on long-term trends that have led to current conditions and on variability over various time scales.

The recommended addition of these fixed stations to the summer surveys would, however, require strategic decisions by senior management: The surveys are already frequently unable to complete all of their assigned tasks within the limits of their allocated ship time, while Canadian Coast Guard manning procedures prevent minor stretching of the survey cruises by a day or two. Either an additional week of ship time, allowing for a return to port for a crew change, must be added to each summer survey or else existing demands must be trimmed to free time for MPA monitoring.

Longline Surveys

Indicator 18: Current halibut abundance data are gathered using longlines in three modes (Trzcinski *et al.* 2009). Firstly, there is a fixed-station survey, conducted by commercial vessels but following a standardized protocol with an observer on board. Only one of the fixed stations, Station 65, is within the Gully MPA and that has shown poor catches of halibut – though it has seen much better catches of barndoor skate, spiny dogfish and white hake. (There are four other stations in the head of The Gully, north of the MPA boundary, some of which have seen rich halibut catches.) The same commercial vessels also conduct index fishing, generally following the standardized protocols, though with some variations, but they do so at locations of the fishermen's choosing within areas that they are licensed to fish. About a third of those trips have observers on board and gather a full suite of data, while the rest see the fishermen themselves gathering a lesser sub-set. A number of such index sets are made within The Gully each year. Finally, there is regular commercial fishing, including in Zones 2 and 3 of the MPA, which fishing may deviate substantially from the standard survey protocols.

The fixed-station survey is currently due for consideration of a possible reconfiguration (K. Trzcinski, BIO, *pers. comm.*). It is recommended that, as that process proceeds, it should consider placing two or more fixed stations within the MPA, where they would serve both MPA- and resource-monitoring needs. In the interim, the index-fishery data from within the boundaries of the MPA should be analyzed to produce a baseline, while continued fishing through that program will serve to monitor the longline-vulnerable species. Steps should be taken to ensure that all index fishing within the MPA uses the approved standardized protocols, while observer deployments should be adjusted such that as high a proportion as possible of the index fishing within the MPA is fully recorded – though it will be necessary to ensure that the increase in observer coverage does not produce a significant disincentive for halibut fishermen considering a trip to The Gully, else the required data collection would be severely curtailed.

Trap Surveys

Indicator 19: In past years, DFO has operated a trap survey along the Scotian Slope east of The Gully, in cooperation with the snow crab industry, with the aim of estimating crab-resource biomass. That survey cannot simply be extended into The Gully, since the crab species of interest in the MPA (likely primarily stone crab) will primarily occur in a different depth range, meaning that snow crab catches are unlikely to be sufficient to cover the costs of participation for the boats involved in the survey work. Nevertheless, the existing surveys provide a model from which a DFO-funded trap survey of the MPA, utilizing chartered commercial vessels as survey platforms, could be developed. Considerable care will, however, be needed in survey design to ensure that any impacts of the traps and their associated lines on the seabed and benthos are acceptably minimized.

The immediate task for this component program should be to design and implement a pilot survey.

Mesopelagic Surveys

Indicator 20: Methods for midwater-trawl surveys of the meso- and bathypelagic nekton of The Gully have been developed in recent years, building on the initial experience of Kenchington *et al.* (2009), while data that may reveal the structure of the pelagic ecosystem within the MPA have being gathered on a series of survey cruises from 2007 to 2010. Additional full surveys are required to determine the patterns of seasonal variation in catches, while extensive analysis will be necessary for the development of a baseline description of the system. That work will extend beyond the end of fiscal 2011 but, once it is completed, a reduced survey design, suited to routine monitoring, should be developed and implemented.

Pelagic Longline Baseline

At this time, no requirement is seen for the routine monitoring of large pelagic fish (particularly swordfish and sharks) in or around The Gully. However, that component of the MPA's ecosystems remains poorly understood and it is recommended that a pelagic longline survey be conducted to establish a baseline. In view of the high mobility of the fish of interest, the survey should not be confined to The Gully but should include surrounding waters.

Seabird Surveys

Indicator 29: Since 2005, Environment Canada's Canadian Wildlife Service has deployed seabird observers aboard ships for pelagic bird surveys, the routine deployments including AZMP cruises and specifically the AZMP cruises which work in The Gully. Observers have also been placed aboard other DFO research ships operating in the area. Hence, seabird-survey data from within the MPA are already being gathered and it is recommended that the process continue, through agreement between DFO and Environment Canada, as a component of the MPA monitoring program.

The observers' data are included in the Eastern Canada Seabird at Sea (ECSAS) database, which also holds data from a former program, PIROP, which operated from 1965 until 1992. Hence, the foundations of a quantitative baseline already exist. It is recommended that the data from what is now the Gully MPA be extracted and analyzed to create a specific baseline for Indicator 29.

Oceanographic Monitoring: Shipboard

Indicators 21, 22, 25 in part, 27, 28: This component program and the next two 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 assessments of their respective indicators. These three component programs also form a distinct group in that, in contrast to the remainder of this recommended monitoring plan, very large data sets already exist that can support development of detailed, quantitative baselines for most of the indicators to be monitored by the three. Those data have not, however, been worked up to provide the required information in usable form for monitoring purposes. The immediate task for fiscal 2010 and 2011 is thus to direct staff time towards the compilation, analysis, interpretation and presentation of existing data – which necessitates either additional (perhaps temporary) positions or a re-direction of staff from other programs. The data sets of particular relevance, spanning all three component programs, include AZMP monitoring of the Louisbourg, Halifax and Halifax Extended lines, as well as the available AZMP data from The Gully itself, other accumulated physical- and chemical-oceanographic data from the surrounding region, sea surface temperature records from satellites and meteorological data from the station on Sable Island, supplemented by both meteorological and sea-state data from the Banquereau and Laurentian Fan weather buoys. There are also extensive plankton collections (phytoplankton as well as zooplankton), potentially holding the key to an understanding of the Gully ecosystem, which require staff time to work up.

The analytical work should have three goals. Firstly, it should generate statements of baseline conditions, including indications of variability around mean values and any discernable long-term trends, allowing future monitoring results to be presented in the form of anomalies around and within those baselines. The baselines should not be confined to directly measurable variables, such as temperature and salinity, but should include derived variables, particularly density profiles (indicative of vertical mixing) and steric height (leading to an understanding of circulation). Selection and development of the most appropriate derived variables is part of the required task. Secondly, the work should produce a new understanding of the oceanographic forcing factors which shape the conditions in the Gully. That may allow more cost-effective monitoring (e.g. monitoring of wind-driven water movements using Sable Island meteorological data, rather than moored current meters, and estimation of phytoplankton production from satellite data on ocean colour, rather than through shipboard methods). It may also show that additional variables require monitoring and it will certainly provide a basis for directing managers' and stakeholders' attention to the most important results amongst the welter of available information. Finally, this phase of the work should develop formats for communicating the results of on-going oceanographic monitoring to stakeholders and MPA managers, along with software for automatic generation of reports in the chosen formats. A particular portion of that third task should be the development of indices to be used in assessments of Indicator 25. Those would necessarily draw on the data gathered by the next two component programs, as well as on data gathered from ship-borne instruments.

There is a particular need for the results of the oceanographic monitoring to be related to the corals in The Gully, since the primary remaining threat to them (after elimination of most potential for anthropogenic physical contact) stems from trends in seawater characteristics, particularly pH, including trends associated with climate change. To facilitate interpretation of the oceanographic data with reference to coral conservation, a literature study should be conducted to produce initial estimates of optimal and critical values of the measured parameters for the corals.

While analysis of existing monitoring-data should be the first step in research to underpin future monitoring of the oceanographic environment in The Gully, it alone will not be sufficient. Further characterization studies using intensive and extensive CTD deployments (covering the canyon and its surroundings in both space and time), plus moorings with current meters and other instruments, will be necessary – not least to provide ground-truthing for future (cost-effective) model-based monitoring of some indicators.

In the interim and indeed for the foreseeable future, the existing and on-going oceanographic monitoring of the Gully MPA should be continued. Specifically, it is recommended that such MPA monitoring continues to rely on the AZMP, largely using existing protocols (which include monitoring of temperature, salinity, oxygen concentration, chlorophyll, photosynthetic pigments by HPLC, plant nutrients, plus plankton sampling) and stations, particularly on the Louisbourg and Halifax lines, including the Extended Halifax Line, plus the five stations which have already been established in The Gully. One additional CTD station should be added at 43°52.7′N 58°56.3′W, over the canyon thalweg in the centre of the bottlenose-whale distribution. That station should be worked to the greatest depth achievable without risk of bottom contact by the instruments. In addition, it would be valuable if the Louisbourg Line were extended into deeper water further beyond the shelf break, as has been suggested for AZMP's own purposes, thus providing more data on the shelf-edge current, upstream from the mouth of The Gully.

As resources permit, the AZMP protocols should be expanded to include monitoring of alkalinity and pH in the deep waters of The Gully (to at least 500 m depth and preferably deeper) to cover the potential effects of increased dissolved carbon dioxide on deepwater corals. Consideration should also be given to adding a sensor for underwater light levels to the instrument package used on CTD casts.

A more-challenging requirement, which may not progress beyond methodological development within the time horizon addressed by these recommendations, is to take much the same suite of measurements as are made on the CTD casts but within a few metres of the seabed. The combination of a drifting ship, complex and variable currents at different depths (and particularly in proximity to the canyon walls) and the rugged bathymetry of The Gully makes it impossible to place instruments on the end of a hydro wire close enough to the seabed to meet the data requirement, without unacceptable risk of loss of both instruments and seabed biota. It may be necessary to place the instrument package on an ROV, with thrusters that would allow maintenance of position close to the canyon walls without contacting them, though the costs would be very high. Alternatively, moored instrument packages deployed near the seabed might be needed.

Indicator 27 requires particular development. Zooplankton are currently sampled on the AZMP cruises and no additional field sampling is recommended here. However, more work is needed to develop indices and select species that would provide information to managers which would be at once meaningful and comprehensible. Species that are important to ecosystem function, such as the *Calanus* copepods, have obvious interest but quite other species may be more sensitive to the sorts of environmental changes that are of particular concern – notably acidification associated with climate change. Invertebrate larvae, the planktonic terapod molluscs or some of the gelatinous plankton may be most useful but research is needed in support of a final selection.

The AZMP cruises currently include capture of acoustic data, using echo sounders, while the ship is in The Gully. That collection should be made a standard part of the monitoring, while the ship's track should be modified to follow selected transects, either along or across the canyon, that are standardized in time (date and point in the diel cycle) and space. Dual sounders should be used, with one at high frequency (e.g. 120 kHz) to detect krill at the expense of short range (maximum depth of detection about 200 m) and the second lower (e.g. 38 kHz) to detect myctophids and other fish, potentially down to the maximum depths in the MPA.

Consideration should also be given to supplementing ship-borne sounders with seabed-deployed, upward-looking sounders, which could be deployed by research vessels operating in The Gully and left in place potentially year-round – thus obtaining long-term coverage at the expense of losing the spatial extent of the coverage of a mobile instrument. Such a bottom-deployed sounder would need to operate at a relatively low frequency (e.g. 38 kHz) if its range of effective detection was to reach to the biologically-interesting near-surface layers. That would place the sounder's transmissions into the frequency range of the hunting sonars of bottlenose whales, which could introduce a serious stress on the cetaceans. However, selecting locations for the sounders that were away from the bottlenose whale concentrations and using low acquisition rates (e.g. one pulse per minute) might mitigate the impacts to an acceptable extent.

As the formal baseline is established, all of this on-going monitoring will become the beginning of long-term trend monitoring.

Oceanographic Monitoring: Satellite

Indicators 23, 26: As outlined in the section on shipboard monitoring of the Gully's environment, the immediate need for this component program is analysis of existing accumulated data. Routine archiving of satellite imagery of sea surface temperatures and ocean colour in the northwest Atlantic, including over The Gully, should also continue, with data from new sensors being added as they become available.

There is a particular need for the development of data products that would allow assessment of Indicator 26. Means for determining the composition of phytoplankton communities from ocean-colour data will be particularly challenging.

Meteorological Monitoring

Indicator 24: For this component program also, the immediate need is analysis of existing data, as outlined above. That process should include development of automated means to extract the data of interest, for interpreting events in The Gully, from the voluminous meterological datasets.

Collection of meteorological and sea-state data at the Sable Island weather station and the two weather-buoy sites will continue, as a routine responsibility of Environment Canada. DFO's tasks will be confined to obtaining and archiving copies of such of those data as are needed and, more demanding, uniting those data with others in analyses and assessments of the state of the Gully MPA.

Sediment Carbon Baseline

A supply of organic detritus down the canyon may be important for the productivity of benthic ecosystems in The Gully – including the corals on the canyon walls but particularly for the deposit feeders (such as the recently-discovered Xenophyophores) which appear to dominate the benthos in the fine sediments along the thalweg. An excess organic supply, however, could result in hypoxia in the sediments, stressing many of the species which might otherwise live there.

Current knowledge of this detrital pathway is insufficient to support either the development of a specific indicator or its routine monitoring but the issue is considered important enough that characterization studies should be undertaken to establish a baseline understanding. Those studies should include deployment of sediment traps, to measure the flux of organic detritus, and sediment sampling in the patches of fine deposits along the thalweg, with those samples being analyzed for organic-carbon content. The sampling would have to meet stringent requirements, both to minimize harm to the Gully ecosystems and to preserve the structure of the sediment in the sample. A "slo corer" should be used but it might need to be deployed by an ROV, rather than directly from a surface ship. Other instrumentation could provide further information on particle size and composition in what would be more of a research than routine-monitoring task. Carbon deposition tends to be episodic and hence the baseline would require sampling across various time intervals to determine temporal patchiness in both the concentration and the rate of movement.

Contaminants Baseline

Existing knowledge of the levels of various contaminants in The Gully has recently been reviewed (Yeats *et al.* 2008). It was concluded that The Gully generally has a very low level of contamination and that that level is not expected to change quickly. Hence, no specific monitoring indicators are recommended at this time, other than Indicators 6, 44 and 45 – the first of which is needed to meet the requirements of the special case of bottlenose whales, while the latter pair can be conveniently monitored by other component programs.

Notwithstanding that general lack of immediate concern, a comprehensive baseline survey to document the current low levels of contaminants (covering all of metals, organics and microplastics, in the water column, sediments and organisms) would be valuable – not least to reassure stakeholders. It should gather information on spatial and temporal variability, over time scales of up to a few years, and should explore the pathways along which contaminants move into and through the Gully ecosystem. Knowledge of those pathways will be important in understanding and interpreting the observations of contaminants in the blubber of northern bottlenose whales. While it would serve as baseline monitoring, however, the survey should be structured as a research program. When that work is completed, it may indicate that routine monitoring is needed and, if so, the understanding of processes and pathways derived from the research would support design of a long-term monitoring program. Given present knowledge, however, it is expected that contaminant levels are only changing very slowly. If so, there would be no point in routine monitoring *per se* but only a requirement for separate contaminants surveys at decadal or longer intervals.

Monitoring of Vessel Traffic

Indicator 30: Cost-effective monitoring of the traffic of large vessels through the MPA is now possible through routine reception of Automatic Identification System transmissions from the vessels themselves. While AIS is intended as an aid in collision avoidance, the transmissions provide data on ships' identities, positions, courses and speeds. All large surface vessels are now required to carry the equipment.

There are a number of options for receiving AIS transmissions from ships in The Gully and for transmitting those data to shore. They include mounting the receiver at the weather station on Sable Island or at the East Light (though either may be further from The Gully than the effective range of the system), mounting it on the Venture or South Venture gas platforms, or utilizing an existing satellite-mounted receiver. The Gully MPA managers are presently examining the alternatives and are expected to implement data collection shortly. Once routine monitoring is in progress, additional work will be required to develop optimal formats for display and reporting of the data.

Enhanced Logbooks and Reporting

Indicators 31, 35, 36, 37, 38, 39, 46 The seven indicators grouped under this component program can be monitored largely through existing mechanisms but not without some enhancement of the data currently gathered.

Vessels other than commercial and naval shipping in transit (monitored through AIS), commercial fishing vessels (monitored through other logbooks) and pleasure craft (deemed unnecessary to monitor) should only be in the MPA when operating there under permits. It is recommended that the permit conditions be expanded to require reporting of hours of operations within the MPA by each permitted vessel, which reports should be submitted to the MPA managers for compilation into annual summary statistics for Indicator 31. Similarly, the Chief Scientists of research and monitoring vessels operating in the MPA should be required to file data on any coral taken, on other catches and on seabed areas swept by their gear or the lengths of bottom-set lines deployed, for use in assessments of Indicators 35, 37, 38 and 39. Corals removed from the seabed within the MPA by research activities should all be returned to shore, identified, their quantities determined and a report filed. Any permitted activities within the MPA other than research or commercial fishing should be required to follow the same practice. In order to avoid discouraging research or a waste of resources on duplication of recording, the reporting requirements should only gather the minimum amount of data needed for the monitoring of the four indicators.

Commercial fishing vessels operating within The Gully, along with other commercial fishing vessels in Canadian waters, are already required to maintain logbooks recording fishing effort and the resulting catches. A proportion of trips carry observers who record additional data. The resulting data streams should be reviewed to determine what additional reporting requirements are needed for vessels fishing in the MPA and/or for the observers deployed aboard those vessels in order for Indicators 35, 36 and 39 to be monitored efficiently. Landing of corals taken during commercial fishing (if any) is unlikely to be practical and those should be recorded and discarded at sea. However, provision should be made to record the locations of any coral capture to high precision. Commercial fishermen usually spare little attention for the material that they discard and hence discards (especially discards of corals) may need to be monitored on observed trips alone, with expansion to estimates of fleet-wide discarding. If so, it may become necessary to set minimum levels of observer coverage for fishing trips into the MPA. It will, however, be important to ensure that paperwork burdens and the expense of carrying observers do not amount to a discouragement to fishing The Gully.

Unlike most other data gathered during this monitoring program, which can be reviewed annually or less often, reports of coral catches should be monitored in real time so that destruction of coral "forests" can be swiftly stopped. The extremely slow recovery from such damage necessitates an immediate flow of information and a rapid management response.

There is a special requirement for reporting of observations of potential invasive species in The Gully (Indicator 46), yet any such observations are expected to be so rare that no specific reporting format can be recommended. Rather, scientists sampling the biota within the MPA should be encouraged to watch for invasives and to report any observations.

Compilation of Existing Records

Indicators 9, 10, 11, 12, 32, 33, 34, 40, 41, 42, 43: The data required for the assessment of the remaining eleven indicators are all already routinely gathered by or in collaboration with public agencies: records of whale strandings by the Marine Animal Response Society, data on offshore-petroleum activities on the Scotian Shelf by the CNSOPB, reports on ballast-water exchanges by Transport Canada and the rest primarily or exclusively by DFO. During fiscal 2010 and 2011, MPA managers should liaise with those who are gathering the data and should develop efficient and expeditious means of transferring required and available information on this suite of indicators into the Gully MPA monitoring archive – which means might range from e-mail notification, in the case of rarely-reported events, to automated, electronic data transfer between databases. It will also be necessary to develop formats for reporting the received data to managers and stakeholders.

GOVERNANCE OF THE MONITORING PROGRAM

Most of the recommended component programs are already in operation as existing DFO monitoring programs or could be implemented by minor extensions of existing programs. Aside from directives from senior management to support the needs of the MPA monitoring and accompanying allocations of staff time, little additional program-management activity would be required – though budgets for MPA monitoring and arrangements for transferring funds to the component programs remain to be determined. Formal commitment of resources would be needed for the coral and mesopelagic surveys, which are currently organized as short-term research programs rather than as on-going, long-term monitoring. Parallel commitments would be needed for much of the recommended baseline work.

Contractual agreements would be required with vessel operators for the cetacean-, longline- and trap-survey components of the recommended program, though the second and third could be provided through extensions of existing and previous arrangements for halibut and snow crab surveys. A further agreement with the Whitehead laboratory at Dalhousie University would be needed to implement the cetacean surveys, as they are recommended here. Other formal agreements would be required with Environment Canada, Transport Canada, DRDC and CNSOPB.

It is further recommended that coordination of the various component programs be provided through a committee comprising the project leaders of the component programs, co-chaired by a Gully MPA manager. While it may need to meet more frequently, the Committee should hold an annual Gully Monitoring Workshop, at which the data collected and results of preliminary analyses are examined. Emerging problems and shifting priorities in the monitoring would then be discussed, leading to recommendations for such modifications to the program as may be needed. The 2011 annual meeting should be expanded to include specific planning for the monitoring program during 2012–16.

In conjunction with the Monitoring Workshops, the Committee might usefully conduct Gully Research Workshops to review progress on the baseline understanding of the Gully ecosystem and to promote interactions among the scientists working in the area.

MANAGEMENT OF MONITORING DATA

Much of the data collected by this recommended monitoring program would reside in existing databases currently used by the various component programs. However, a web-based data-management system should be developed, modelled on that used by the AZMP [http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html]. That should serve as the Gully MPA 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 Gully and to stakeholders. Even with the AZMP model to follow, development of the website will require a substantial commitment of resources.

Continuous support would 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.

REPORTING

Select data types (particularly concerning Indicators 9, 10, 11, 12, 34 and 35) may usefully be reported to MPA managers at shorter time intervals but, overall, this monitoring program should report annually, following the Gully Monitoring Workshop, which should be charged with alerting the MPA managers to any pressing issues that may be revealed by the monitoring, including warnings of potentially emerging problems. The workshops may best be set within the SAP 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 monitoring (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 appear as *Science Advisory Reports* but an additional format, accessible to stakeholders, may also be required.

Throughout, there will be the challenge of reducing voluminous data, often on variables of limited direct interest to managers or stakeholders, into understandable and yet meaningful summaries. 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 the MPA monitoring is to be expected as managers and stakeholders respond to initial offerings. This is, fortunately, one aspect of the monitoring program that can be allowed to develop over time, with new products being calculated from both archived and incoming data.

INDICATORS CONSIDERED AND REJECTED

A number of additional monitoring indicators were considered during the development of this recommended plan. Aside from socio-economic and governance indicators, which are not part of the recommendations offered here, the reasons for rejection were as follows:

Canyon bathymetry:
The designation of the Gully MPA stressed the unique size and bathymetry of the canyon. Those, however, are not subject to human modification nor can human intervention prevent on-going natural change. The bathymetry of the canyon has nevertheless been characterized, in the form of a baseline multibeam survey. At some future time, that will no doubt be replaced when improved technology becomes available and a comparison of the surveys will then be of value to MPA managers. However, no such work is foreseen as part of this monitoring plan.

Records of turbidity currents in the canyon and the feeder canyons:
The bathymetry and surficial sediments in the MPA are subject to on-going natural change. There is slow but steady evolution, perhaps mostly caused by the supply of sediment into the heads of the feeder canyons. The effects of that are expected to be very minor and localized. Hence, they do not merit monitoring.

At long intervals, it is to be expected that there will be much larger and far more rapid change when some of the accumulated sediment pours down the canyon in the form of a turbidity current. Such an event would have profound consequences, particularly for benthic habitats along the canyon thalweg. However, turbidity currents are expected to be so infrequent that no monitoring of their occurrence would be worthwhile – not by direct observation certainly but also not by monitoring existing data streams (such as from seismographs) which could give notice of an earthquake that might shake loose sediments, precipitating a turbidity current. Instead, should observations provide evidence that such an event has occurred in The Gully, available data should be examined *post hoc*.

MPA-wide surveys of coral biomass and diversity:
Besides the monitoring of corals at selected sites in the canyon, the option of spatially-extensive surveys that could provide MPA-wide estimates of coral biomass and other variables was considered. The idea was rejected because the costs of operating remote vehicles capable of carrying the required video cameras to the necessary depths are so high that even the largest conceivable survey program would have low precision – expected to be too low to be useful.

As the development of new platforms, particularly AUVs, proceeds it may become possible to run usefully-precise, cost-effective coral surveys throughout The Gully. If so, additional monitoring indicators should be considered.

Mechanical damage to and diseases in corals:
With the effective prohibition on bottom-tending mobile fishing gears in the areas where corals are found in the MPA, direct mechanical damage to the corals (a major risk in areas open to trawling and other seabed operations) is expected to be far too rare to be detectable with any reasonable survey effort. The emphasis for monitoring physical anthropogenic impacts on corals has thus been placed on documenting human activities which might cause damage and the amounts of corals brought to the surface.

While the corals are likely subject to a variety of “health” issues (and may be more so if temperatures and pH change with atmospheric carbon dioxide levels), the only form of “disease” that is detectable by current video surveys is the overgrowth of zooanthids. Disease monitoring is, therefore, recommended to be restricted to that one indicator.

Levels of contaminants in coral skeletons in the MPA:
This indicator was suggested not as a means of monitoring a threat to the corals but as a way to examine the past history of contamination in The Gully through traces of metals left in the skeletons of the coral. While that was noted as a useful one-time research project, no value was seen in its routine monitoring.

Diversity of macro-epibenthos within the MPA:
Two indicators focused on the macro-epibenthos (other than corals) were suggested, one relying on broad-area surveys and the other on selected monitoring sites. Either would face very high costs, mostly for the specialist staff needed to identify the many species. There would also be considerable technical difficulties in field surveys in the canyon areas, since many of the species of concern cannot be identified from video records alone, necessitating physical sampling. The species that could be monitored by video survey are either short-lived, and hence too temporally variable for affordable monitoring or else, like the large sponges, too scarce for effective monitoring with usefully-high precision at any affordable cost. Grab sampling in Zone 3 would be technically straightforward but would not yield much information of interest to MPA management and would still need a great deal of laboratory time processing samples, as well as ship time operating in areas where the sampling could not be combined with other monitoring activities. Hence, it is recommended that benthic monitoring be confined to the corals, the conservation of which has been specified among the goals of the MPA.

Knowledge of the very deep benthos (below about 1,500 m) remains weak, however. A requirement for additional indicators may emerge as research proceeds in such depths.

Frequency of anthropogenic marks on the seabed of the MPA:
There was a suggestion that this indicator should be monitored as a means of confirming that no physical harm is being done to the seabeds of the MPA by, for example, otter trawling or anchoring of vessels. However, running video transects within the canyon itself is very expensive while there are better ways of ensuring that no more than minimal bottom contact occurs there. Imaging of the shallower seabed would be possible but much of the MPA's Zone 3 is floored with highly-mobile sands which would not show the marks of physical disturbance for long, while the benthic ecosystem in those areas is well adapted to such disturbance. The costs and complexities of mounting a separate field program simply to confirm that few anthropogenic marks exist would not be justified.

Miles of submarine cable laid in The Gully:
Despite the declaration of the MPA, there is still a possibility that submarine cables will be laid in The Gully and it was suggested that there be a formal indicator to record the extent of any such cable laying. However, the activity will never be more than very rare and it requires so much pre-planning and authorization that it will be well known in advance to MPA managers, negating any value in formalizing its recording within this monitoring plan.

Relative abundances and size distributions, monitored at paired sampling stations inside and outside the MPA boundary:
Two indicators of this type were proposed, one for groundfish to be monitored by fixed stations added to the annual groundfish surveys, the other for snow crab, to be monitored by an expansion of the existing crab surveys. In each case, the intent was to document the effect of the MPA's protections on resource species that are fished outside its boundaries – an issue of interest to some stakeholders, even though the MPA was not established to be a fishery-

enhancing closure. However, the size of the MPA is small compared to the ranges of most resource species. Hence, it is not expected that there will be much enhancement of the segments of their populations that are within the MPA's boundary. Moreover, fishing pressure around that boundary is not currently high and so the effect of the MPA on even sedentary species is expected to be small, while it would require a great deal of expensive survey work to detect minor differences in relative abundance. Thus, these indicators were not deemed worthwhile.

Snow crab trawl survey:
A resource survey for snow crab, using a *Nephrops* trawl, is routinely conducted on the eastern Scotian Shelf. The area included extends towards The Gully but does not reach the MPA. That survey could be extended into Zone 3 and would provide an alternative perspective on groundfish and epibenthic invertebrates from the one offered by the fish trawls of the groundfish survey. That option is not recommended, however, since there seems little need for dual trawl surveys as means to inform management of the MPA.

Small-hook longline survey:
The Fishermen Scientists Research Society has operated a longline survey in NAFO Divisions 4VsW since 1995. Until 2003, the survey was extensive and included sampling in The Gully, with a few sets being made in what are now Zones 2 and 3 of the MPA. The survey gear uses 12/0 circle hooks, suited to haddock, rather than the large hooks of the halibut longline survey. As with the snow crab trawl survey, the use of a second longline gear would give a different perspective on the biota of the canyon but, even so, it is not clear that a duplicate longline-based indicator would be worthwhile. Halibut gear is designed for deployment at great depth and is used commercially in The Gully. Of the two alternatives, it appears the more appropriate for monitoring.

Phytoplankton production within the MPA:
Phytoplankton production within the MPA could be estimated on board research vessels using standard isotope methods but the costs would be considerable, especially if there was a need for sampling outside the periods when vessels are deployed in The Gully for other purposes. Moreover, the data would be of limited value as most of the energy in higher trophic levels in the MPA appears to come from primary production elsewhere.

Thus, it is recommended that calculation of primary production from satellite imagery of ocean colour, which can be regional rather than local in extent, be used in place of direct estimation.

Toxic phytoplankton blooms within the MPA:
Blooms of toxic phytoplankton may occur within the MPA but they are not thought to be likely so far offshore. No monitoring of them is recommended.

Zooplankton blooms within the MPA:
It would be desirable to monitor the timing of zooplankton blooms in The Gully as those are important to the survival of fish larvae and hence to future recruitment. However, they can only be recorded using ship-towed nets and the burden of stationing ships over the canyon awaiting the emergence of the zooplankton cannot be recommended.

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TABLES

Table 1: Concordance between MPA objectives and monitoring indicators. Objectives are abbreviated. See main text for full wording. Monitoring indicators are identified by number.

Objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Conservation and protection of fishery resources and their habitats																	
Halibut																	
Myctophid lanternfish																	
Conservation and protection of endangered or threatened species and their habitats																	
Bottlenose whales																	
Other whales																	
Conservation and protection of unique habitats																	
Benthic habitat																	
Cold-water corals																	
Conservation and protection of areas of high biodiversity or productivity																	
Demersal fish																	
Benthic habitats																	
Cold-water corals																	
Other high diversity																	
High productivity																	
Conservation and protection of any other marine resource or habitat																	
Physical structures																	
Physical and chemical properties																	
Water and sediment quality																	

Table 1 (continued).

Objective	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Conservation and protection of fishery resources and their habitats																	
Halibut	■														■	■	■
Myctophid lanternfish			■								■	■					
Conservation and protection of endangered or threatened species and their habitats																	
Bottlenose whales													■	■	■	■	■
Other whales													■	■	■	■	■
Conservation and protection of unique habitats																	
Benthic habitat		■													■	■	■
Cold-water corals															■	■	■
Conservation and protection of areas of high biodiversity or productivity																	
Demersal fish	■														■	■	■
Benthic habitats		■													■	■	■
Cold-water corals															■	■	■
Other high diversity		■	■									■			■	■	■
High productivity	■	■	■			■			■	■	■	■			■	■	■
Conservation and protection of any other marine resource or habitat																	
Physical structures															■	■	■
Physical and chemical properties				■	■	■	■	■									
Water and sediment quality													■	■	■	■	■

Table 1 continued.

Objective	35	36	37	38	39	40	41	42	43	44	45	46	47
Conservation and protection of fishery resources and their habitats													
Halibut		■	■										■
Myctophid lanternfish			■				■						■
Conservation and protection of endangered or threatened species and their habitats													
Bottlenose whales						■	■			■			■
Other whales						■	■			■			■
Conservation and protection of unique habitats													
Benthic habitat	■	■	■	■	■	■	■	■			■	■	
Cold-water corals	■			■	■			■			■	■	
Conservation and protection of areas of high biodiversity or productivity													
Demersal fish		■	■										■
Benthic habitats	■	■	■	■	■	■	■	■			■	■	
Cold-water corals	■			■	■			■			■	■	
Other high diversity		■	■	■	■	■	■	■				■	
High productivity	■	■	■			■	■						
Conservation and protection of any other marine resource or habitat													
Physical structure	■			■	■	■							
Physical and chemical properties						■							■
Water and sediment quality						■	■		■	■	■		

Table 2: Concordance between perceived threats and monitoring indicators. Threats are abbreviated. See text for full wording. Monitoring indicators are identified by number. Yellow shading: Threats monitored. Red shading: Indicators potentially affected by threats.

Threat	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Extractive use of fish and invertebrate populations																	
Fishing													■	■	■		■
Research													■	■	■		■
Seabed disturbance																	
Fishing													■	■	■	■	■
Research													■	■	■	■	■
Cable laying													■	■	■	■	■
Oil and gas development													■	■	■	■	■
Whale entanglement																	
Fishing	■	■	■	■	■		■	■	■		■						
Research	■	■	■	■	■		■	■	■		■						
Vessel traffic																	
Ships in transit	■	■	■		■		■	■	■	■		■					
Fishing vessels												■					
Research vessels	■	■	■		■		■	■	■	■		■					
Other vessels	■	■	■		■		■	■	■	■		■					
Contaminants																	
Non-point source	■	■	■		■	■	■	■	■			■	■	■	■	■	■
Point source	■	■	■		■	■	■	■	■			■	■	■	■	■	■
Sound	■	■	■		■		■	■	■			■					■
Climate change	■	■	■		■		■	■	■				■	■	■	■	■

Table 2 continued.

Threat	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Extractive use of fish and invertebrate populations																	
Fishing																	
Research																	
Seabed disturbance																	
Fishing																	
Research																	
Cable laying																	
Oil and gas development																	
Whale entanglement																	
Fishing																	
Research																	
Vessel traffic																	
Ships in transit																	
Fishing vessels																	
Research vessels																	
Other vessels																	
Contaminants																	
Non-point source																	
Point source																	
Sound																	
Climate change																	

Table 2 continued.

Threat	35	36	37	38	39	40	41	42	43	44	45	46	47
Extractive use of fish and invertebrate populations													
Fishing													
Research													
Seabed disturbance													
Fishing													
Research													
Cable laying													
Oil and gas development													
Whale entanglement													
Fishing													
Research													
Vessel traffic													
Ships in transit													
Fishing vessels													
Research vessels													
Other vessels													
Contaminants													
Non-point source													
Point source													
Sound													
Climate change													

Table 3: Concordance between theoretical monitoring types and monitoring indicators. (See text for explanation of types of monitoring. Monitoring indicators are identified by number.)

Monitoring Types	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Baseline		■			■			■	■	■	■		■	■	■	■	■
Trend	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■
Effectiveness	■	■	■	■	■	■		■	■	■	■		■	■	■	■	■
Activity										■	■						
Compliance																	
Regulatory																	
Threat												■				■	

Monitoring Types	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Baseline	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■
Trend	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Effectiveness	■	■	■						■	■	■						
Activity																	
Compliance																	
Regulatory																	
Threat				■	■	■	■	■					■	■	■	■	■

Monitoring Types	35	36	37	38	39	40	41	42	43	44	45	46	47
Baseline	■	■	■	■	■			■	■		■		■
Trend	■	■	■	■	■	■	■	■	■	■	■		■
Effectiveness										■	■		
Activity	■	■	■	■	■	■	■	■	■				
Compliance													
Regulatory													
Threat	■	■	■	■	■	■	■	■	■	■	■	■	■